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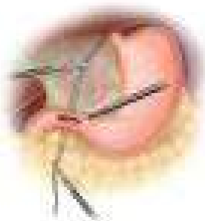



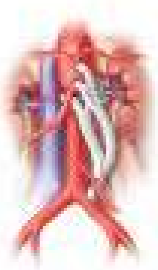

OPERATIVE TECHNIQUES IN SURGERY

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VOLUME ONE

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VOLUME ONE

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Preface

Operative therapy is complex, technically demanding, and rapidly evolving. Although there are a number of standard textbooks that cover aspects of general, thoracic, vascular, or transplant surgery, *Operative Techniques in Surgery* is unique in offering a comprehensive treatment of contemporary procedures. Open operations, laparoscopic procedures, and newly described robotic approaches are all included. Where alternative or complementary approaches exist, all are provided. The scope and ambition of the project is one of a kind.

The text is organized anatomically in sections covering thoracic surgery, upper gastrointestinal surgery, hepato-pancreatico-biliary surgery, colorectal surgery, breast surgery, endocrine surgery, and topics related to surgical oncology and modern approaches to vascular surgery.

The editors are renowned surgeons with expertise in their respective fields. Each is a leader in the discipline of surgery, each recognized for superb surgical judgment and outstanding operative skill. Breast surgery, endocrine procedures, and surgical oncology topics were edited by Dr. Michael Sabel of the University of Michigan. Thoracic and upper gastrointestinal surgery topics were edited by Dr. Mary Hawn of the University of Alabama at Birmingham, with Dr. Steven Hughes of the University of Florida directing the section on hepato-pancreatico-biliary surgery. Dr. Daniel Albo of Baylor College of Medicine directed the section dedicated to colorectal surgery. Dr. Ronald Dalman of Stanford University edited topics related to vascular surgery, including both open and endovascular approaches. In turn, the editors have recruited contributors that are world-renowned; the resulting volumes have a distinctly international flavor.

Surgery is a visual discipline. *Operative Techniques in Surgery* is lavishly illustrated with a compelling combination of line art and intraoperative photography. The illustrated material was all executed by a single source, Body Scientific International, to provide a uniform style emphasizing clarity and strong, clean lines. Intraoperative photographs are taken from the perspective of the operating surgeon so that operations might be visualized as they would be performed. The result is visually striking, often beautiful. The accompanying text is intentionally spare, with a focus on crucial operative details and important aspects of postoperative management.

The text is designed for surgeons at all levels of practice, from surgical residents to advanced practice fellows to surgeons of wide experience. The incredible pace at which surgical technique evolves means that the volumes will offer new insights and novel approaches to all surgeons.

Operative Techniques in Surgery would be possible only at Wolters Kluwer Health, an organization of unique vision, organization, and talent. Brian Brown, executive editor, Keith Donnellan, acquisition editor, and Brendan Huffman, product development editor, of Wolters Kluwer Health deserve special recognition for vision and perseverance.

Michael W. Mulholland, MD, PhD

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Part 1 Operative Techniques in Thoracic and Esophageal Surgery

Chapter 1

Open Tracheostomy

Sam T. Windham, III   John Christopher McAuliffe

DEFINITION

- Tracheostomy is a procedure defined as the creation of a communication between the trachea and the skin of the neck anteriorly. In general, this technique is viewed as a definitive airway for the management of the critically ill patient needing prolonged ventilator support.

PATIENT HISTORY AND PHYSICAL FINDINGS

- The history from the patient may be limited as compared to standard history and physical exams normally performed on patients during routine evaluations for surgery; however, the history and physical exam should focus to determine (1) the indications for tracheostomy, (2) optimal timing for the performance of the tracheostomy, and (3) which approach will provide the safest tracheostomy for the patient.
- With respect to the indication for tracheostomy, the first and foremost indication should be that of the patient with a difficult airway who requires prolonged mechanical ventilator support. In these patients, loss of the airway can have devastating consequences. Pertinent history might include a difficult airway at the time of surgery; prior maxillofacial trauma; presence of severe inflammation or edema in the mandibular, pharyngeal, or base of tongue regions; prior head and neck radiation; or conditions that limit the mobility of the neck (e.g., ankylosing spondylitis, cervical trauma, or fixation). In these patients, early tracheostomy should be considered.
- With respect to timing of the tracheostomy, many studies have evaluated this question.
  - When endotracheal tubes were first created, the tubes were less flexible than modern tubes with low-volume, high-pressure cuffs that resulted in more tracheal trauma than modern tubes. However, tracheal trauma and stenosis still occur with modern endotracheal tubes, and as a result, this leads to one of the indications for timing of the tracheostomy. In order to minimize the risk of tracheal stenosis, most recommend performance of tracheostomy in patients for whom 2 weeks of mechanical ventilation is expected. Pena et al.[1] found that 86% of patients requiring laryngotracheal surgery for stenosis had a mean duration of 17 days of mechanical ventilation. So to minimize this risk, tracheostomy is usually recommended for expected duration of 14 days.
  - Other studies have looked at the timing of tracheostomies based on outcomes for the patients. Most studies evaluating performance of tracheostomies within the first 10 days of intensive care unit (ICU) course suggest statistically significant improvement in days on ventilator, days in the ICU, need for sedation, costs, and total hospital length of stay.[2–4] In busy hospitals, with increased ICU usage, early tracheostomy should be considered.
  - With respect to timing of the tracheostomy, an important aspect of the history to evaluate is the disease process that required the need for mechanical ventilator support. In patients with severe brain injury,[5] spinal cord injury associated with ineffective cough, severe multiple system organ failure, or in whom multiple-staged operations are planned, early tracheostomy should be considered.
- The final aspect to the history and physical exam that should be considered alters whether the patient should undergo percutaneous dilatational tracheostomy versus standard surgical tracheostomy. Certain conditions might warrant open technique over percutaneous tracheostomy.
  - In the setting of altered patient anatomy, the safer option would favor standard surgical tracheostomy with direct exposure of the trachea.
  - With respect to morbid obesity, Byhahn et al.[6] reported a greater complication rate with percutaneous dilatational tracheostomy over surgical tracheostomy (43% vs. 18%). If an extended length tracheostomy is anticipated to be needed, then surgical tracheostomy may be safer and easier approach.
  - The final consideration in preprocedural evaluation is the ventilator settings. In this setting, the surgeon must be comfortable either performing nonbronchoscopic percutaneous tracheostomies or choosing an open approach in order to minimize derecruitment.

SURGICAL MANAGEMENT

Preoperative Planning

- Prior to taking the patient for open tracheostomy, clotting parameters such as prothrombin time, partial thromboplastin time, and platelet count should be evaluated and optimized.
- Cervical spine status should be evaluated in the setting of trauma.
- Periprocedural antibiotics should be administered.

Positioning

- The patient is positioned supine with arms tucked to the side. Often, a pack is placed behind the shoulders to aid with neck extension (FIG 1).

FIG 1 ● Patient is positioned with a pack behind the scapulae in order to increase cervical extension.

TECHNIQUES

INCISION

- A no. 15 blade scalpel is used to make a vertical, midline incision approximately 30 to 40 mm along the lower neck. The cephalad extent of the incision begins at the level of the cricoid cartilage and extends caudally toward the sternal notch.
- The skin edges are elevated with Adson forceps and the dissection continues with Bovie electrocautery through the platysma and between the strap muscles (FIG 2).
- Once between the strap muscles, a Weitlaner retractor may be placed to retract the skin edges, the subdermal tissue, and the strap muscles laterally.

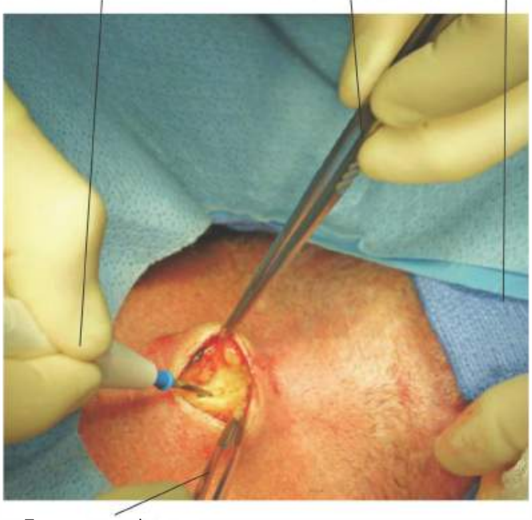

FIG 2 ● Division between the strap muscles using electrocautery.

PRETRACHEAL DISSECTION

- A gently curved, right-angle clamp is then placed in the pretracheal space at the level of the cricoid cartilage. In general, it is safest to develop the pretracheal space from cephalad to caudal direction beginning at the level of the cricoid cartilage (FIG 3A).
- Bovie electrocautery is used to divide the tissue exposed between the right-angle clamp.
- The isthmus of the thyroid is then divided using the Bovie electrocautery between the right-angle clamp (FIG 3B).
- A plane is then developed between the pretracheal tissue and the trachea laterally on each side using Bovie electrocautery (FIG 3C, 3D).

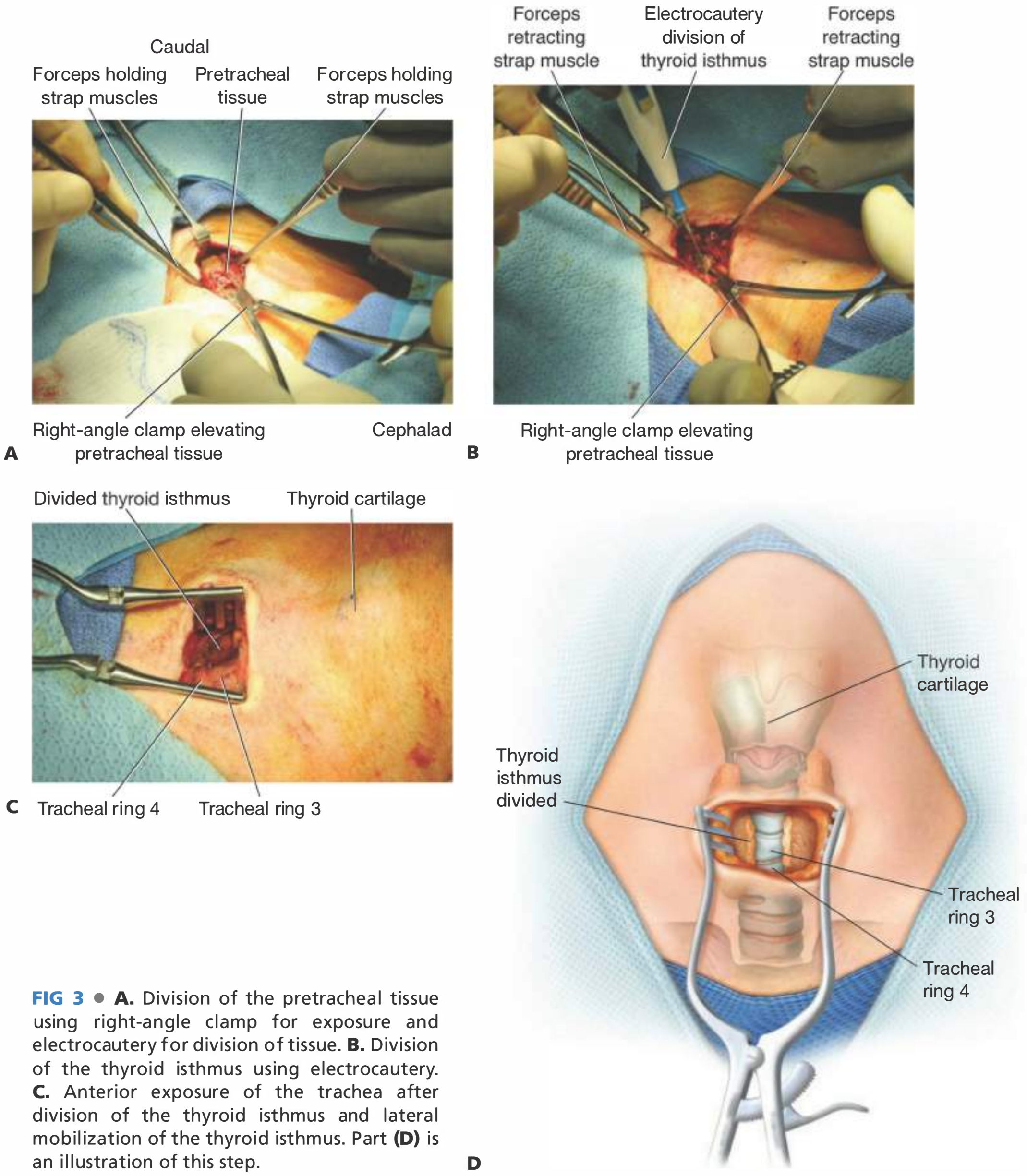

FIG 3 ● **A.** Division of the pretracheal tissue using right-angle clamp for exposure and electrocautery for division of tissue. **B.** Division of the thyroid isthmus using electrocautery. **C.** Anterior exposure of the trachea after division of the thyroid isthmus and lateral mobilization of the thyroid isthmus. Part **(D)** is an illustration of this step.

RING FIXATION

- Once the anterior and anterior lateral exposure of the trachea has been obtained, a 2-0 Prolene suture is placed through the 3rd tracheal ring laterally on each side. The endotracheal cuff should be briefly deflated as each stitch is placed so as not to incorporate the cuff with the suture (FIG 4).

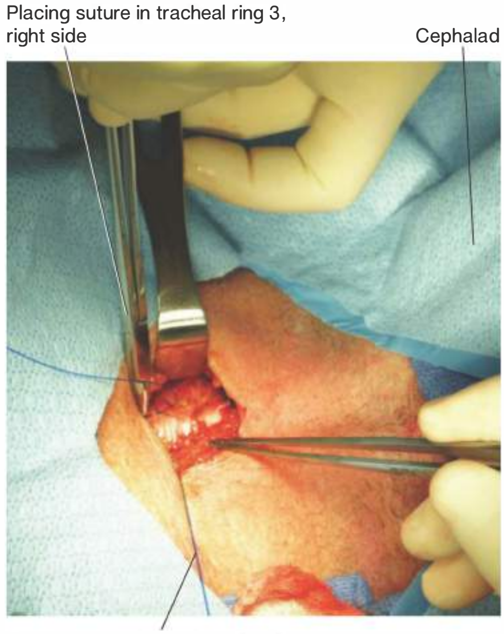

FIG 4 ● A 2-0 Prolene suture placement into the 3rd tracheal ring on each side.

TRACHEAL ENTRY

- An incision is then made with a no. 11 blade scalpel in the space between rings 2 and 3 and in the space between rings 3 and 4.
- The scalpel is then used to divide the 3rd ring, thus creating a sideways "H-shaped" opening in the trachea (FIG 5).
- A Kelly clamp or tracheal spreader is then inserted, opening the trachea.

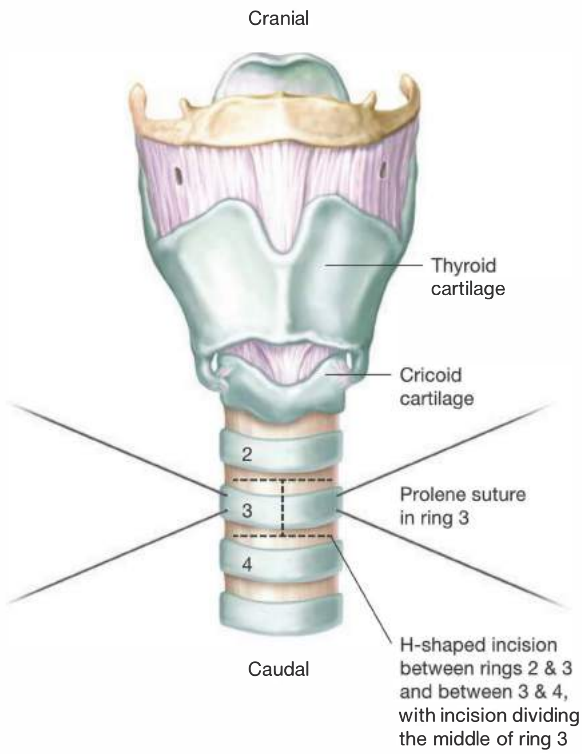

FIG 5 ● Illustration showing H-shaped incision of the trachea.

CANNULATION OF THE TRACHEA

- The endotracheal tube is then slowly withdrawn until the tip is just proximal to the tracheotomy site.
- The tracheostomy tube is then inserted into the trachea (FIG 6A,B).
- The tracheostomy tube is connected to anesthesia ventilator and end-tidal carbon dioxide (CO_2) is confirmed.

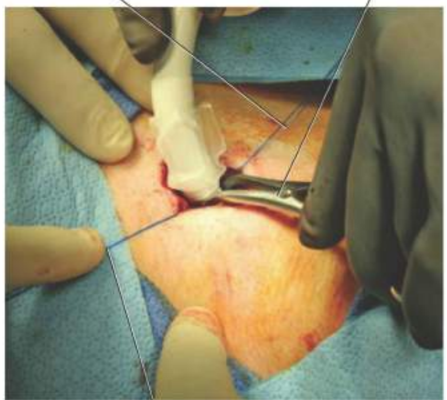

FIG 6 ● **A.** Tracheal spreader opening of the trachea. Note the endotracheal tube has been withdrawn to a location proximal to the tracheotomy. **B.** Introduction of the tracheostomy tube into the tracheotomy.

CLOSURE

- A 2-0 Prolene suture is then used to reapproximate skin edges above and below the tracheostomy tube.
- The tracheostomy tube is secured to the skin using interrupted 2-0 Prolene sutures.

PEARLS AND PITFALLS

Pretracheal dissection	■ Working from cephalad to caudad in the pretracheal plane results in less bleeding.
Ring fixation	■ Placing the sutures in the 3rd ring allows for lateral traction to open the tracheotomy for insertion of the tracheostomy tube. ■ The ring sutures also allow for reinsertion of tracheostomy tube in the case of accidental dislodgement before a tract is formed.
Tracheal entry	■ Airway fires have been described with the use of electrocautery to enter the trachea or to control bleeding of the trachea. Sharp entry with scalpel is the safest means to enter the trachea. Otherwise, fraction of inspired oxygen (FiO_2) needs to be reduced to less than 40% to minimize risk (experiments have shown flammable conditions in FiO_2 as low as 25% with use of laser).[7] ■ If division of the 3rd ring is not possible with scalpel, curved Mayo scissors can be used. ■ Insertion of the tracheostomy tube into the trachea should be at 90 degrees to the trachea. Tangential entry increases the chance of pretracheal placement of the tracheostomy tube.

POSTOPERATIVE CARE

- The 3rd ring stay sutures should stay until a tract develops between the skin and the trachea. Usually, these are removed after the first exchange of the tracheostomy tube.
- The tracheostomy tube should be exchanged between days 7 and 12 for hygiene purpose as well as to decrease the granulation tissue ingrowth into the tracheostomy tube.
- Once off the ventilator and as long as secretions are manageable, the tracheostomy tube can be downsized. Usually, the tube is downsized every other day, until the tube is size 4, at which time decannulation is performed.
- A decannulated tracheostomy stoma is covered with sterile gauze and tape and generally closes within 2 to 4 days.

COMPLICATIONS

- Rate of skin infection at surgical site: 2% to 3%
- Bleeding
- Tracheoinnominate fistula
- Tracheostomy dislodgement

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Chapter 2

Cricothyroidotomy

Sam T. Windham, III

DEFINITION

- Cricothyroidotomy is an emergency procedure to establish airway access when orotracheal intubation is not possible or attempts have failed. As cricothyroidotomy has a high rate of complications compared to orotracheal intubation and tracheostomy, its role is limited to a rescue procedure for emergent airway access.

PATIENT HISTORY AND PHYSICAL FINDINGS

- The circumstances surrounding the loss of airway are paramount to the use of cricothyroidotomy for establishment of the airway. These are broken down into patient-specific circumstances and setting-specific circumstances.
  - Patient-specific circumstances include trauma to face or upper airway, concern for cervical spine fractures, traumatic brain injury, limitations to cervical mobility, previous radiation to head and neck, and other circumstances leading to a difficult airway.
    - In certain circumstances such as potential isolated cervical spine fracture in a patient with a competent airway, attempts can be made to establish an airway by other means such as awake fiberoptic intubation or other intubation-assist devices.
    - In the setting of severe maxillofacial trauma where direct laryngoscopy is impeded by deranged anatomy, bleeding, and/or difficulty ventilating the patient, cricothyroidotomy should be considered early in the airway management algorithm.
  - Setting-specific circumstances also play a role as to the timing of emergency cricothyroidotomy in the airway algorithm. For example, considering the location where the airway is lost (such as the emergency department, operating room, or intensive care unit) will play a role in deciding what other options, equipment, and help are available.
    - If the loss of airway occurs in the operating room where full technical support is available, the full difficult airway algorithm may be used.[1]
    - The most common setting for the performance of cricothyroidotomy is for the trauma patient in an emergency room. In these patients with multiple injuries, suboptimal airway exposure due to need to maintain in-line cervical stabilization, and/or facial trauma, cricothyroidotomy should be prepared for at the first indication of a difficult airway.

SURGICAL MANAGEMENT

Preoperative Planning

- Planning for the cricothyroidotomy begins before the situation arises, such as familiarization with the steps involved in the procedure and knowledge of the equipment available to perform the procedure.
- Prepping the neck and obtaining equipment should begin with the second attempt of direct laryngoscopy in the difficult airway or at any sign of significant desaturation. Direct laryngoscopy may continue as the cricothyroidotomy is begun but should not delay the procedure.
- The pertinent anatomy and location of the cricothyroid membrane are illustrated in **FIG 1**.

Positioning

- The patient is placed in the supine position with in-line cervical spine stabilization for trauma patients.

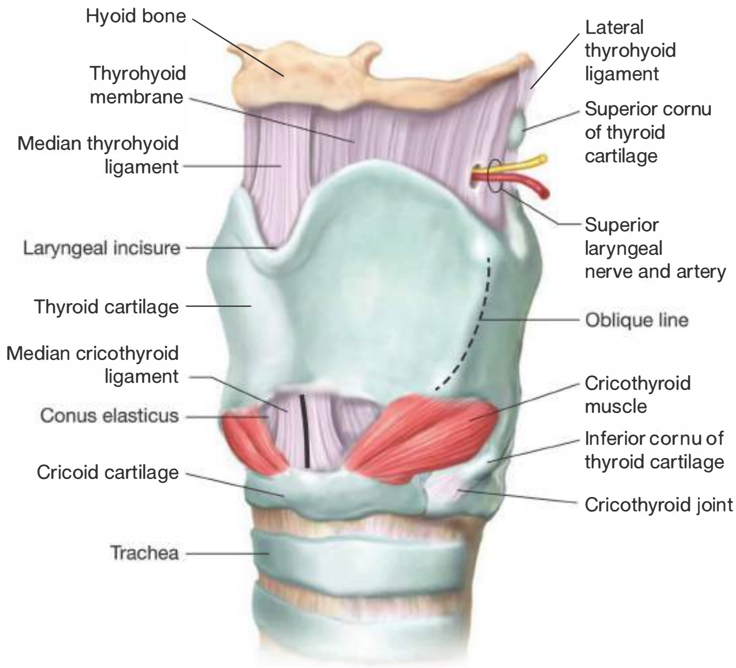

FIG 1 • Pertinent anatomy illustrating position of the cricothyroid membrane.

TECHNIQUES

PREP

- Betadine or available skin prep should be used to prep the anterior neck as quickly as possible.

INCISION

- Using a no. 10 blade or no. 15 blade scalpel, a vertical incision should be made from the prominence of the thyroid cartilage to below the level of the cricoid cartilage. This incision should be through the epidermis, dermis, and subdermal tissues (**FIGS 2** and **3**).

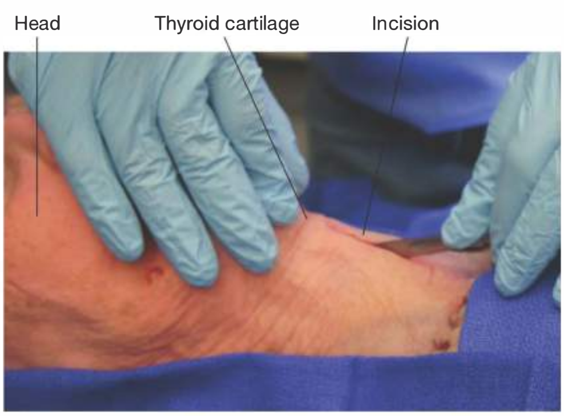

FIG 2 • Incision of the anterior neck, incising through epidermis, dermis, and subdermal tissues.

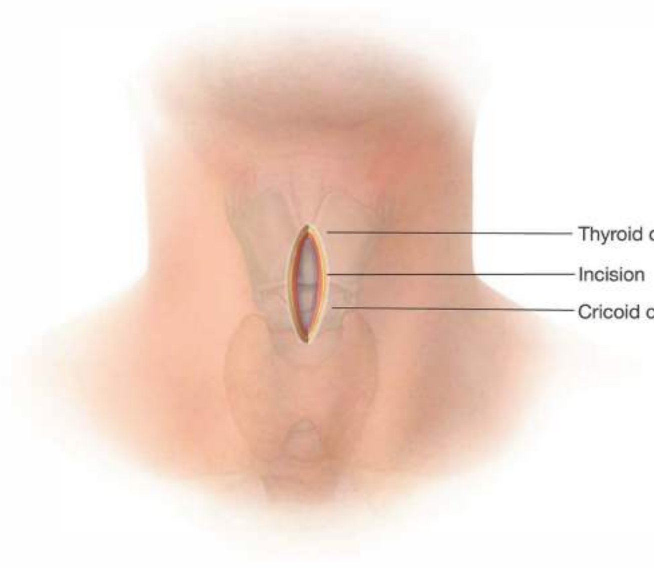

FIG 3 ● Location of the skin incision relative to anatomic landmarks.

CRICOTHYROID MEMBRANE ENTRY

- A curved hemostat is placed on the cricothyroid membrane and "popped" through the membrane. The hemostats are then opened in a vertical-oriented manner and left in place to maintain the opening in the cricothyroid membrane (**FIG 4**).
- A bougie (15 Fr) is advanced through the opening of the hemostats and into the trachea (**FIG 5**).

FIG 4 ● Curved hemostat placed onto cricothyroid membrane.

FIG 5 ● Hemostat spread to open cricothyroid membrane in able to introduce bougie into the trachea.

TECHNIQUES

INTUBATION

- A 6-0 endotracheal tube (ETT) is advanced over the bougie into the trachea and the balloon is insufflated (**FIG 6**).
- Confirmation of a tube placement should be performed with auscultation of the lung fields, end-tidal CO_2 monitor, if available, and portable chest x-ray.
- 0 Silk (or other large suture) is used to secure the ETT to the skin and prevent accidental dislodgement of the tube (**FIG 7**).

FIG 6 ● 6-0 ETT introduced into the trachea over the bougie catheter.

FIG 7 ● 2-0 Prolene used to secure the ETT in place and to close the wound.

PEARLS AND PITFALLS

Incision	■ A vertical incision is preferable, as a transverse/horizontal incision can transect the anterior jugular veins, leading to significant bleeding, and impede visualization.
Cricothyroid membrane entry	■ If a hemostat is not readily available, the blade of the scalpel can be used to incise the membrane and the handle can be used to open the membrane.
Intubation	■ A bougie does not have to be used, but once in place, it facilitates the introduction of the ETT and maintains the control of the airway. ■ Giving a twist to the ETT allows for easier introduction of the ETT through the cricothyroid membrane. ■ A tracheostomy tube can be used instead of the ETT, but often these are more difficult to find and the ETT are usually readily available.

POSTOPERATIVE CARE

- The cricothyroidotomy should be formalized to a tracheostomy within the first 48 hours to minimize risk of long-term complications of tracheal stenosis as well as to establish a safer, more definitive airway.
- In general, the cricothyroidotomy is converted to an open tracheostomy. At the same time, the wound of the cricothyroidotomy is surgically cleaned and a strap muscle can be pulled down to the site of the cricothyroidotomy to aid with wound healing.

COMPLICATIONS

- Subglottic stenosis
- Wound complications
- Occlusion of the small ETT with blood

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Chapter 3

Tracheostomy: Endoscopic

Sam T. Windham, III

DEFINITION

- Tracheostomy is defined as a procedure creating a communication between the trachea and the skin of the neck anteriorly. Tracheostomy is used as a definitive manner of airway management as opposed to translaryngeal intubation for the needs of the critically ill patient. Since the mid-1980s, percutaneous dilational tracheostomy (PDT) has gained acceptance with equivalent safety as compared to standard surgical tracheostomy, with equal or fewer complications, and decreased resource usage and costs.[1,2]

PATIENT HISTORY AND PHYSICAL FINDINGS

- The history from the patient may be limited as compared to standard history and physical exams normally performed during routine evaluations for surgery; however, the history and physical exam should focus on (1) the indications for tracheostomy, (2) optimal timing for the performance of the tracheostomy, and (3) which approach will provide the safest tracheostomy for the patient.
- With respect to the indication for tracheostomy, the first and foremost indication should be that of the patient with a difficult airway who requires prolonged mechanical ventilator support. In these patients, loss of the airway can have devastating consequences. Pertinent history might include a difficult airway at the time of surgery; prior maxillofacial trauma; presence of inflammation or edema in the mandibular, pharyngeal, or base of tongue regions; prior head and neck radiation; or conditions that limit the mobility of the neck (e.g., ankylosing spondylitis, cervical trauma, or fixation). In these patients, early tracheostomy should be considered.
- With respect to timing of the tracheostomy, many studies have aimed to evaluate this question.
  - When endotracheal tubes were first created, the tubes were less flexible than modern tubes with low-volume and high-pressure cuffs that resulted in more tracheal trauma than modern endotracheal tubes. However, tracheal trauma and stenosis still occur with modern tubes, and as a result, this leads to one of the indications for timing of the tracheostomy. In order to minimize the risk of tracheal stenosis, most recommend performance of tracheostomy in patients for whom 2 weeks of mechanical ventilation is expected. Pena et al.[3] found that 86% of patients requiring laryngotracheal surgery for stenosis had a mean duration of 17 days of mechanical ventilation. So to minimize this risk, tracheostomy is usually recommended for expected duration of 14 days.
  - Other studies have looked at the timing for when to perform tracheostomies based on outcomes for the patients. Most studies evaluating performance of tracheostomies within the first 10 days of intensive care unit (ICU) course suggest statistically significant improvement in days on ventilator, days in the ICU, need for sedation, costs, and total hospital length of stay.[4–6] In busy hospitals, with increased ICU usage, early tracheostomy should be considered.
  - With respect to timing of the tracheostomy, a final aspect to the history to evaluate is the disease process that required the need for mechanical ventilator support. In patients with severe brain injury,[7] spinal cord injury associated with ineffective cough, severe multiple system organ failure, or in whom multiple-staged operations are planned, early tracheostomy should be considered.
- Another aspect of the history and physical exam that should be considered alters whether the patient should undergo PDT versus standard surgical tracheostomy. In the past, frequently cited contraindications to PDT were altered patient anatomy, morbid obesity, coagulopathy, cervical fracture, previous tracheostomy, and high ventilator setting, all of which should be evaluated in preprocedural setting.
  - In the setting of altered anatomy, certainly, the safer option would favor standard surgical tracheostomy with direct exposure of the trachea.
  - With respect to morbid obesity, Byhahn et al.[8] reported greater complication rate with PDT over surgical tracheostomy. If an extended length tracheostomy (XLT) is anticipated due to the distance between skin and trachea, then surgical tracheostomy may be a safer approach.
  - With respect to coagulopathy, PDT can be safely performed in patients with a coagulopathy as long as the risk factors are modified prior to the procedure. If the platelet count is less than 50,000/μL, platelets should be given at the time of the procedure.[9] If the platelet count is less than 75,000/μL and the patient has other risk factors for platelet dysfunction (i.e., azotemia, antiplatelet therapy) or abnormal coagulation cascade (i.e., elevated prothrombin time or partial thromboplastin time), platelets should be given periprocedural, as well as fresh frozen plasma if the international normalized ratio (INR) is greater than 1.7.
  - With respect to cervical fixation and cervical fractures, studies have shown that PDT can be safely performed without cervical spine clearance or fixation[10] as long as cervical extension is not needed to gain adequate exposure on physical exam.
  - In patients with prior tracheostomies, PDT has been shown to be a safe approach to tracheostomy placement.[11]
  - The final consideration in preprocedural evaluation is the ventilator settings. High ventilator settings (e.g., positive end-expiratory pressure [PEEP] >14 cm H_2O, vent rate >20 breaths per minute) are a relative contraindication to PDT due to derecruitment issues during bronchoscopy. Depending on the comfort of the surgeon, a PDT can be performed with nonbronchoscopic or a standard open surgical approach.

SURGICAL MANAGEMENT

Preoperative Planning

- Probably one of the most important components for safely performing this procedure is preparation and setup.
  - Medications for the procedure usually consist of an anxiolytic (Versed), a narcotic, and a neuromuscular relaxant.

- The bed is positioned to allow access to the head of the bed so that translaryngeal reintubation can be performed.
- An intubation/airway tray should be at the bedside as well as supplies for reintubation (e.g., Yankauer suction apparatus, Ambu bag, free flowing intravenous fluid).
- The head of the bed is positioned at approximately 30 degrees.
- A respiratory therapist and a nurse are both available as part of the preoperative planning and setup portions of the procedure.
- A bronchoscopy cart is set up to be used during the procedure.
- Periprocedural antibiotics are administered.

Positioning

- For most patients, if the head of bed is elevated, a pack is not needed behind the back for neck extension, as it often does not increase the number of cartilaginous rings above the sternal notch. It is helpful, however, if the working distance between the chin and sternal notch is limited, such as in those patients with a "second chin."
- If the pack is used, usually one to two rectangular-shaped towels are positioned behind the shoulder blades.

SETUP

- The ventilator is set to deliver 100% fraction of inspired oxygen (FiO_2) in order to preoxygenate the patient. The ventilator is also adjusted to deliver a set volume, and the rate is increased in order to preventilate the patient.
- At the same time of adjusting the ventilator settings, if the patient is conscious, the anxiolytic is given. If the patient tolerates the dosing of the anxiolytic from a hemodynamic standpoint, then a narcotic is given shortly thereafter.
- Finally, the neuromuscular relaxant medication is administered.
  - The base of the neck is prepped with chlorhexidine from the chin to the nipples and from lateral aspect of the neck to the other lateral aspect of the neck.
  - Three sterile towels are used to drape the lateral aspects of the surgical field and the caudal aspect of the field. A sterile sheet is then placed to cover the entire body of the patient and is used to lay out the equipment for the procedure (**FIG 1**).

FIG 1 ● To aid with the procedure, the equipment is positioned on a sheet on the patient to minimize turning away from the operative field.

INCISION

- Lidocaine with epinephrine is infiltrated along lower midline cervical region from the externally palpated cricoid cartilage to the sternal notch.
- A 12- to 15-mm length incision is made with a no. 15 blade scalpel through the dermis along the midline. The cephalad portion of the incision should start at or just below the level of the cricoid cartilage (**FIG 2**).
- Lidocaine with epinephrine is often used to infiltrate small points of bleeding at the lower portion of the dermis and then pressure held for 10 to 20 seconds to achieve relative hemostasis before proceeding.
- Curved hemostats are then used to perform blunt dissection along the length of the incision between the strap muscles in order to better palpate the trachea to determine the point of entry.

FIG 2 ● A 12- to 15-mm incision is made along the lower midline portion of the neck. The incision is made through the epidermis, dermis, and platysma.

CANNULATION OF THE TRACHEA

- If the bronchoscope is used, it is inserted down the endotracheal tube at this point to the end of the endotracheal tube but still inside the endotracheal tube so as to protect the endoscope from trauma (**FIG 3A**).
    - The curved hemostat or the introducer needle is then used to palpate the trachea between cartilage rings 2 and 3 (**FIG 3B**).
    - The endotracheal tube and bronchoscope are withdrawn slowly until they are positioned just above the point of palpation, then the introducer needle enters the trachea under visualization of the bronchoscope (**FIG 3C**).
    - The guidewire is then passed through the introducer needle under visualization of the bronchoscope (**FIG 3D,E**).
    - If the patient has limited "reserve"/required high ventilator settings prior to the procedure, the bronchoscope can be removed prior to the dilation portion of the procedure.
- If bronchoscope is not used for the procedure, the endotracheal tube is left in position, and the introducer needle is placed on the interspace between cartilage rings 2 and 3.
    - The needle is advanced into the trachea, aspirating with a syringe as the trachea is entered. Most commonly, air or airway secretion fluid is aspirated as the trachea is entered with the introducer needle. The endotracheal tube is left down at this step to decrease the chance for a posterior tracheal wall injury with the needle.
    - The guidewire is advanced through the introducer needle.

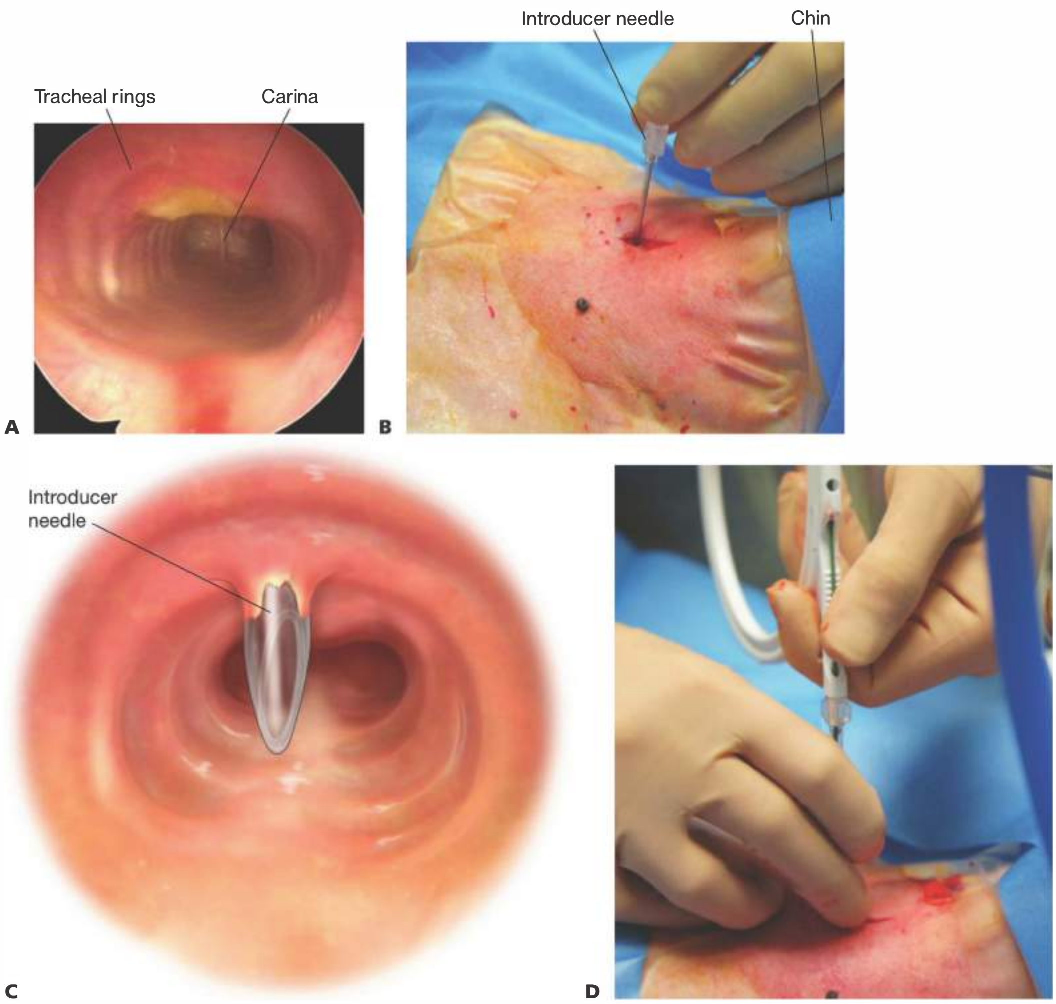
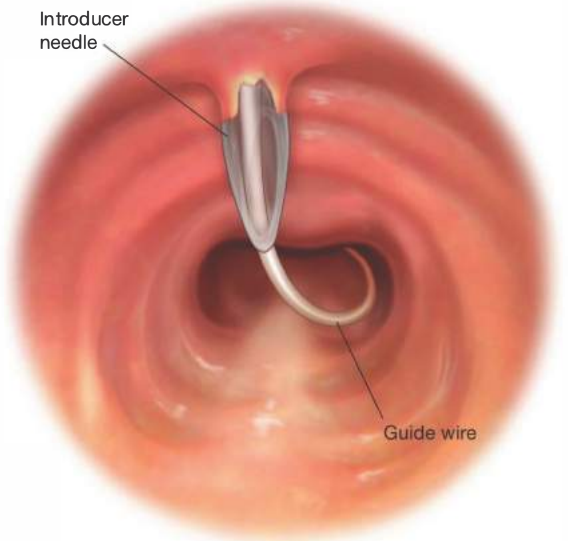


FIG 3 ● **A.** Image from the bronchoscope viewing the entire trachea. **B.** The needle is then used to apply pressure on the anterior wall of the trachea. **C.** Needle entry into the trachea under endoscopic vision. **D.** Guidewire insertion through the introducer needle from the external view. *(continued)*



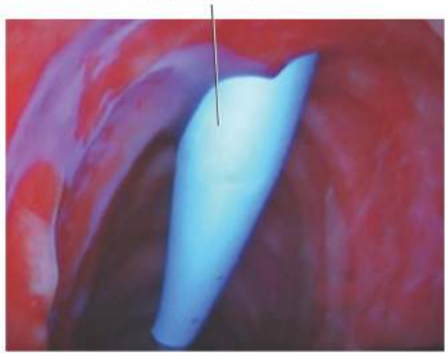
E

FIG 3 ● *(continued)* **E.** Guidewire insertion through the introducer needle from the endoscopic view.

DILATION

- The short, pretracheal dilator is then advanced over the guidewire, entering the trachea at 90 degrees to the trachea. As the dilator is entering into the trachea, a slight twist is applied to the dilator to aid with entry into the trachea (**FIG 4A,B**).
- Next, the tapered dilator and the guiding catheter are advanced as a unit over the guidewire. Once again, the catheters should enter the trachea at 90-degree angle to the trachea. The tapered dilator is advanced to dilate the trachea until the skin level mark on the dilator is at the skin incision. If the bronchoscope is not used, the endotracheal tube is withdrawn at this point by several centimeters as the respiratory therapist, who is holding the endotracheal tube, begins to feel the tapered dilator pull and hit the endotracheal tube (**FIG 4C,D**).
- The tapered dilator is removed from the guiding catheter and the guidewire, leaving the two of these in place.

A



B

FIG 4 ● **A.** Pretracheal dilator being passed over guidewire to perform pretracheal dilation. **B.** Endoscopic view of pretracheal dilator. *(continued)*

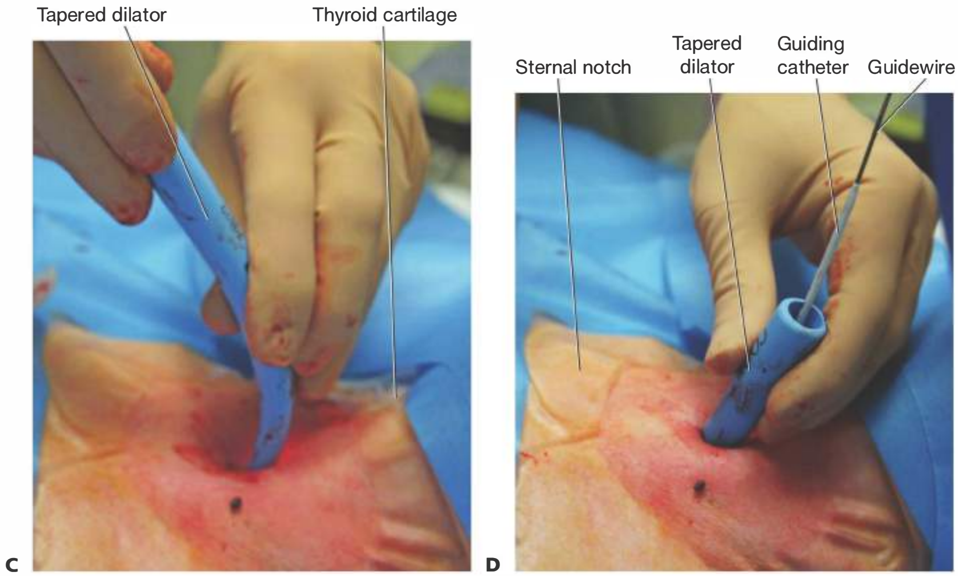


FIG 4 ● *(continued)* **C,D.** Tapered dilator being passed over guidewire and guidance catheter.

INSERTION OF TRACHEOSTOMY TUBE

- Finally, the loading dilator and the tracheostomy are loaded onto the guidewire and guidance catheter with caution to make sure the guidance catheter emerges from the distal end of the tracheostomy and loading dilator.
- Once the loading dilator is at the safety ridge of the guidance catheter, the guidance catheter, loading dilator, and tracheostomy tube are advanced as a unit into the trachea (**FIG 5A,B**).
- The guidewire, guidance catheter, and loading dilator are removed as a unit. The cuff of the tracheostomy tube is inflated. The inner cannula is then inserted into the tracheostomy. End-tidal carbon dioxide (CO_2) detection should be assessed as the patient is placed back on the ventilator or the bronchoscope should be quickly passed through the tracheostomy tube to confirm appropriate positioning of the tracheostomy tube.

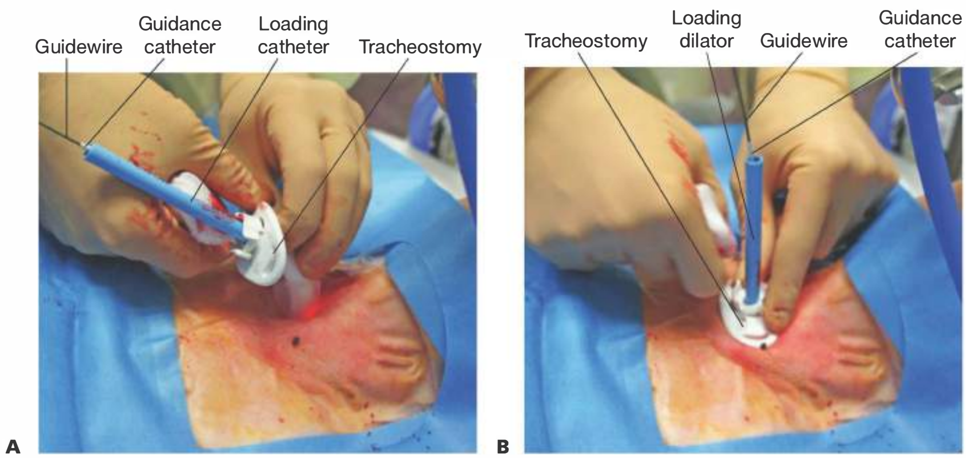


FIG 5 ● **A.** Tracheostomy tube being advanced into trachea over the guidewire, guidance catheter, and loading dilator. **B.** Completion of introduction of tracheostomy tube into trachea.

TECHNIQUES

COMPLETION OF THE PROCEDURE

- A 4 × 4 gauze should be cut to rest between the skin and tracheostomy tube for 24 hours, after which it is removed.
- The tracheostomy tube should be sewn to the neck with 2-0 Prolene sutures that remain in place for 7 to 10 days.
- A Velcro reinforcement collar also provides support to prevent accidental dislodgement prior to tract formation.
- A chest radiograph is routinely obtained postprocedure to evaluate for appropriate positioning of the tracheostomy tube, rule out pneumothorax, and evaluate for bronchial obstruction.
- The stylet of the tracheostomy tube should be taped to the wall above the patient's bed to be used for tracheostomy reinsertion should accidental dislodgement occurs.

PEARLS AND PITFALLS

Indications	■ In the obese patient, if a computed tomography (CT) scan is available, this can be used to measure the distance between the skin and trachea if an XLT tracheostomy tube is being considered.
Incision	■ If an anterior jugular vein is encountered in the incision (even if no injury is suspected), consider ligation proximally and distally as this is easiest to perform before the tracheostomy tube has been placed.
Cannulation	■ The introducing needle should be stabilized with the 1st and 2nd digits of the left hand while the 3rd–5th digits rest on the trachea to stabilize it; this helps prevent the needle from sliding off the lateral wall of the trachea. ■ The guidewire should pass easily through the introducer needle into the trachea.
Dilation	■ All catheters (pretracheal dilator, tapered dilator, and introducing catheter) should enter perpendicular to the trachea as to prevent pretracheal dissection or false passage.
Insertion of tracheostomy tube	■ Confirmation with bronchoscope should be performed if the bronchoscope is used or confirmation of end-tidal CO_2 if the bronchoscope is not used.

POSTOPERATIVE CARE

- The coagulopathic patient should be evaluated for bleeding, with platelets and/or blood products given if bleeding is present in the first 6 hours.
- A 4 × 4 gauze placed between the tracheostomy and skin should be removed 24 hours after placement.
- The initial tracheostomy tube should be exchanged between days 7 and 12 to help minimize secretions and decrease the ingrowth of granulation tissue.

COMPLICATIONS

- Rate of skin infection at surgical site: 2% to 3%
- Bleeding
- Tracheoinnominate fistula
- Tracheostomy dislodgement

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Chapter 4

Tracheal Resection and Reconstruction

Alexander T. Hillel William Grist

DEFINITION

- Tracheal resection is usually performed for the external excision of tracheal stenosis or hypertrophic scarring of the trachea with critical obstruction of the airway. The term cricotracheal resection is used when the anterior section of the cricoid cartilage requires removal due to extension of the scar near the vocal folds. Tracheal resection is performed following failure of other surgical therapy, primarily endoscopic excision and dilation of tracheal stenosis. A successful tracheal resection allows the patient to avoid a lifelong tracheostomy tube.

DIFFERENTIAL DIAGNOSIS

- Tracheal stenosis is primarily due to postintubation injury, although autoimmune disease can also cause subglottic stenosis. Acquired stenosis is usually secondary to pathogenic wound healing, with the formation of permanent scar tissue in the airway.
- Tracheal neoplasms, including adenoid cystic and squamous cell carcinoma, or thyroid tumors with tracheal invasion are less frequent etiologies for segmental tracheal or cricotracheal resection.[1]

PATIENT HISTORY AND PHYSICAL FINDINGS

- A thorough history should be performed, including past medical history, past surgical history—including previous intubations or surgery on the trachea or esophagus, medications, allergies, and a family history of autoimmune disease.
- Patients with an idiopathic etiology, who have not undergone intubation, or those with a history/family history of autoimmune disease should have an autoimmune serum panel.
- A detailed medical history for comorbidities that could affect recovery following resection includes diabetes, coronary artery disease, and lung disease including chronic obstructive pulmonary disease (COPD) and tracheobronchial malacia. Severe COPD and tracheobronchial malacia may necessitate the need for tracheostomy even following successful resection.
- Patients who had multiple previous procedures, especially open tracheostomies or cervical tracheoesophageal fistula repair, may have extratracheal fibrosis, making dissection more challenging and increasing the risk of injury to the recurrent laryngeal nerve (RLN).
- Thorough evaluation of vocal fold mobility is recommended to document preoperative function. Patients often have multiple levels of stenosis, and glottic narrowing due to a second stenosis at level of vocal folds (relative contraindication) may limit the efficacy of successful tracheal resection.
- Accurate understanding of the length of stenosis will impact the necessity of surgical release maneuvers. These are rarely required for stenosis less than 5 cm.
- Contraindications for tracheal resection are listed in Table 1.

Table 1: Absolute and Relative Contraindications for Tracheal Resection

1. Active autoimmune diseases affecting the airway (Wegener's granulomatosis, relapsing polychondritis)
2. Stenosis extending to include the vocal folds
3. Stenosis greater than half the length of the trachea (relative contraindication)
4. Concurrent laryngeal stenosis (relative contraindication)—tracheostomy will need to remain in place until laryngeal stenosis is addressed.

IMAGING AND OTHER DIAGNOSTIC STUDIES

- Bronchoscopy is required to accurately map out the stenosis, including its length, width, and distance from the vocal folds and carina when appropriate. Bronchoscopy is usually performed in the operating room or endoscopy suite (**FIG 1**); however, with appropriate topical anesthesia, in-office bronchoscopy can provide similar results and avoid a trip to the operating room.
- As detailed in the preceding section, laryngoscopy or stroboscopy, when indicated, should be performed to assess preoperative vocal fold mobility and the presence of laryngeal stenosis.
- Computed tomography (CT) can provide key anatomic detail of the trachea, especially of the external trachea and adjacent vasculature. Three-dimensional CT provides excellent reconstructions of the tracheal and bronchial airways (**FIG 2**).
- If the patient complains of dysphagia, a modified barium swallow study may yield relevant results especially if the patient requires infra- or suprahyoid laryngeal release maneuvers, which will adversely affect swallowing postoperatively.

SURGICAL MANAGEMENT

Preoperative Planning

- When relevant, preoperative discussion between surgical teams about the extent of the stenosis is recommended. If the otolaryngologist represents the primary surgeon and repair of the stenosis may require a sternotomy, thoracic surgery should be consulted.

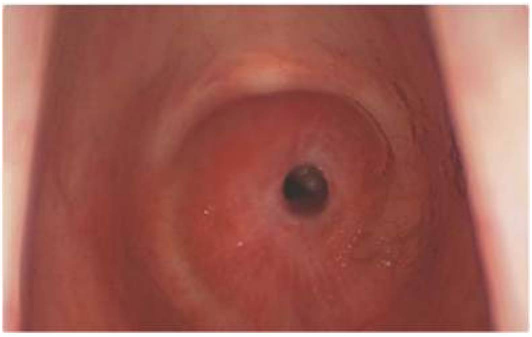

FIG 1 ● Bronchoscopic view of tracheal stenosis taken at the level of the vocal folds.

FIG 2 ● Three-dimensional sagittal CT image of cervical tracheal stenosis with dilated segment proximal to stenosis.

- Similarly, if it is a primary thoracic team performing surgery and the stenosis requires a suprahyoid release maneuver, preoperative inclusion of otolaryngology team is recommended.
- Use of an NIM™ RLN monitoring endotracheal tube (ETT) is recommended to allow for monitoring of the RLN during dissection.
- Having a second anesthesia circuit in a sterile sleeve allows for easy control of the airway when the anode tube is placed in the distal trachea following the tracheal cuts.

Positioning

- An inflatable shoulder roll should be inflated to provide complete neck extension and deflated prior to closure.
- Initial bronchoscopy may be performed with the bed rotated 90 degrees from the anesthesia team to allow the surgical team to dilate the stenosis in order to place an ETT.
- Following intubation, the bed should be rotated another 90 degrees to have the head 180 degrees from anesthesia. This allows for adequate room around the head and neck.
- If tracheostomy tube cannot be replaced with placement of an ETT following dilation, replace the tracheostomy tube with an anode tube to remove the flange from the operative field.

TECHNIQUES

BRONCHOSCOPY

- Initial bronchoscopy is recommended to assess the stenosis; dilate and place an ETT prior to resection. We encourage perioperative placement of an ETT in patients with tracheostomies to remove the tracheostomy tube from the surgical field.
- A key determination on bronchoscopy is the proximity of the stenosis to the vocal folds. If the proximal portion is within 2 cm of the superior aspect of the vocal folds, the cricoid will usually need to be included in the excision, which will influence the location of the initial tracheal incision.

PLACEMENT OF INCISION

- A low transverse neck incision should be placed in a neck crease below the cricoid cartilage extending from the anterior border of the sternocleidomastoid muscles on each side of the neck.
- If there is existing tracheostomy skin scar, the incision should include the scar around the tracheostomy site in an ellipse fashion.

SKIN INCISION AND RAISING OF FLAPS

- An incision is extended deep to the platysma, and inferior and superior subplatysmal flaps should be elevated from the sternal notch to the hyoid superiorly.
- The authors are proponents of the Mayfield thyroid retractor to provide adequate exposure.

EXPOSURE OF TRACHEA

- The sternohyoid and the sternothyroid muscles should be dissected and retracted laterally to expose the thyroid isthmus, which should be transected and reflected laterally.
- This provides exposure of the trachea, which should be skeletonized with blunt dissection to free up the anterior ligamentous attachments to just above the carina. This assists in for tension-free anastomosis. Lateral dissection should be limited to maintain the vascular supply.

SEPARATION OF COMMON PARTY WALL

- Following skeletonizing the anterior trachea, the trachea should be dissected circumferentially at the level of the stenosis. During exposure of tracheoesophageal groove, care should be taken with the dissection given proximity of RLNs. Given the greater ascending length of the left RLN, it tends to run in a more cranial–caudal course, whereas the right may be more oblique in a lateral to medial direction.
- Dissection may be used with a (Crile) clamp to separate the common party wall, separating the posterior membranous tracheal wall from the anterior wall of the esophagus (**FIG 3A**). This should be done at the level of stenosis, however, not superior to the 1st tracheal ring to prevent injury to the RLNs.
- Palpate the tip of the clamp on the contralateral side to gently dissect through the tissue plane. Tissue bunching up between clamp tip and finger suggesting the dissection is in wrong plane with the tissue is likely representing folded membranous tracheal wall or the esophagus.
- After the wall is separated, placement of a 1-inch thick Penrose drain maintains control (**FIG 3B**).

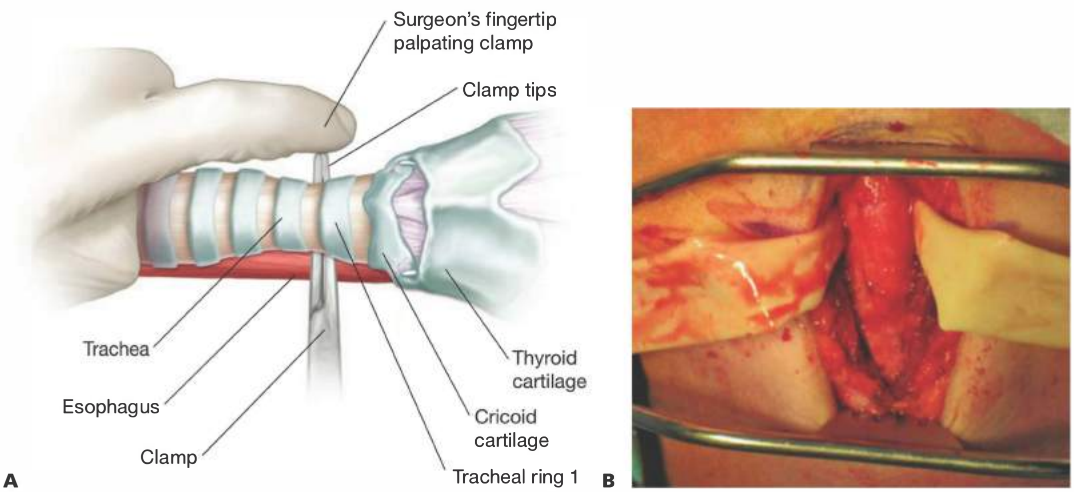

FIG 3 ● **A.** Blunt clamp dissection separating posterior tracheal wall from esophagus. **B.** Mayfield retractor providing cranial–caudal exposure of trachea after 1-in Penrose placed between trachea and esophagus.

TRACHEAL INCISION

- Prior to the tracheal incision, two retention sutures should be placed with 2-0 Vicryl sutures (on a CT-1 needle) around one or two tracheal rings below the planned inferior incision line. These are placed at 10 o'clock and 2 o'clock positions. This provides a substantial hold on the trachea should the trachea retract following the incision.
- The superior incision should be made first. If the subglottic stenosis is high, in proximity to the cricoid, the initial incision should be made at the inferior aspect of the cricothyroid membrane. A curved Mayo scissors is used to cut through anterolateral cricoid, angling the cut laterally in a superoinferior direction (**FIG 4A**). Usually, only 120 to 180 degrees of the anterior cricoid require excision; however, up to 240 degrees may be excised (**FIG 4B**).[2] If posterior cricoid remains thickened with concern for airway obstruction following anastomosis, it may be excised or ablated.
- For cervical tracheal stenosis, enter at top portion of the stenosis as estimated by bronchoscopy. Initially, favor the incision toward the stenosis so healthy trachea is not excised.
- If the ETT is interfering with the superior incision, it may be retracted by the anesthesia team and surgery may continue under intermittent apneic conditions. Tying a 2-0 silk suture through the Murphy's eye of the ETT will allow for easy advancement later in the procedure.
- Next, the posterior incision is made through the membranous trachea. This may be inferior to the anterior incision, resulting in a beveled cut.
- The inferior incision is made one ring below the inferior aspect of stenosis, again beveled inferiorly in an anterior–posterior direction to match the superior cut.
- At this point, a sterile anode tube on a second anesthesia circuit is placed into the open aspect of the trachea to ventilate the patient (**FIG 4C**). Close communication with the anesthesia team is paramount during placement and subsequent removal of the anode tube.

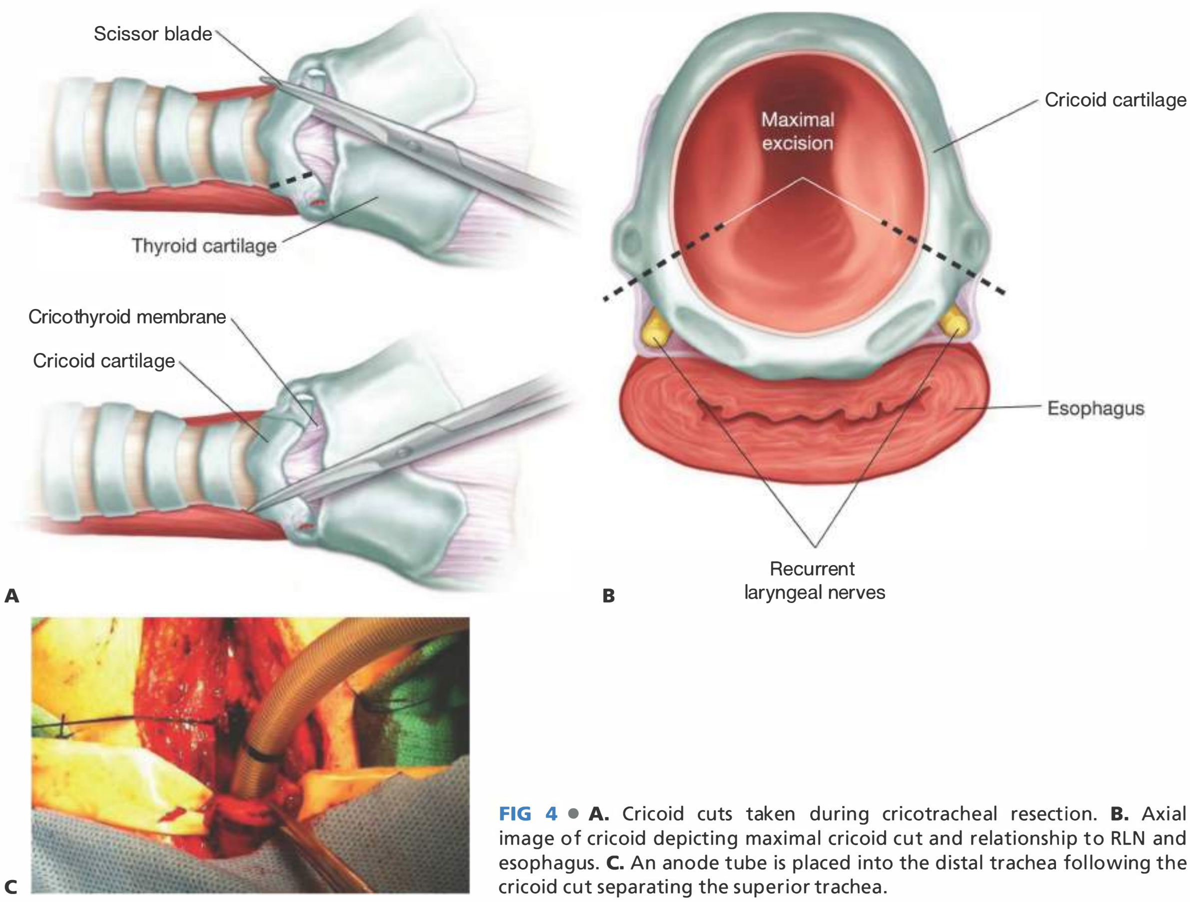

FIG 4 ● **A.** Cricoid cuts taken during cricotracheal resection. **B.** Axial image of cricoid depicting maximal cricoid cut and relationship to RLN and esophagus. **C.** An anode tube is placed into the distal trachea following the cricoid cut separating the superior trachea.

ANASTOMOSIS

- During the anastomosis, the anode tube is intermittently removed to place the sutures and replaced to ventilate.
- The posterior membranous wall should be lined up first with a 2-0 polydioxanone (PDS) suture placed at the corner bilaterally, leaving the suture knot external to the trachea (**FIG 5A,B**). If a central tracheal resection is performed, the suture spans from the corner of the membranous trachea inferiorly to the posterior aspect of the cricoid superiorly. Prior to tying the corner sutures, a running 2-0 PDS is used to close the membranous trachea. After the corner sutures are tied, the running suture is sutured to one side, pulled tight, and sutured to the contralateral corner suture (**FIG 5C**).
- Closure continues in a lateral to anterior direction from each corner using 3-0 Vicryl interrupted sutures with the suture knots kept outside the lumen (**FIG 5D,E**).
- Prior to placing the anterior sutures, the anode is ultimately removed and the ETT is advanced past the anastomosis. The cuff should be advanced beyond the anastomosis to prevent anterior sutures from including the cuff.
- If there is some concern for tension, the shoulder roll may be deflated and the head flexed to reduce tension.
- Superior retention sutures are placed through the thyroid cartilage superiorly at 10 o'clock and 2 o'clock positions and tied to the inferior stay sutures to release tension from the anastomosis (**FIG 5F,G**).[3]
- Finger dissection along anterior trachea is usually adequate for tension release in most cases (<5 cm). If extra length is needed, suprahyoid laryngeal release provides 1 to 2 cm in length with less risk of injury to the internal branch of the superior laryngeal nerve than infrahyoid release.[4] Hilar release is not usually performed for lengthy benign stenosis; instead, the substantially less morbid Tracheal T-Tube reconstruction is recommended.[2]
- After thoroughly irrigating the surgical bed, the anastomosis may be tested by filling the bed with saline, deflating the cuff, and having anesthesia provide positive pressure ventilation. If bubbles are appreciated, the leak should be localized and closed.

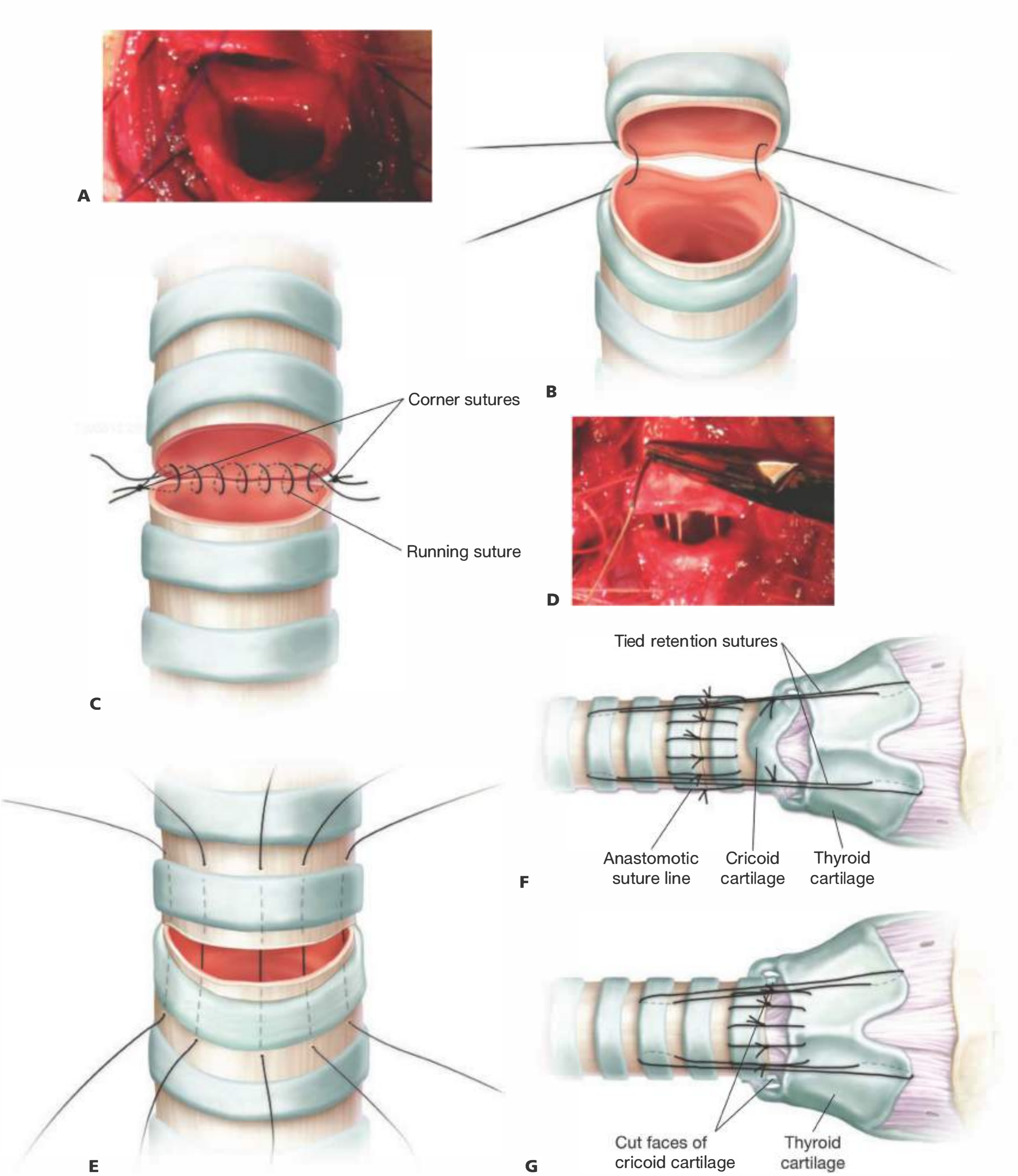

FIG 5 ● **A.** The anastomosis begins with sutures passed at each posterolateral corner of the membranous trachea inferiorly and the posterior cricoid using 2-0 dyed PDS suture. Panel **(B)** is an illustration of this step. **C.** Closure of membranous tracheal wall initially with two posterolateral corner sutures and then a running suture along the membranous wall. After all three are placed, the two corner sutures are tied, and then each end of the running suture is tied to the respective corner suture. All suture knots are kept outside the lumen. **D.** After the lateral trachea is approximated with interrupted Vicryl sutures, the ETT is advanced (ETT no pictured) and the anterior wall is closed. Panel **(E)** is an illustration of this step. **F.** Retention sutures are tied to relieve tension off the anastomotic suture line in a tracheal resection. **G.** The anastomosis in a cricotracheal resection, sutured to the thyroid anteriorly, showing the lateral presence of the cricoid, which is included in the anastomosis laterally (and posteriorly—not pictured).

TECHNIQUES

CLOSURE

- After hemostasis is verified, a Penrose drain may be placed deep to the strap muscles. We favor a Penrose drain because a negative pressure bulb drain may propagate a small tracheal dehiscence. The 3-0 Vicryl sutures are used to close the sternohyoid and sternothyroid muscles and to reapproximate the platysma layer. Finally, the epidermis is closed with a nylon suture.
- Grillo[2] proposed a "guardian" suture (Grillo stitch) passed through the skin of the submentum to the presternal skin as a reminder to the patient to prevent excessive neck extension and limit postoperative tension on the anastomosis. The placement of cartilaginous retention sutures creates a higher force requirement for tracheal anastomotic rupture beyond native tracheal rupture. This provides support for not placing a guardian suture, allowing patients to avoid the associated postoperative discomfort.[3,5]

PEARLS AND PITFALLS

Indications	■ A thorough history should be performed, including past medical, surgical, and family history along with preoperative bronchoscopy and imaging to assess if the patient is an appropriate surgical candidate. ■ Postintubation stenosis represents the primary indication along with tracheal neoplasms and, rarely, tracheoesophageal fistula. ■ Avoid operating on patients with active autoimmune disease.
Incision	■ A low transverse neck incision is usually placed in a neck crease just below the cricoid cartilage. ■ Existing tracheotomy scars should be excised.
Exposure	■ Subplatysmal flaps are elevated from the sternal notch inferiorly and superiorly to the thyroid cartilage for tracheal resection and hyoid cartilage for cricotracheal resection.
Excision	■ The posterior wall of the trachea should be separated from the esophagus with a clamp. ■ Inferior retention sutures prevent tracheal retraction. ■ Including a margin of one tracheal ring, when possible, is ideal to prevent restenosis.
Closure	■ Absorbable sutures reduce the risk of anastomotic restenosis. ■ Tying the superior and inferior retention sutures relaxes tension on the anastomosis. ■ A Penrose drain may be placed and an optional Grillo stitch may be used to remind the patient not to extend their neck.
Postoperative care	■ Extubation following the procedure is highly recommended.

POSTOPERATIVE CARE

- We are proponents of immediate extubation following tracheal resection. Close observation with the patient placed on proton pump inhibitors, antibiotics, and pain control is recommended. If there is no concern for esophageal injury, an initial soft diet may be advanced as tolerated. The patient should be instructed to limit neck extension.

OUTCOMES

- Long-term outcomes from tracheal resection are excellent with 95% of patients, maintaining a patent airway and mortality between 1% and 2%.[1,6] Anastomotic complications occur less than 10% of the time, with significant risk factors including reoperation, diabetes, lengthy resections (>4 cm), and laryngotracheal resection.[1]

COMPLICATIONS

- Anastomotic dehiscence
- Anastomotic granulation tissue and restenosis
- Infection (wound or pulmonary)
- Vocal fold paralysis
- Loss of high-pitched phonation (with sacrifice of cricothyroid muscles)
- Dysphagia (increased with superior release maneuvers)
- Hemorrhage

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Chapter 5 Lobectomy: Open

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DEFINITION

- Anatomic resection of one or more of the pulmonary lobes with ligation and resection of their respective bronchus, arterial supply, and venous drainage (**FIG 1**).

Indications

- Appropriately staged and selected patients with non–small cell lung cancer (NSCLC). For the purposes of this chapter, we will focus on oncologic resection of pulmonary lobe together with lymph node (LN) dissection (**FIG 2**).
- Destroyed lobe from chronic infections such as aspergillosis or tuberculosis (TB)

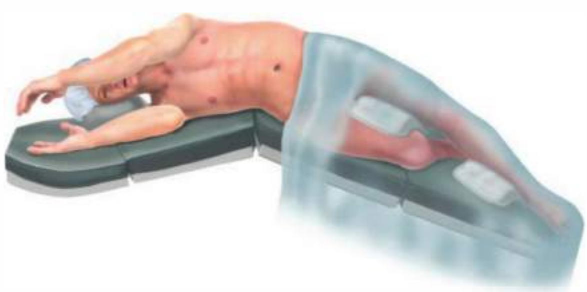


FIG 1 • Provides an overview of the surgical anatomy and related LN stations.

PATIENT HISTORY AND PHYSICAL FINDINGS

- Growing nodules in a smoker
- Chronic cough and/or hemoptysis
- Dyspnea
- Age older than 50 years
- History of smoking
- Family or personal history of cancer
- Lymphadenopathy
- Horner's syndrome

IMAGING AND OTHER DIAGNOSTIC STUDIES

- Chest x-ray: Plain films may show a pulmonary nodule and are also useful to evaluate for chronic lung conditions such as chronic obstructive pulmonary disease (COPD). Historically, the pattern of calcification of the nodule has been used to differentiate between benign and malignant lesions. However, this is not sensitive, as up to 20% of malignant nodules had benign appearance. Serial x-rays may be required to follow the lesion.
- Contrast-enhanced computed tomography (CT) scan: A solitary pulmonary nodule is most likely benign; however, high index of suspicion should prompt further investigation to rule out the possibility of malignancy. Typically, malignant nodules enhance more than 20 Hounsfield units (HU), whereas benign nodules are usually less than 15. CT is useful to identify the location (central vs. peripheral), size, characteristics, single versus multiple, presence or absence of direct

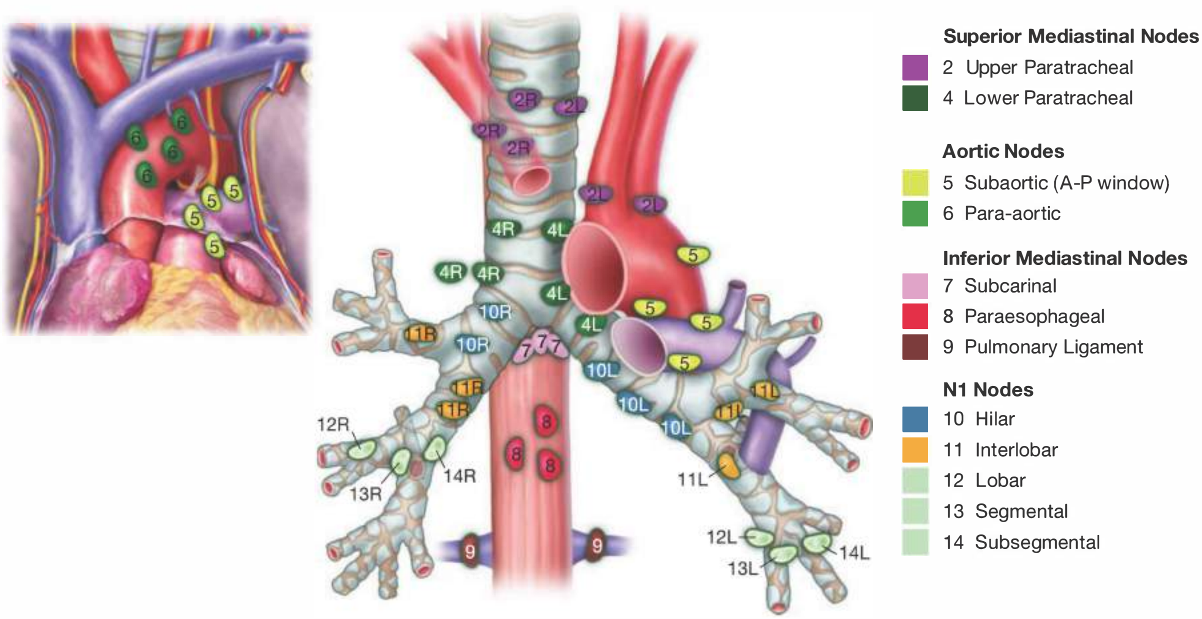


FIG 2 • Lymph node classification for lung cancer staging.

extension to mediastinal structures and/or chest wall, and presence or absence of suspicious LNs and their location.
- Positron emission tomography (PET) scan: The PET scan is less sensitive, however, more specific than CT in identifying malignant lesions. A lesion with standard uptake value (SUV) of 4.6 is associated with 96% likelihood of malignancy. An uptake of 0 to 2.5 is associated with 25% likelihood of malignancy. For staging purposes, PET scan helps identify the presence or absence of PET avid lymphatic and/or systemic metastasis.
- Mediastinoscopy for LN biopsy and staging
- Endobronchial ultrasound (EBUS) for LN status and biopsy of suspicious LNs
- Navigational bronchoscopy
- Pulmonary function test: with focus on forced expiratory volume (FEV_1) and diffusing capacity of the lung for carbon monoxide (DL_{CO}). These measures help predict the postresection pulmonary function.
- Video-assisted thoracoscopic surgery (VATS) biopsy if the diagnosis is still in doubt
- Brain and/or spine CT or magnetic resonance imaging (MRI) should be considered to identify possible metastasis, especially if the patient has neurologic symptoms. It was found that up to 18% of NSCLC has brain metastasis at presentation, with 10% asymptomatic.

SURGICAL MANAGEMENT—PULMONARY LOBECTOMY

Positioning and Preoperative Planning

- Position the patient supine.
- Intubate with a double lumen endotracheal tube.
- Perform complete bronchoscopy and confirm position of the double lumen tube for single-lung ventilation.
- Place a Foley catheter.
- After intubation, place the patient in full lateral decubitus position, the operated side exposed.
- Arms in swimmer's position to display the axilla
- Shoulder higher than hip
- Legs are positioned with the bottom leg bent and pillow in between to stabilize patient's lateral position.
- Break table (kidney bend/flex) and use additional reverse Trendlenburg to position the patient's lateral chest wall almost parallel to the floor and the legs are angled toward the floor.
- Pad pressure points and bony prominences; appropriately secure body position.
- A body warmer to prevent patient hypothermia can be applied.
- Curvilinear posterolateral incision at the 5th intercostal space is made starting midway between the medial edge of scapula and spine ending at the anterior axillary line, passing at a point two fingerbreadths below the scapular tip.
- We spare the rib as well as the serratus anterior muscle during dissection.
- Inject local anesthetic directly into the 5th and 6th intercostals nerve roots.
- Apply rib spreader retractor with gradual retraction.
- First inspect the pleural space and explore to ensure there are no metastatic lesions on the diaphragm or the parietal or visceral pleura.
- The hilum is identified after the lung is retracted posteriorly and inferiorly. The dissection is carried down between the hilar structures and the phrenic nerve.
- Sweep phrenic nerve gently down to remove the station 10R LN, avoiding the small phrenic vein that goes to the large station 10R LN that is routinely found in this area.
- Divide the inferior pulmonary ligament up to the level of the inferior pulmonary vein (IPV). Resect the LNs encountered in this area (stations 8 and 9) and clean the esophagus and vagus nerve of hilar tissue (**FIG 3**).

NOTE: It is important to place the patients flank exactly over the breaking point (flex or kidney break) of the table. We use the break table/flex function to maximize rib separation.

FIG 3 ● The inferior pulmonary ligament exposed by retracting the lung superiorly.

TECHNIQUES

RIGHT UPPER LOBECTOMY

- Develop the bifurcation between middle and upper lobe veins by bluntly dissecting it off of the underlying pulmonary artery (PA) (**FIG 4**).
- Continue en bloc dissection of the hilar tissue to clearly expose the main PA.
- Encircle the superior pulmonary vein with a vessel loop and retract it off the PA behind it. Using the vessel loop as a guide, the linear stapling device is passed across the right superior pulmonary vein and fired (**FIG 5A–C**).

FIG 4 ● Identification of superior PA.

FIG 5 ● Transection of right superior pulmonary vein: **(A)** vessel loop placed, **(B)** vessel loop guiding stapler, and **(C)** vein transected.

- Next, the anterior-apical trunk PA branch is encircled with a vessel loop and transected with a linear stapler in the same fashion as the vein (**FIG 6**).
- The right upper lobe (RUL) bronchus' anatomy is exposed. Its upper aspect is easily seen coming off the trachea. The dissection is continued inferiorly to expose the inferior edge of the RUL bronchus and free it from the bronchus intermedius (**FIG 7**).
- LN dissection (stations 10R and 11R, hilar and interlobar) is continued along the right main bronchus and the bifurcation between the bronchus intermedius with the upper lobe bronchus identified (**FIG 8**).
- Encircle the RUL bronchus with a vessel loop and transect with a linear stapler. Care must be taken to apply only minimal retraction on the specimen to avoid tearing of PA branches (**FIG 9**).
- Next, the posterior segment of the PA is exposed. The surrounding N1 nodes can be removed and the posterior artery can be encircled with a vessel loop and taken with a vascular stapler (**FIG 10**).
- Prior to stapling the fissure, the anterior aspect of the PA is carefully inspected to ensure there are no PA branches remaining. If so, these are usually quite small and can be easily torn and must be carefully ligated.
- The fissure between the RUL and the right middle lobe (RML) is now taken with a stapler (**FIG 11**). This is usually taken from anterior to posterior; however, it can also be taken from the back.
- As division of the fissure is completed, the main PA should be seen and the stapler should be placed just above it after ensuring that all small PA branches to the RUL have been taken. The RML PA branch can be easily seen and should be preserved, and the RUL must be lifted to ensure the bronchus is included in the resected specimen.
- To delineate the minor fissure, the upper lobe is retracted superiorly and the middle and lower lobe are pushed inferiorly (**FIG 12**).
- The minor fissure is divided with a linear stapler (**FIG 13**).
- The remaining LN dissection of stations 2R and 4R should be performed (**FIG 14**).

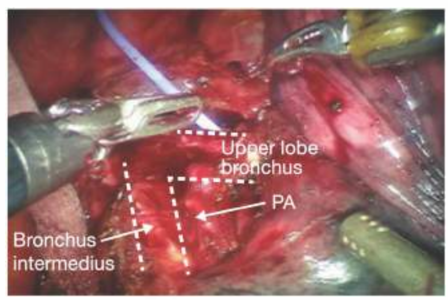


FIG 7 ● Identification of RUL bronchus, bronchus intermedius, and PA.

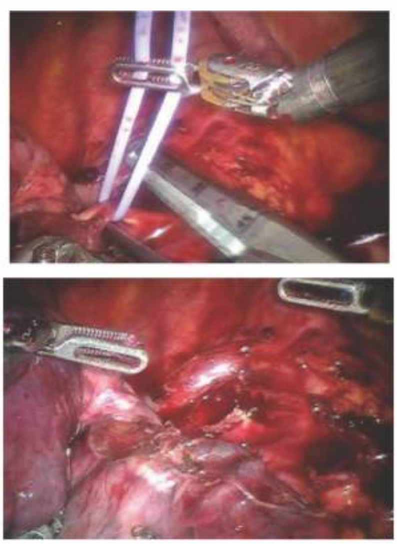


FIG 6 ● **A,B.** Transection of anterior-apical PA branch.

FIG 8 ● Removal of hilar and interlobar LN stations (10R and 11R).

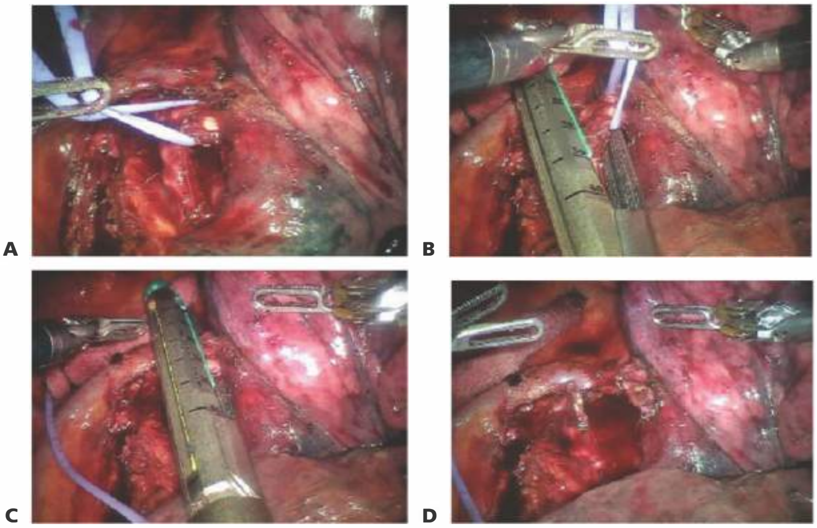


FIG 9 ● Transection of RUL bronchus: **(A)** vessel loop placed, **(B)** vessel loop guiding stapler, **(C)** stapler placed, and **(D)** bronchus transected.

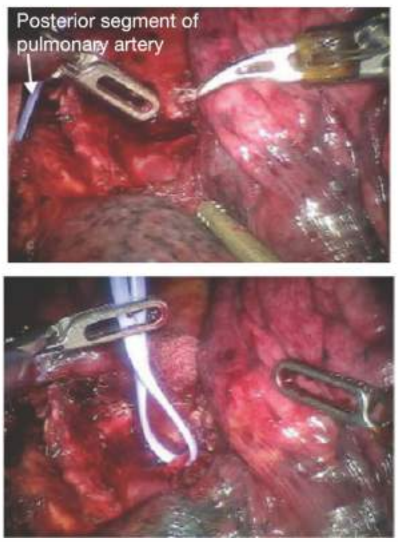


FIG 10 ● Identification of posterior segment of PA.

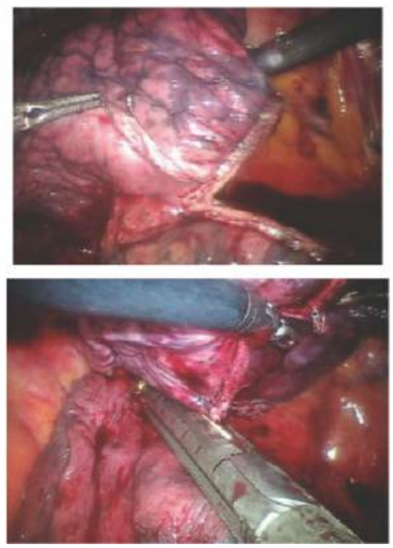


FIG 11 ● Transection of major fissure.

FIG 12 ● Minor fissure exposed for transection.

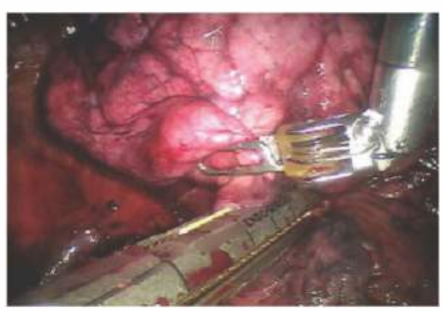


FIG 13 ● Transection of minor fissure.

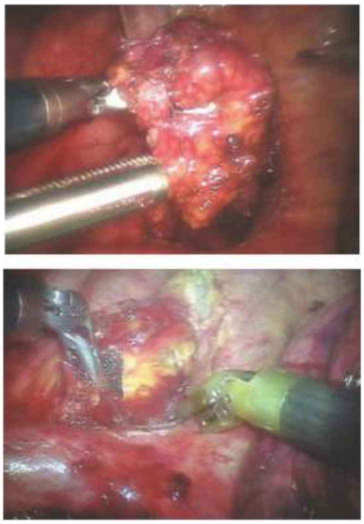


FIG 14 ● Removal of superior mediastinal LN stations (2R and 4R).

RIGHT MIDDLE LOBE RESECTION

- Bluntly dissect and identify the origin of the superior pulmonary vein. Continue the dissection inferiorly to view the RML vein branch. It can be a separate branch that drains into the left atrium, but most commonly, it joins the main trunk of the superior pulmonary vein.
- The RML vein is identified and cleaned circumferentially of hilar tissue. The LNs 10R is removed.
- A vessel loop is placed around the RML vein, and then, using the vessel loop as a guide, a linear vascular stapling device is passed across the vein and fired.
- Next, the anterior fissure between the RML and right lower lobe (RLL) is stapled.
- Care is taken to ensure the PA branches to the RLL are left intact and the RML bronchus is not injured as the dissection continues anterior to it. This will expose multiple LNs (11R and 12R) that surround the RML bronchus.
- Encircle the RML bronchus with a vessel loop and transect with a linear stapler.
- Expose the hilar tissue surrounding the arterial branches to the middle lobe and the origin of the RML bronchus.
- Identify the anterior PA branch to the RLL, and continue dissection along the top of the PA posteriorly until the superior segmental artery to the RLL is recognized.
- Dissect the hilar tissue (LN stations 10, 11, and 12R) from the interlobar portion of the arterial branches and then ligate the one or two RML PA branches. This is accomplished by first removing the LNs off of and between the PA branches and then encircling them with a vessel loop.
- The RML fissure is stapled; take care to avoid the RML vein.
- After the RML is free of all attachments, all of the N2 and N1 LNs should then be removed.
- Often, the LNs of stations 2R and 4R have not been removed yet and should be at this point. For completion of LN dissection in the subcarinal (station 7) and right and anterior mediastinal tissue (station 4R), the same exposure and dissection can be performed as with the upper lobe.

RIGHT LOWER LOBE RESECTION

- Divide the pleura enclosing the RLL anteriorly to the level of the RML vein branch. Continue the dissection in the plane between the superior and inferior pulmonary vein.
- Identify the junction between RUL bronchus and bronchus intermedius and resect the LN that is commonly found in this location.
- Encircle the IPV with a vessel loop and, using the vessel loop as a guide, the linear stapling device is passed across the right IPV and fired.
- Continue dissection on the inferior side of the bronchus intermedius into the carina removing the subcarinal LN station 7.
- Identify the superior segment of the lower lobe and develop the subadventitial plane of the right PA.
- At this point, all major vessel branches should be identified (RML artery, posterior recurring branch to the RUL, and the segmental vessels to the RLL).
- Next, the major fissure is stapled.
- Dissection is continued along the artery to circumferentially free the branches of the right PA supplying the lower lobe.
- Encircle the superior segmental artery with a vessel loop and transect with a linear stapler in the same fashion as the vein. Take care to not interfere with the takeoff of the posterior recurring branch to the RUL, because it can originate from the superior segmental artery.

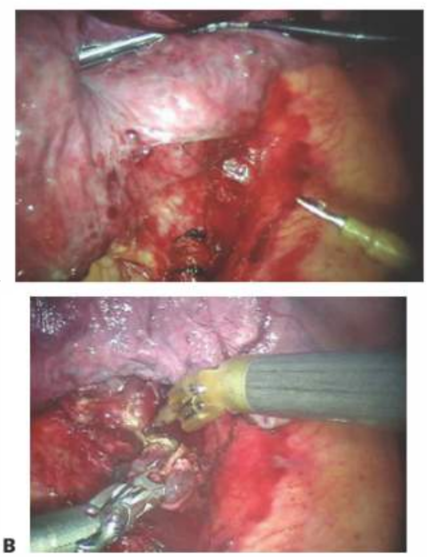
- The bifurcation of the RML bronchus and bronchus intermedius is identified. A vessel loop can be passed around the bronchus intermedius to assist with exposure.
- Dissect the RLL bronchus circumferentially and confirm complete dissection by placing a vessel loop around it.
- Ensure the RML bronchus is seen and not kinked prior to stapling the RLL bronchus.
- Transect the RLL bronchus with a linear stapler. Care must be taken to apply only minimal retraction on the specimen to avoid tearing of pulmonary structures.
- The division of the remaining fissure is completed with a linear stapler.
- Residual LN stations 7, 8R, 9R, and 4R are dissected for completion of appropriate hilar nodal resection.

LEFT UPPER LOBECTOMY

- Dissection is started at the N2 mediastinal LNs. If the lung deflates well, the nodes 9, 8, and 7 can be completely removed. If the lung does not deflate sufficiently, it is best to start at station 7 and then move cephalad toward the trachea and remove the LN 10L plus 5 and 6.
- Removal of the LNs first exposes the anatomy and affords visual inspection of the N2 nodes.
- The dissection is continued between the hilar structures and in between the aorta and PA and posterior to the phrenic nerve.
- Identify the origin of the superior pulmonary vein and ensure there are two pulmonary veins and develop the space between the superior and the IPV.
- Because the fissure may be complete or incomplete, we recommend finding the PA posteriorly and then dissect along its surface to develop the fissure posteriorly.
- Identify the posterior segmental PA branch and encircle with a vessel loop. Using the vessel loop as a guide, the linear stapling device is used to divide the vessel.
- Next, staple the posterior fissure. Sometimes, the fissure may need to be taken before the posterior segmental PA can be divided.
- Continue the dissection following the PA anteriorly until all the branches are ligated and finally the lingular artery is stapled in the same fashion as the posterior segmental branch.
- Subsequently, the anterior fissure is encircled by placing a vessel loop from the divided lingular artery stump to the space between the two pulmonary veins and then transected with a linear stapler.
- The superior pulmonary vein is dissected off the bronchus and carefully encircled. Ensure the most superior aspect of the vein is dissected off of the main PA so when the stapler is passed around the vein, the artery is clearly seen.
- Using the vessel loop as a guide, the linear stapling device is passed across the vein and fired.
- The only vascular structures remaining are the anterior and apical branches of the PA to the left upper lobe (LUL).
- Therefore, remove the N1 LNs off of the LUL bronchus and encircle it with a vessel loop. Using the vessel loop as a guide, the linear stapling device is passed across the bronchus and fired. Care must be taken to apply only minimal retraction on the specimen to avoid tearing of PA branches.
- Once the LUL bronchus is transected, the final remaining branches of the PA are easily seen and stapled.
- The remaining LN stations are dissected.

LEFT LOWER LOBECTOMY

- Divide the inferior pulmonary ligament up to the level of the IPV. Resect the LNs encountered in this area (LN 9 first and then the periesophageal LN 8). Dissect the hilar tissue off the esophagus and vagus nerve (**FIG 3**), staying close to the pericardium to approach the subcarinal space.
- Continue the dissection toward the carina and remove subcarinal LN station 7 (**FIG 15A,B**).
- Next, the trajectory is changed and the left lower lobe is lifted anteriorly and cephalad to expose the origin of the IPV (**FIG 16**).
- Dissect the IPV off the underlying bronchus and free from hilar tissue (**FIG 17**).
- Encircle the IPV with a vessel loop and using the vessel loop as a guide, the linear stapling device is passed across the vein and fired (**FIG 18A–D**). Sometimes, it is best to take the vein later in the operation once the artery is dissected out and the fissure completed. This may help prevent the lobe from becoming edematous.
- The trajectory is changed back to expose the posterior aspect of the hilum and the arterial structures (**FIG 19**).



A

B

FIG 15 ● **A.** Exposing mediastinum for **(B)** removal of subcarinal LNs station 7.

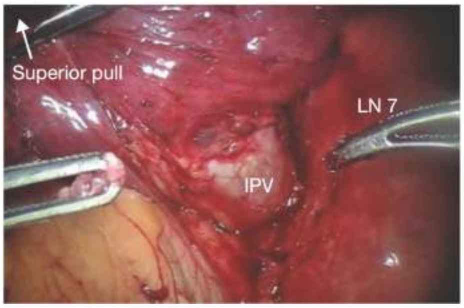


FIG 16 ● Identification of IPV.

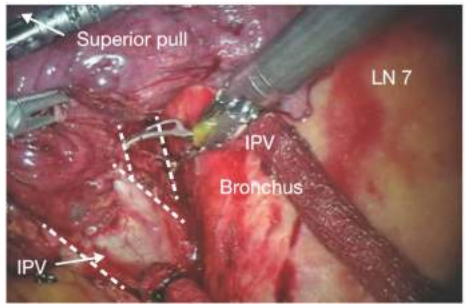
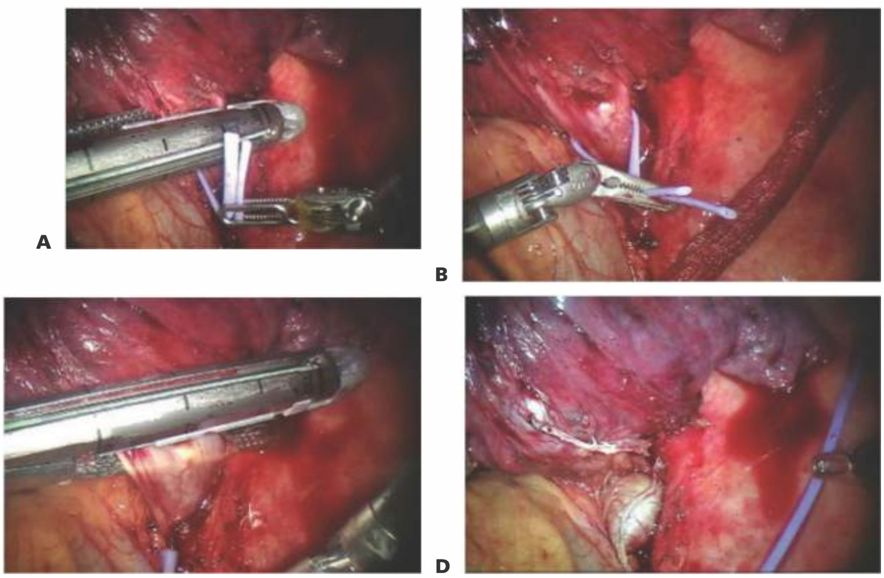


FIG 17 ● Peeling IPV off the bronchus and removal of hilar tissue.

- Identify the left PA posteriorly and then work along it to identify the major branches (superior segmental branch basilar PA (FIG 20).
- The superior segment of the PA is exposed as well as the remaining large basilar PA. The surrounding N1 nodes are removed from the arterial branches allowing them to be clearly exposed (FIG 21). The bronchial bifurcation of the upper and lower lobe can be identified below the PA in this location.
- The superior segmental PA is usually taken next using a vascular stapler (FIG 22).
- After the superior segmental artery is stapled, the remaining large basilar PA is stapled next.
- Now the IPV can be taken or the left lower lobe bronchus can be stapled and the vein divided last.
- The LN dissection (stations 11L and 12L) is continued along the lower lobe bronchus to free it circumferentially (FIG 23A–C).
- Encircle the left lower lobe bronchus with a vessel loop and transect with a linear stapler. Care must be taken to apply only minimal retraction on the specimen to avoid tearing of the lingular branch (FIG 24A–D).
- Next, the fissure between the LUL and the left lower lobe is exposed and taken with a linear stapler (FIG 25).
- The superior mediastinum is exposed and the removal of residual LN stations 5 and 6 is performed (FIG 26A,B).



A B C D

FIG 18 ● Transection of left IPV: **(A)** vessel loop placed, **(B)** vessel loop guiding stapler, **(C)** stapler placed, and **(D)** vein transected.

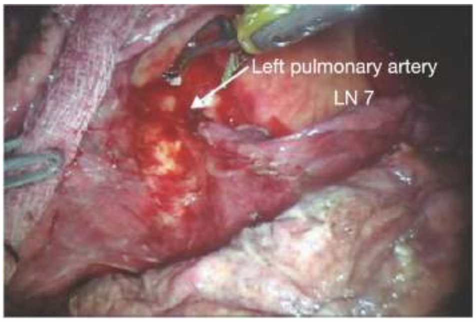


FIG 19 ● Identification of anterior segment of PA.

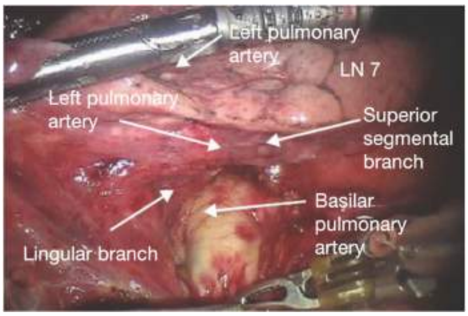


FIG 20 ● Identification of major branches of left PA.

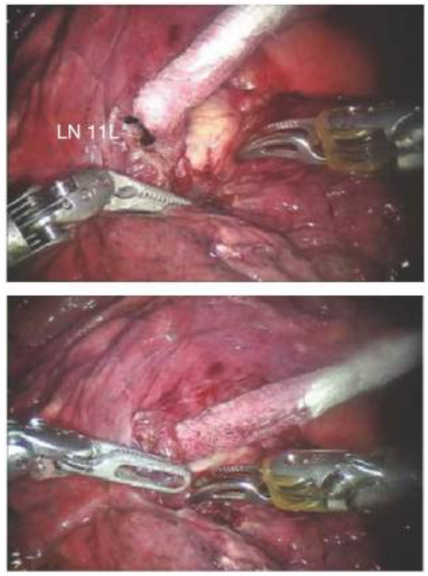


FIG 21 ● Removal of N1 nodes (station 11L) from the origin of the lingular artery.

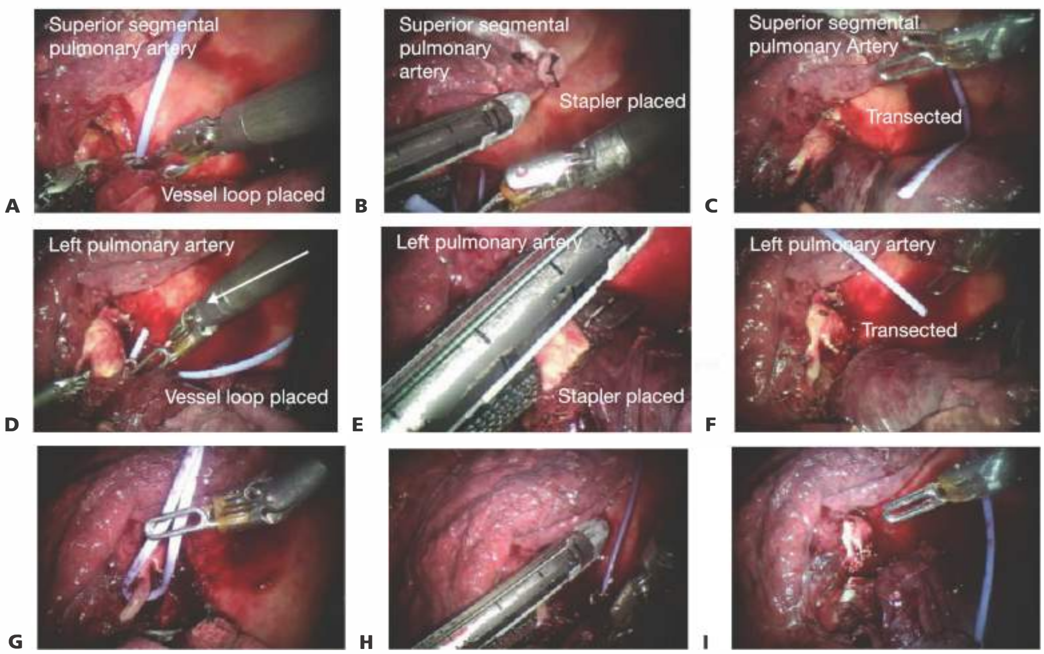


FIG 22 ● **A–C.** Transection of superior segmental PA. **D–F.** Transection of inferior PA. **G–I.** Transection of lower lobe basilar artery.

FIG 23 ● Removal of N1 nodes along lower lobe bronchus **(A)** LN 10L, **(B)** LN 11L, and **(C)** LN 12L.

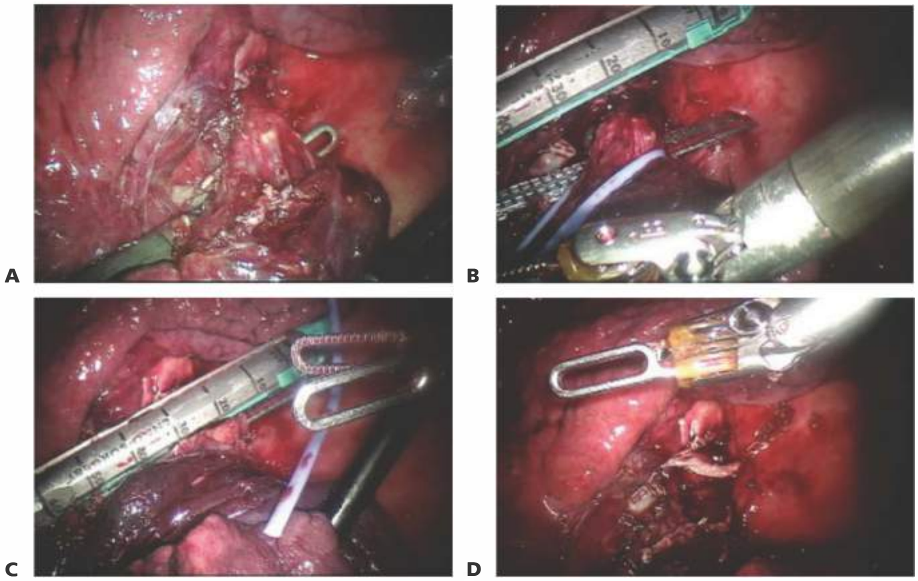


FIG 24 ● Transection of left lower lobe bronchus: **(A)** circumferential dissection, **(B)** vessel loop guiding stapler, **(C)** stapler placed, and **(D)** bronchus transected.

FIG 25 ● Transection of fissure.

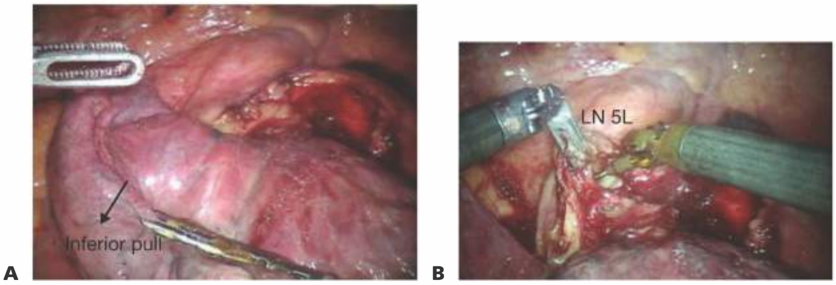


FIG 26 ● **A.** Thoracic grasper exposing superior mediastinum for **(B)** removal of residual LN station (5L).

TECHNIQUES

CLOSURE AND DRAINAGE

- The chest is filled with irrigation fluid and the remaining lung inflated to 20 cm H_2O to make certain there is no leak at the bronchial stump.
- If there is a leak, a 3-0 Prolene stitch on an RB needle is used to oversew the bronchial stump.
- Chest tube is employed per surgeon's standard routine.
- Rib approximation is achieved by drilling holes through the rib and passing the suture material through the holes.
- The muscle facial edges are approximated using absorbable running suture.
- Skin closed with subcuticular absorbable suture.
- The bronchial margin is sent for frozen section, and the tumor is sent for genetic testing and tumor markers.

PEARLS AND PITFALLS

Right upper lobectomy	■ Injuring the right main PA while getting circumferential control of the right superior pulmonary vein ■ Failure to identify the posterior ascending branch to the posterior segment of the RUL
Right middle lobectomy	■ Failure to identify the RLL bronchus while obtaining control of the RML bronchus ■ Injury of the posterior segmental vein while completing the fissure between the RUL and the RML
Right lower lobectomy	■ Injuring or kinking the RML bronchus while stapling the RLL bronchus
Left upper lobectomy	■ Injury to the anterior apical trunk of the LUL, with resultant massive bleeding ■ Failure to recognize the lingular artery
Left lower lobectomy	■ Failure to identify the superior segmental artery to the left lower lobe

POSTOPERATIVE CARE

- Postoperative pain management
  - Dispense pain medication per usual postoperative regimen.
  - The patient is placed on aspiration precautions (no oral intake until fully awake and able to sit upright).
  - *Inpatient hospital follow-up and discharge should be based on surgeon's experience and preference.*
  - Almost all patients should be extubated in the operating room.
  - Extubated patients are transferred to the recovery room and to the appropriate hospital inpatient setting (bed with monitoring until discharge).
  - No postoperative antibiotics are used.
  - Patients should be monitored with oximetry around-the-clock.
  - Chest drain removal once output is less than 450 mL per day
  - The patient is discharged from the hospital, if stable, most commonly on postoperative day 3 or 4.
- Outpatient follow-up
  - Follow-up visit 2 weeks postoperatively
  - In cases of malignancy following pathology review, counsel the patient concerning the need for additional therapy or adjuvant chemotherapy as indicated. Adjuvant therapy, even radiotherapy, which is rarely indicated, as soon as 3 to 6 weeks postoperative, depending on patient's performance status.

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Chapter 6

Lobectomy: Thoracoscopic

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DEFINITION

- Video-assisted thoracic surgery (VATS) lobectomy is defined as an anatomic lobectomy in which bronchial and vascular ligation is performed with lymph node sampling or dissection through several small incisions while avoiding spreading of the ribs. VATS is an appealing alternative to thoracotomy but must follow the same principles with vascular ligation, resection with negative margins, and appropriate lymph node dissection.

PATIENT HISTORY AND PHYSICAL FINDINGS

- A detailed history and physical must be performed prior to any treatment including past medical and surgical history, allergies, medications, social, and family history.
- The patient's previous history of tobacco use as well as any chemical or asbestos exposures should be determined. Cessation of tobacco use preoperatively should be strongly encouraged for 4 weeks prior to any surgical intervention.
- The history should include the patient's current functional status and exercise tolerance.
- A complete physical examination should be performed with particular attention to auscultation of the heart and lungs and any evidence of cervical or supraclavicular lymphadenopathy or peripheral edema.
- Routine laboratory studies including a complete blood count and basic chemistry panel should be included as part of the preoperative evaluation.

IMAGING AND OTHER DIAGNOSTIC STUDIES

- Patients typically present with abnormal chest radiograph (**FIG 1A**) or chest computed tomography (CT) findings. If available, the findings should be compared to previous imaging to determine any interval changes. Lesions that are stable for more than 2 years are generally considered benign. Indeterminate lesions less than 1 cm in size can be followed on serial imaging according to the recommendations of the Fleischner Society.[1]
- A chest CT (**FIG 1B**) should be obtained in all patients with a suspicious lung nodule to evaluate the size and characteristics of the nodule; proximity to the chest wall, vessels, airway, and mediastinum; additional pulmonary lesions; and hilar or mediastinal lymphadenopathy. The CT should include the upper abdomen to evaluate the liver and adrenal glands for metastatic disease.
- A positron emission tomography (PET) scan (**FIG 1C**) provides additional information regarding the metabolic activity of the pulmonary nodule and areas of uptake that are suspicious for regional nodal or distant metastatic disease

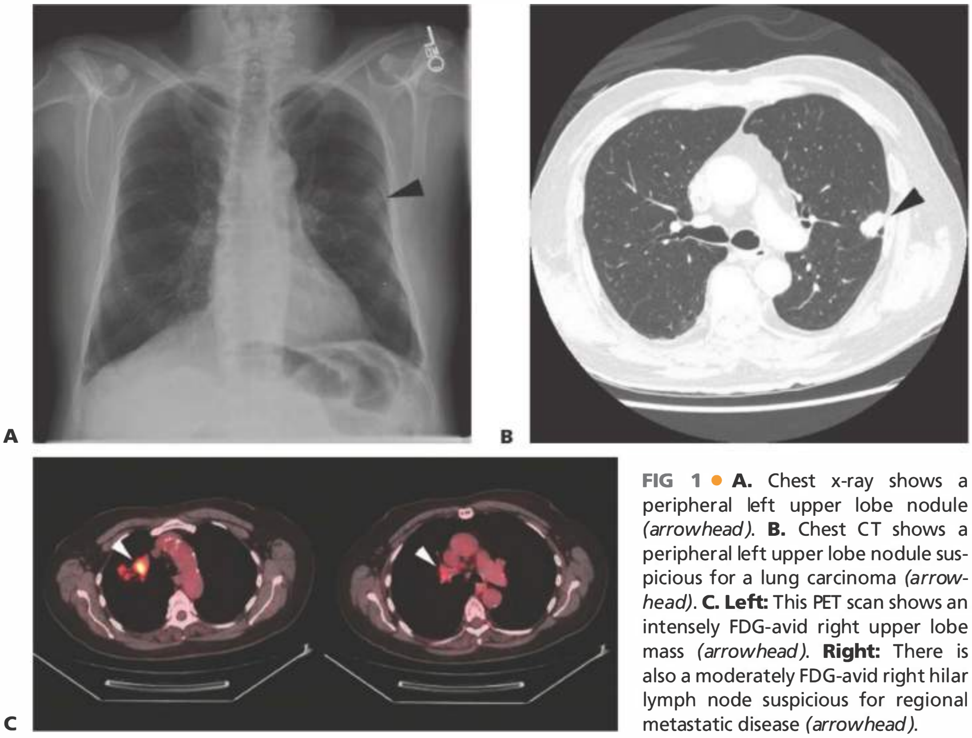


FIG 1 • **A.** Chest x-ray shows a peripheral left upper lobe nodule *(arrowhead)*. **B.** Chest CT shows a peripheral left upper lobe nodule suspicious for a lung carcinoma *(arrowhead)*. **C. Left:** This PET scan shows an intensely FDG-avid right upper lobe mass *(arrowhead)*. **Right:** There is also a moderately FDG-avid right hilar lymph node suspicious for regional metastatic disease *(arrowhead)*.

and should be obtained in all patients suspected of having a non–small cell lung carcinoma.[2] In patients with abnormal findings on fluorodeoxyglucose (FDG)-PET imaging, sampling of the abnormal lymph node should be performed prior to lung resection either by endobronchial ultrasound (EBUS) or mediastinoscopy.

- For patients with non–small cell lung carcinoma who are surgical candidates, anatomic lobectomy and mediastinal lymph node dissection for complete oncologic resection and staging is recommended.[3]
- Due to the low morbidity and mortality after wedge resection, our preference for nodules that are highly suspicious for lung carcinoma based on PET or serial imaging is to perform a VATS wedge resection for a tissue diagnosis. Needle biopsies are performed less often and are reserved for cases where the diagnosis is less clear or for central lesions that would require a lobectomy for diagnosis alone.

SURGICAL MANAGEMENT

Preoperative Planning

- Preoperative risk assessment determines whether a patient will tolerate pulmonary resection based on pulmonary reserve (pulmonary function tests [PFTs]) and other comorbidities.[4] Patients with significant cardiovascular risk factors or symptoms should undergo preoperative cardiac evaluation.
- Patients with a preoperative forced expiratory volume in 1 second (FEV_1) of more than 60% predicted and diffusing capacity of lung for carbon monoxide (DLCO) of more than 50% predicted are candidates for lobectomy. Patients not meeting these criteria should undergo further evaluation with a quantitative ventilation perfusion scan to determine their postoperative predicted pulmonary function with a minimum postoperative value of 40% predicted.
- Cardiopulmonary exercise testing is occasionally helpful in patients whose symptoms do not correlate with the severity of their pulmonary function results.
- For patients who will not tolerate an anatomic lobectomy, alternatives include a sublobar resection such as a segmentectomy or wedge resection, stereotactic body radiation therapy (SBRT), radiofrequency ablation (RFA), or definitive chemoradiation. These patients are best discussed in a multidisciplinary setting.
- Relative contraindications for VATS lobectomy are listed in Table 1.
- In the preoperative area, the history and physical should be reviewed and consent should be obtained. The operative side should be appropriately marked.

Table 1: Relative Contraindications to Thoracoscopic Lobectomy

Complete resection unable to be achieved with a lobectomy (Need for sleeve resection or pneumonectomy)
A central lesion making it difficult to staple the bronchus or pulmonary arterial branches
Chest wall or mediastinal invasion (T3 or T4)
Nodal disease adherent to the vessels
Neoadjuvant chemoradiation
Positive N3 disease
Patient unable to tolerate single-lung ventilation

- Once in the operating room, a flexible bronchoscopy should be performed to verify airway anatomy and rule out any endobronchial lesions.
- Single-lung ventilation is achieved with a left-sided double lumen endotracheal tube, which is generally preferable to a bronchial blocker.

Positioning

- The patient should be placed in the lateral decubitus position, tilted slightly posteriorly. The bed is flexed taking care to drop the hips out of the way of the camera port (**FIG 2**). The arms should be positioned in an arm holder in neutral position. The patient should then be secured and all pressure points padded.
- Following positioning, the endotracheal tube position should be confirmed again by the anesthesiologist.

FIG 2 ● The patient is placed in the lateral decubitus position. It is important to drop the hip out of the way of the camera, which is placed in the most inferior port.

TECHNIQUES

PLACEMENT OF INCISIONS

- Port placement is important to obtain the ideal angles for stapler placement and lung retraction. Our general port placement for a VATS lobectomy is shown (**FIG 3**).
- Port 1 is placed just below the inframammary crease in the 6th intercostal space in the anterior axillary line. A 5-mm, 30-degree angled scope is preferable to decrease compression of the intercostal nerve. The remaining ports can be placed under direct visualization.
- Port 2 is placed posteriorly in the auscultatory triangle in the 6th intercostal space. Placing this incision one interspace lower is helpful for an upper lobectomy in passing the stapler when dividing the superior pulmonary vein.
- Port 3 is placed in the 8th or 9th intercostal space in the posterior axillary line, taking care to avoid injuring the diaphragm.
- An access incision (<10 cm) is placed in the 4th intercostal space in the midaxillary line (directly above the superior

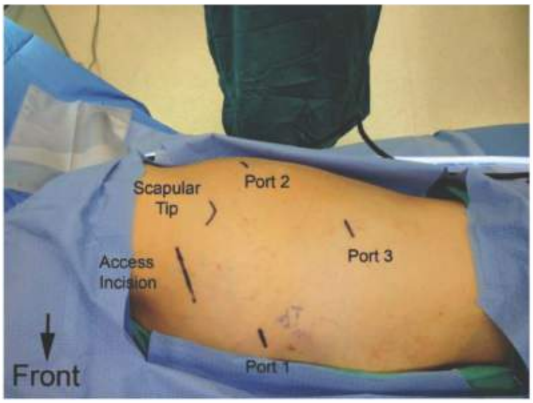


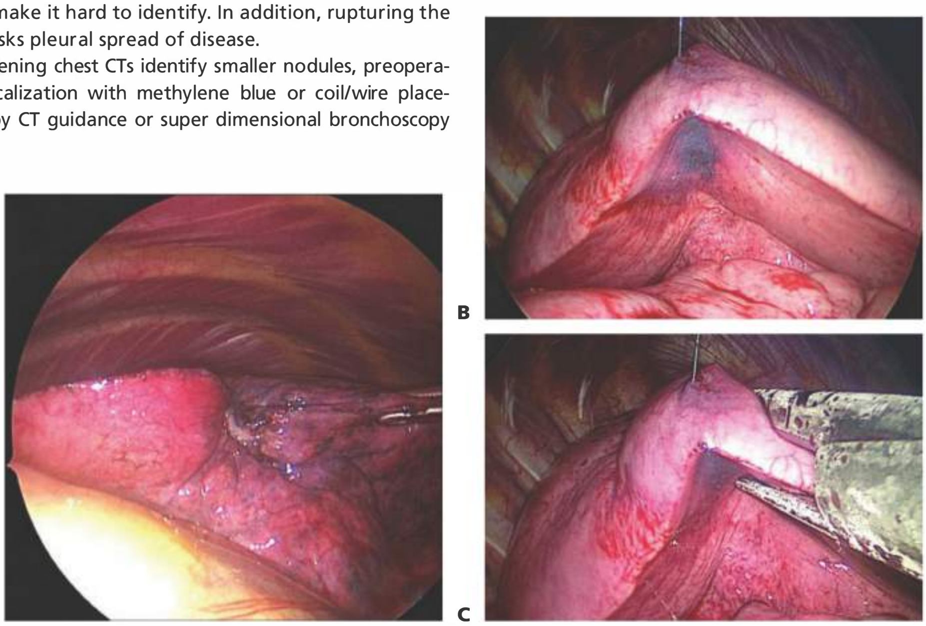
FIG 3 ● Standard port placement for a VATS lobectomy. Port 1 is placed just below the inframammary crease in the 6th intercostal space in the anterior axillary line. Port 2 is placed posteriorly in the auscultatory triangle in the 6th intercostal space. Port 3 is placed in the 8th or 9th intercostal space in the posterior axillary line. An access incision (<10 cm) is placed in the 4th intercostal space in the midaxillary line. The surgeon operates through port 1 and the access incision while the assistant retracts the lung using Foerster clamps in port 2. The camera is placed in the most inferior port 3. (The *arrow* indicates the front of the patient.)

pulmonary vein for an upper lobectomy or one space lower for a middle or lower lobectomy) for dissection and retrieval of the specimen. A Weitlaner retractor is used to hold the incision open to prevent suction from reexpanding the lung. In the event of bleeding, a sponge stick can be quickly inserted through the access incision to hold pressure.

- The surgeon operates through port 1 and the access incision while the assistant positions the lung using Foerster clamps in port 2. The camera is placed in the most inferior port 3.
- Thoracoscopic exploration should be performed looking for any effusion, pleural lesions, or unexpected nodules in the remainder of the lung.
- If the lung is not adequately collapsed, suction should be applied to the appropriate lumen of the endotracheal tube.

LOCALIZATION OF THE LUNG NODULE

- The nodule is localized by correlating the chest CT with the visualized anatomy. The nodule is then palpated with either the surgeon's finger or an instrument (**FIG 4A**). Care should be taken not to crush the nodule, which could make it hard to identify. In addition, rupturing the mass risks pleural spread of disease.
- As screening chest CTs identify smaller nodules, preoperative localization with methylene blue or coil/wire placement by CT guidance or super dimensional bronchoscopy may be helpful in identifying ground glass nodules (<1 cm), small nodules (<5 mm), or nodules deep to the pleural surface intraoperatively (**FIG 4B**).
- A Foerster clamp can be used to compress the lung below the nodule to help with passage of the stapler if needed.



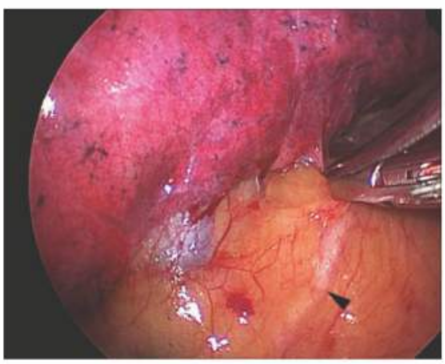
A B C

FIG 4 ● **A.** The nodule is located by visualization as well as palpation with a finger or instrument. **B.** Small or ground glass nodules can be localized preoperatively with dye injection and wire/coil placement. **C.** A wedge resection is performed and sent for frozen section for a tissue diagnosis.

- A stapler (Ethicon, Inc, San Antonio, TX or Covidien, Inc, Mansfield, MA; purple load Endo GIA 3.0- to 4.0-mm stapler height) is used to perform the wedge resection (**FIG 4C**).
- The specimen is placed in a bag to prevent port site recurrence.
- If the specimen is benign, cultures are sent and the procedure is terminated.
- If cancer is confirmed, the access incision is made in the 4th intercostal space and a thoracoscopic lobectomy is performed.

RIGHT UPPER LOBECTOMY

- The major and minor fissures should be inspected, and the location of the tumor in the right upper lobe should be confirmed. The lung is retracted posteriorly to expose the hilum.
- The dissection is performed from anterior to posterior as opposed to the traditional fissure dissection used in an open lobectomy.
- The anterior mediastinal pleura is opened sharply to avoid injuring the phrenic nerve using thoracoscopic Metzenbaum scissors and pickups (**FIG 5A**).
- The superior pulmonary vein is dissected bluntly with a long coronary tip suction. The division between the upper lobe and middle lobe venous branches must be identified (**FIG 5B**). The minor fissure can be followed anteriorly to ensure that the middle lobe vein is preserved. Attention must also be taken to avoid injury to the underlying right pulmonary artery.
- The upper lobe venous branches are isolated and divided using a vascular beige load stapler (2.0- to 3.0-mm stapler height) through the posterior incision (**FIG 5B**). If needed, the vessels can be encircled with a silk tie for traction or a curved-tip stapler can be used to assist in passage of the stapler.
- Following division of the pulmonary vein, the pulmonary artery is then exposed. The truncus anterior branch of the pulmonary artery is then carefully isolated and divided using a beige load stapler through the posterior incision (**FIG 5C**).
- Once the truncus anterior has been divided, the right upper lobe bronchus is exposed. The lung is then retracted anteriorly, and the pleura is opened posteriorly. The branch point between the upper lobe bronchus and the bronchus intermedius is identified (**FIG 5D**). Stations 10R and 11R lymph nodes are often taken at this time, which helps with the dissection.



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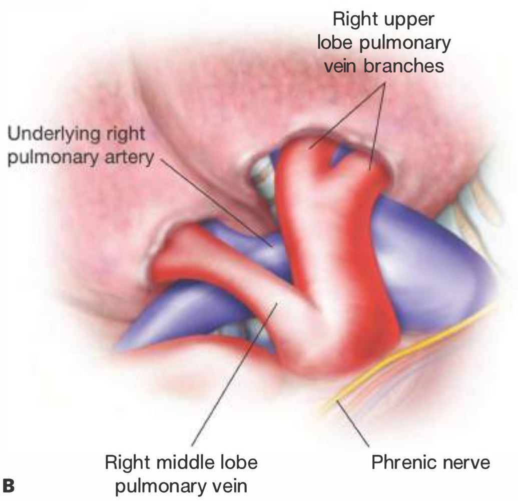
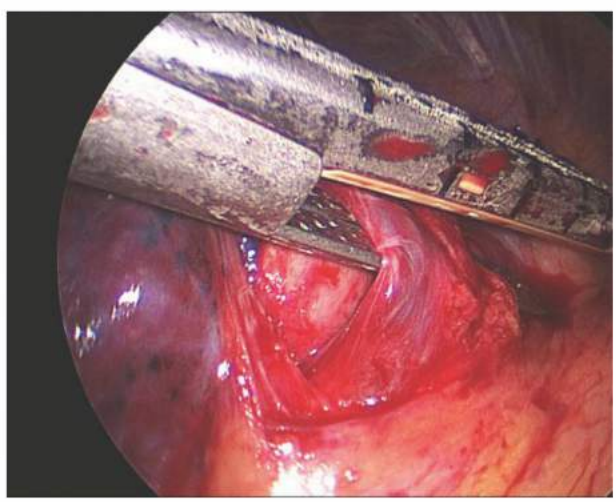
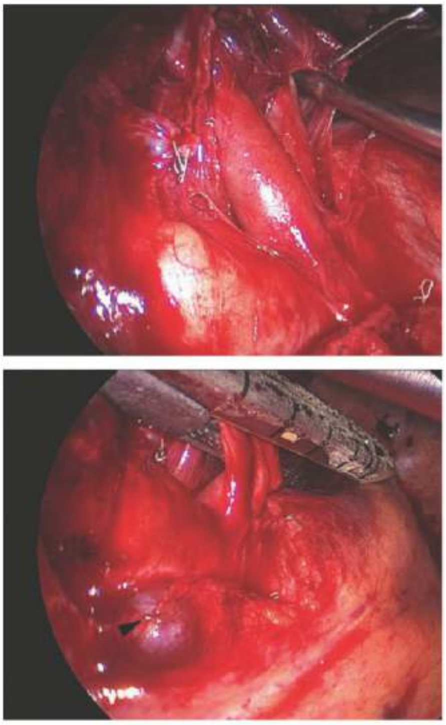




B

FIG 5 ● **A.** The anterior mediastinal pleura is opened sharply, taking care to preserve the phrenic nerve *(arrowhead)*. **B. Left:** The right upper lobe branches of the superior pulmonary vein are dissected free. Care is taken to identify and preserve the right middle lobe vein. Attention must also be taken to avoid injury to the underlying right pulmonary artery. **Right:** The upper lobe pulmonary vein branches are divided with a beige load stapler passed from the posterior port. *(continued)*



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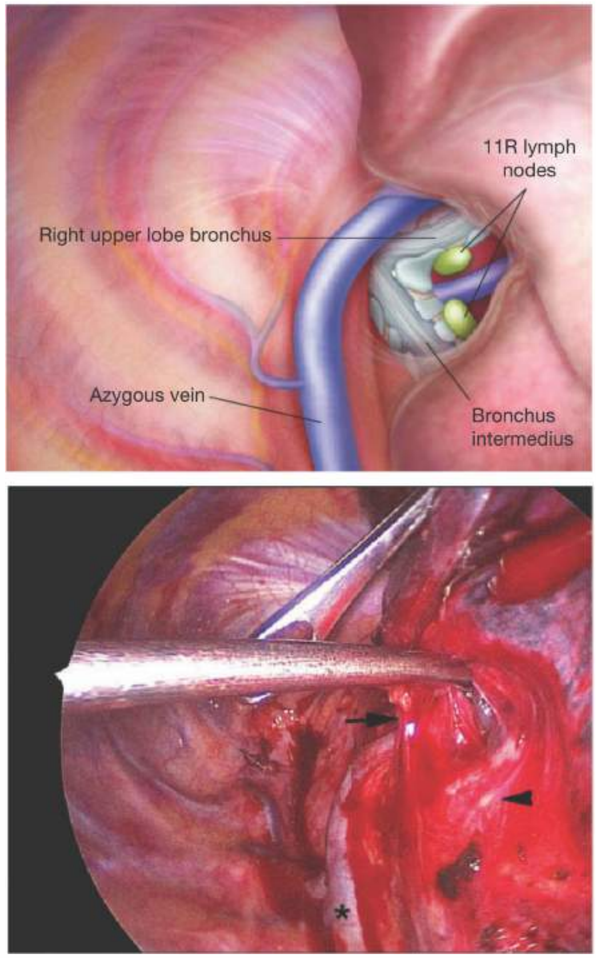

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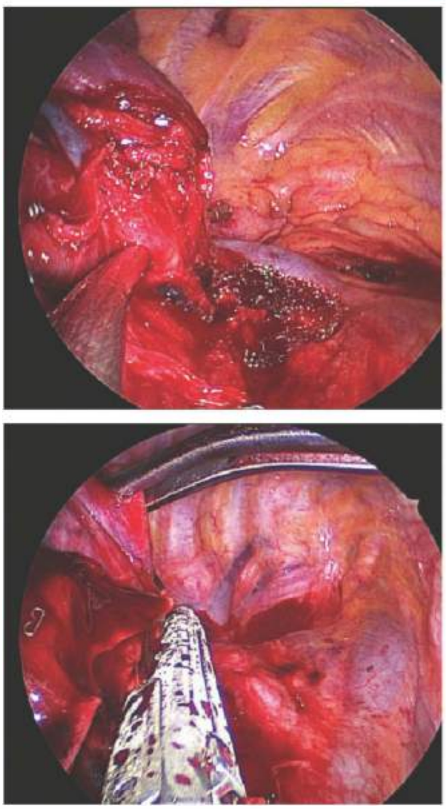
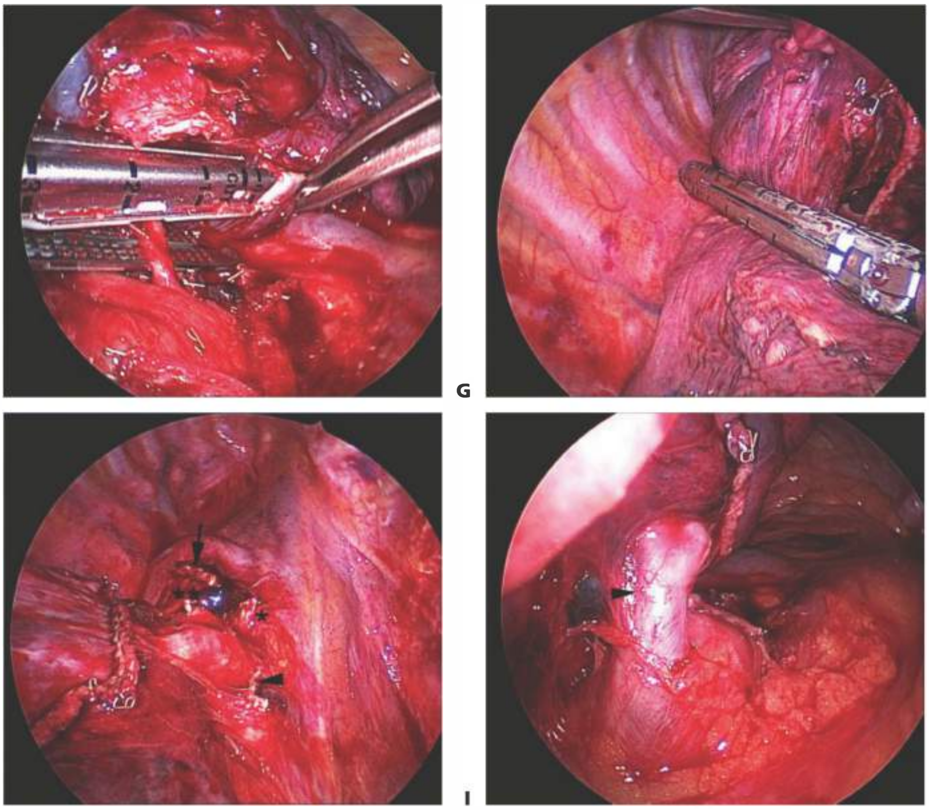


E

FIG 5 ● *(continued)* **C.** The truncus anterior branches **(top)** of the pulmonary artery are dissected free and divided with a beige load stapler **(bottom)**. The pulmonary vein stump is in the foreground *(arrowhead)*. **D.** With the lung retracted anteriorly, the posterior pleura is opened and the bifurcation between the upper lobe bronchus *(arrow)* and the bronchus intermedius *(arrowhead)* is dissected free. An 11R lymph node is usually removed, and care is taken not to injure the posterior ascending pulmonary arterial branch, which is often just behind this lymph node (azygous vein, *asterisk*). **E. Top:** The right upper lobe bronchus is dissected free anteriorly, and any 11R lymph nodes are sent for pathology. **Bottom:** The right upper lobe bronchus is clamped with a purple load stapler passed from the anterior port. The right middle and lower lobes are briefly inflated to confirm that the bronchus intermedius is patent before firing the stapler. *(continued)*



F G H I

FIG 5 ● *(continued)* **F.** The posterior ascending pulmonary artery branch is divided with a beige load stapler passed from the posterior port. **G.** The fissure is completed with a purple load stapler. Care is taken to preserve the middle lobe pulmonary vein and the underlying pulmonary artery. **H.** The right upper lobe pulmonary vein *(arrowhead)*, bronchial *(arrow)*, and truncus anterior *(asterisk)* and posterior ascending *(double asterisk)* pulmonary arterial stumps are checked for hemostasis. **I.** It is important to examine the middle lobe vein *(arrowhead)* to confirm that there is no middle lobe torsion.

- The lung is then retracted posteriorly. The upper lobe bronchus is isolated and clamped flush with the bronchus intermedius. The lung is gently reinflated with a hand breath to ensure that the bronchus intermedius is patent before dividing the upper lobe bronchus using a purple load (size of staple) stapler through the anterior incision (**FIG 5E**).
- The posterior ascending arterial branch to the right upper lobe (**FIG 5F**) is then dissected free and divided using a beige load stapler through the posterior incision.
- A purple load stapler through the anterior incision is then used to divide the minor fissure to complete the resection of the right upper lobe (**FIG 5G**). Care should be taken to preserve the middle lobe vein and underlying pulmonary artery.
- Once the dissection has been completed, the specimen should be removed using a protective retrieval bag (Cook Urological, Bloomington, IN; LapSac).
- A mediastinal lymph node dissection is performed as described in the following text.
- The hemithorax is then irrigated with warm water, and the bronchial stump is inspected for evidence of an air leak with a Valsalva to 25 cm H_2O. If there is evidence of an air leak, endoscopic or open suturing of the bronchial stump using interrupted 4-0 Vicryl may be required. The vascular stumps are checked for hemostasis (**FIG 5H**).
- Prior to closure, chest tubes are placed anteriorly and posteriorly through the anterior and inferior incisions. The lung is reinflated under direct vision to ensure that there is no torsion of the middle lobe (**FIG 5I**).
- The remaining port sites are closed in layers using a running 2-0 Vicryl for the muscle and subcutaneous layers and 4-0 Monocryl to reapproximate the skin.

RIGHT MIDDLE LOBECTOMY

- The minor and major fissures should be inspected and the tumor location in the right middle lobe confirmed.
- The right middle lobe is retracted posteriorly. The anterior mediastinal pleura is opened sharply to avoid injuring the phrenic nerve using thoracoscopic Metzenbaum scissors and pickups.
- The superior pulmonary vein branches to the middle and upper lobes are identified. The minor fissure can be followed anteriorly to ensure that the upper lobe veins are preserved. The middle lobe vein (**FIG 6A**) is dissected free and divided using a beige load stapler through the posterior incision.
- The right middle lobe bronchus is exposed (**FIG 6B**), and any 10R or 11R lymph nodes are obtained. The middle lobe bronchus is then clamped flush with the origin of the lower lobe bronchus. The lung is gently reinflated with a hand breath to ensure that the right lower lobe inflates before dividing the middle lobe bronchus using a purple load stapler through the posterior incision.
- The right middle lobe artery (**FIG 6C**) is then divided using a beige load stapler through the posterior incision. A second middle lobe arterial branch may be present and is divided in a similar fashion.
- The major fissure between the middle and lower lobes and the minor fissure separating the middle and upper lobes (**FIG 6D**) are then divided using a purple load stapler passed through the anterior incision. Care is taken to preserve the upper lobe veins.
- The specimen is then removed using a retrieval bag.

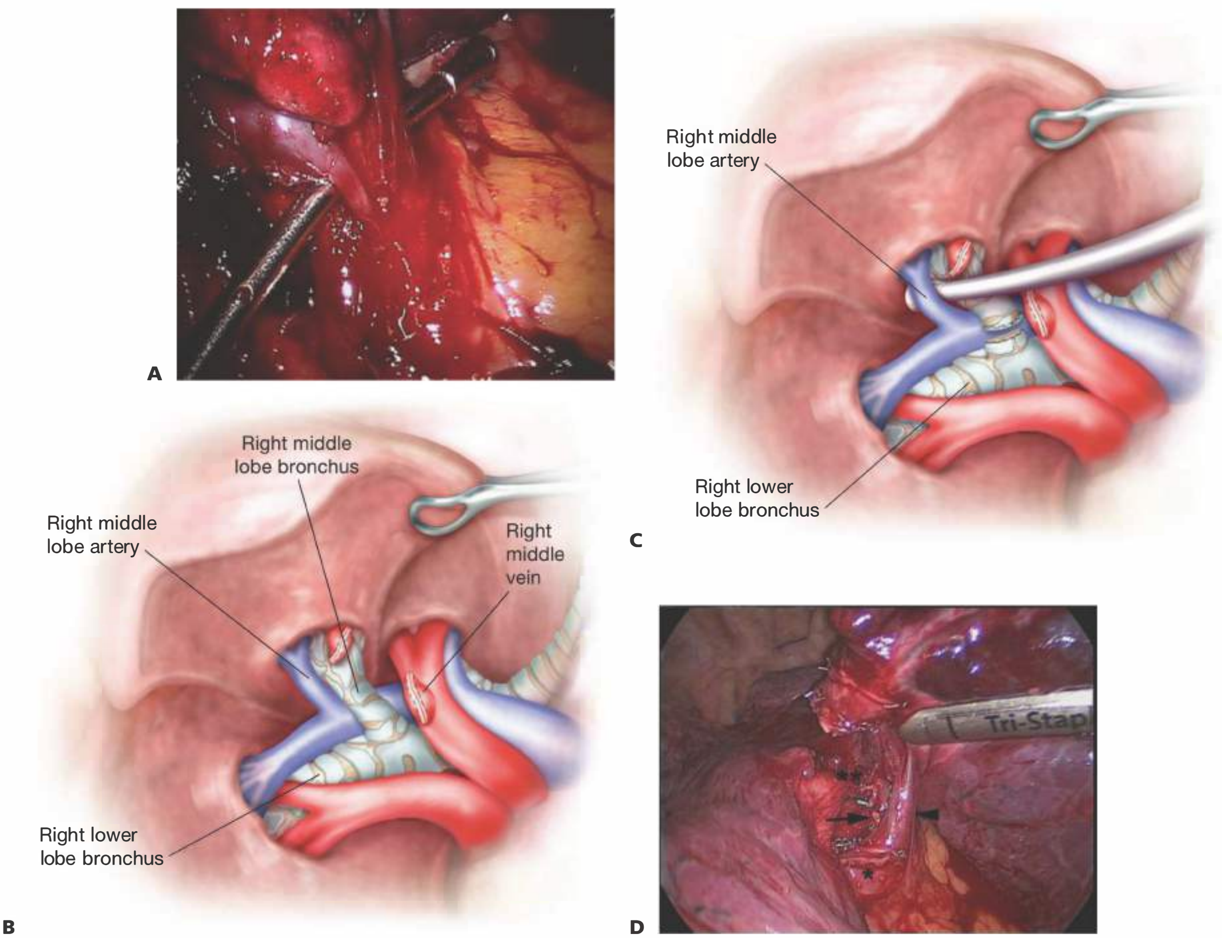


FIG 6 ● **A.** The right middle lobe vein is dissected free. Care is taken to identify and preserve the right upper lobe vein branches before dividing the middle lobe vein with a beige load stapler passed from the posterior port. **B.** The right middle lobe bronchus is dissected free. Before dividing the bronchus, a purple load stapler is passed from the posterior port and clamped. The right lower lobe is briefly inflated to confirm that the lower lobe bronchus is patent. **C.** The right middle lobe arterial branches are dissected free and divided with a beige load stapler passed from the posterior port. **D.** The minor fissure is completed with a purple load stapler. Care is taken to preserve the upper lobe veins *(arrowhead)*. The middle lobe vein *(asterisk)*, bronchial *(arrow)*, and middle lobe pulmonary arterial *(double asterisk)* stumps are checked for hemostasis.

- A mediastinal lymph node dissection is performed as described in the following text.
- The hemithorax is then irrigated with warm water, and the bronchial stump is inspected for evidence of an air leak with a Valsalva to 25 cm H_2O. If there is evidence of an air leak, endoscopic or open suturing of the bronchial stump may be required with interrupted 4-0 Vicryl sutures.
- Prior to closure, chest tubes are placed anteriorly and posteriorly. The lung is reinflated under direct vision to confirm that there is no lobar torsion.

RIGHT LOWER LOBECTOMY

- The location of the tumor in the right lower lobe is confirmed.
- The inferior pulmonary ligament is taken down while retracting the lower lobe superiorly, exposing the inferior pulmonary vein (**FIG 7A**). Level 9R lymph nodes are obtained.
- The anterior and posterior mediastinal pleural reflections are then divided sharply to avoid injuring the phrenic nerve using thoracoscopic Metzenbaum scissors and pickups.
- The inferior pulmonary vein is dissected free. With the lung retracted anteriorly, level 7 lymph nodes may be obtained at this time. The lung is then retracted posteriorly, and the vein is divided using a beige load stapler from the anterior incision (**FIG 7B**). Care is taken to identify and preserve the middle lobe vein.

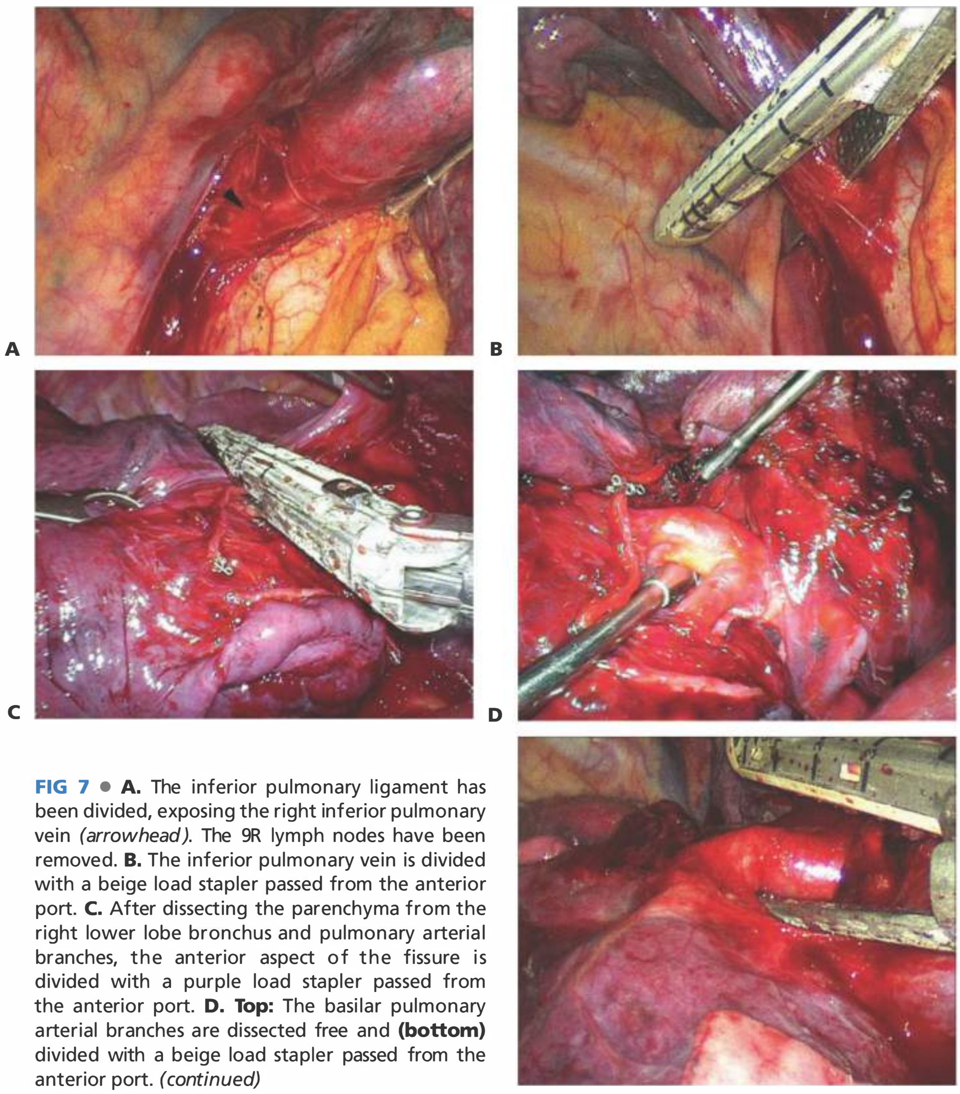


FIG 7 ● **A.** The inferior pulmonary ligament has been divided, exposing the right inferior pulmonary vein *(arrowhead)*. The 9R lymph nodes have been removed. **B.** The inferior pulmonary vein is divided with a beige load stapler passed from the anterior port. **C.** After dissecting the parenchyma from the right lower lobe bronchus and pulmonary arterial branches, the anterior aspect of the fissure is divided with a purple load stapler passed from the anterior port. **D. Top:** The basilar pulmonary arterial branches are dissected free and **(bottom)** divided with a beige load stapler passed from the anterior port. *(continued)*

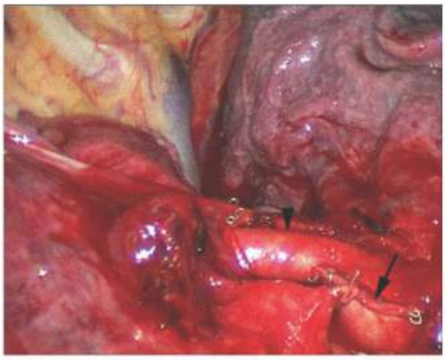


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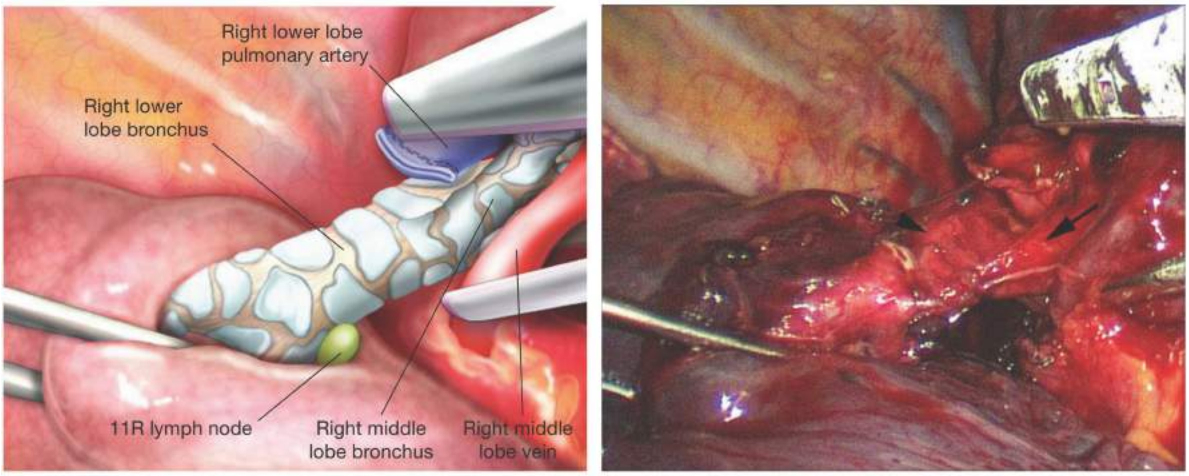
FIG 7 ● *(continued)* **E.** The superior segment pulmonary artery *(arrowhead)* is dissected free and divided with a beige load stapler passed from the anterior port (basilar pulmonary artery stump, *arrow*). **F.** The right lower lobe bronchus *(arrowhead)* is dissected free at the branch point with the right middle lobe bronchus *(arrow)*. The 11R lymph nodes are removed and sent to pathology. Before dividing the bronchus, a purple load stapler passed from the anterior port is clamped, and the right middle lobe is briefly inflated to confirm that the middle lobe bronchus is patent. **G.** The posterior fissure is completed with a purple load stapler passed from the anterior port (superior segment pulmonary artery stump, *asterisk*). **H.** The pulmonary arterial *(asterisk)*, right lower lobe bronchial *(arrow)*, and inferior pulmonary vein stumps *(arrowhead)* are checked for hemostasis. The right middle lobe vein *(double asterisk)* is examined to ensure that there is no lobar torsion.



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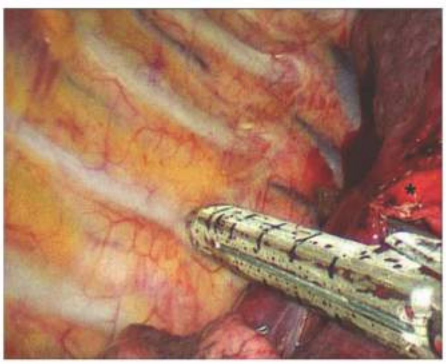

G

H

- Working outward from the hilum, the parenchyma in the major fissure is dissected off the lower lobe bronchus and the lower lobe pulmonary artery branches.
- The fissure is then divided keeping the purple load stapler above the bronchovascular structures, passing the stapler from the anterior port (**FIG 7C**).
- The basilar pulmonary arterial branches (**FIG 7D**) are then dissected free and divided either together or individually with a beige load stapler passed from the anterior incision. After dividing additional fissure in a similar fashion, the superior segment pulmonary arterial branch is dissected free and divided with a beige load stapler passed from the anterior incision (**FIG 7E**).
- The lower lobe bronchus is then isolated and clamped flush with the origin of the middle lobe bronchus. The lung is gently reinflated with a hand breath to ensure that the middle lobe bronchus is patent before dividing the lower lobe bronchus using the purple load stapler through the anterior incision (**FIG 7F**).
- The posterior aspect of the major fissure is completed with a purple load stapler passed from the anterior incision (**FIG 7G**). The specimen is then removed using a retrieval bag.

- A mediastinal lymph node dissection is performed as described in the following text.
- The hemithorax is then irrigated with warm water, and the bronchial stump is inspected for evidence of an air leak with a Valsalva to 25 cm H_2O. If there is evidence of an air leak, endoscopic or open suturing of the bronchial stump may be required using interrupted 4-0 Vicryl sutures. The vascular stumps are checked for hemostasis (**FIG 7H**).
- Prior to closure, chest tubes are placed anteriorly and posteriorly.

ALTERNATIVE APPROACH—FISSURE DISSECTION

- If there is a complete fissure, a fissure dissection can be performed, similar to the approach taken during an open lobectomy through a posterolateral thoracotomy. The advantage of this approach is that the arterial branches are divided before the veins, decreasing pulmonary congestion.
- The fissure is opened sharply using thoracoscopic Metzenbaum scissors and pickups. It is important to dissect down to the correct plane on the wall of the pulmonary artery (**FIG 8A**).
- The basilar and superior segment pulmonary arterial branches in the fissure are then dissected free and divided using a beige load stapler through the anterior incision (**FIG 8B**).
- The inferior pulmonary vein and lower lobe bronchus are divided as described earlier.

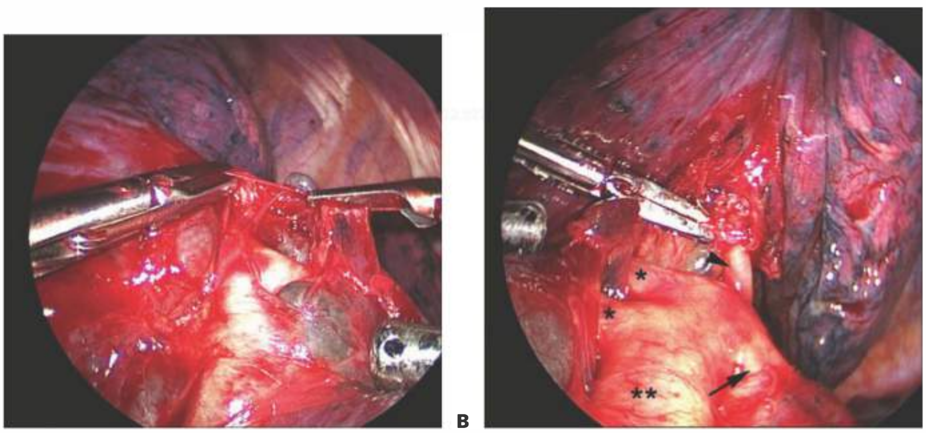

FIG 8 ● **A.** With a complete fissure, an alternative approach is to open the fissure sharply using a thoracoscopic pickup and scissors. **B.** This figure shows a completed fissure dissection on the left showing multiple pulmonary arterial branches, including a posterior segmental branch *(arrowhead)* and two lingular branches *(asterisks)* as well as the superior segmental *(arrow)* and basilar branches *(double asterisk)* to the left lower lobe.

LEFT UPPER LOBECTOMY

- The major fissure should be inspected and the tumor should be localized in the left upper lobe.
- The left upper lobe is retracted posteriorly and the anterior mediastinal pleura is opened sharply to avoid injuring the phrenic nerve using thoracoscopic Metzenbaum scissors and pickups.
- The branches of the left superior pulmonary vein are dissected free (**FIG 9A**) and divided using a beige load stapler through the posterior incision. There are usually three branches, although there can be more.
- The pleura superior to the hilum is then opened sharply. Levels 5 and 6 lymph nodes are obtained. The pulmonary arterial anatomy to the left upper lobe is the most variable and there are often multiple small branches.
- The apical and anterior pulmonary arterial branches are dissected free and divided using a beige load stapler through the anterior incision (**FIG 9B**).
- Working outward from the hilum, the parenchyma in the major fissure is dissected off the lingular pulmonary arterial branches and the bronchus.
- The fissure is then divided, keeping the purple load stapler above the bronchovascular structures passing the stapler from the anterior port.
- The lingular pulmonary arterial branches are then dissected free and divided using a beige load stapler through the anterior incision (**FIG 9C**).
- Retracting the lung superiorly, the branch point between the upper and lower lobe bronchi is identified (**FIG 9D**). Any 11L lymph nodes are removed. The bronchus is then clamped flush with the origin of the lower lobe bronchus.

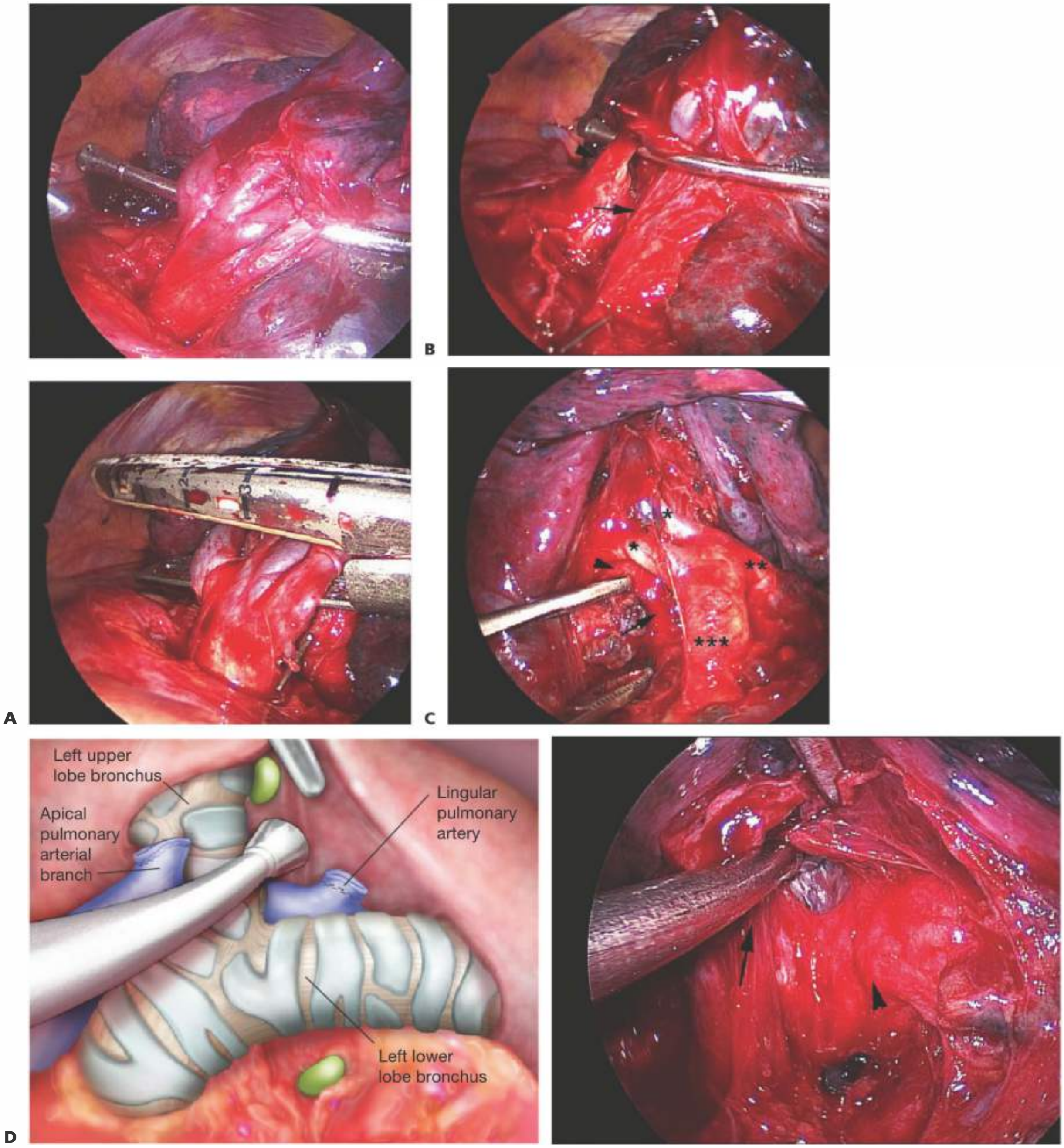

FIG 9 ● **A. Top:** There are multiple left upper lobe superior pulmonary vein branches that are **(bottom)** divided with a beige load stapler passed from the posterior port. **B.** The apical pulmonary arterial branch *(arrowhead)* is dissected free and divided with a beige load stapler passed from the anterior port (left upper lobe bronchus, *arrow*). **C.** The parenchyma has been dissected from the pulmonary artery and left upper lobe bronchus *(arrowhead)*. The anterior fissure has been divided with a stapler. This figure shows the left lower lobe bronchus *(arrow)* and the left lower lobe basilar *(triple asterisk)* and superior segmental *(double asterisk)* pulmonary arterial branches. The lingular branches *(asterisks)* are divided with a beige load stapler passed from the anterior port. **D.** The left upper lobe bronchus *(arrow)* is dissected free at the branch point with the lower lobe bronchus *(arrowhead)*. The 11L lymph nodes are removed and sent to pathology. *(continued)*

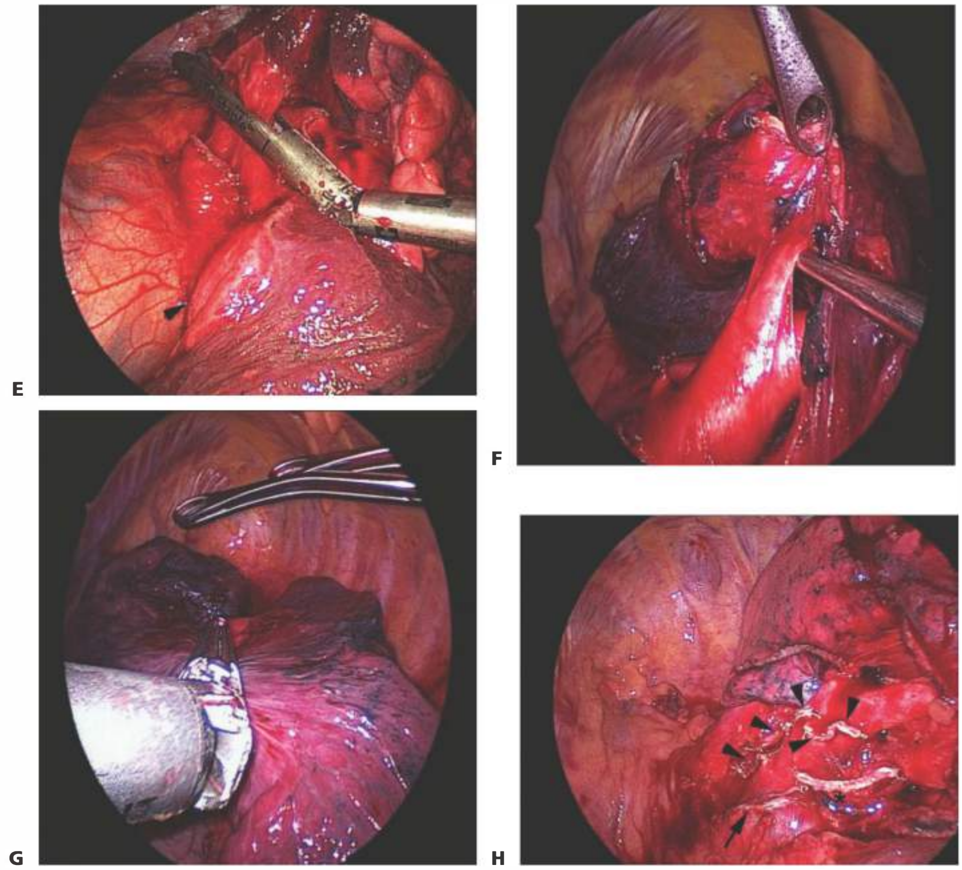

FIG 9 ● *(continued)* **E.** Before dividing the left upper lobe bronchus, a purple load stapler passed from the posterior port is clamped, and the left lower lobe is briefly inflated to confirm that the lower lobe bronchus is patent *(arrowhead)*. **F.** The remaining pulmonary arterial branches are divided with a beige load stapler. **G.** The posterior fissure is completed with a purple load stapler passed from the anterior port. **H.** The left upper lobe pulmonary arterial anatomy is the most variable, and there are frequently multiple short branches. The pulmonary arterial *(arrowheads)*, superior pulmonary vein *(arrow)*, and left upper lobe bronchial *(asterisk)* stumps are checked for hemostasis.

The lung is gently reinflated with a hand breath to ensure that the left lower lobe inflates before dividing the upper lobe bronchus using a purple load stapler passed through the posterior incision (**FIG 9E**).

- The remaining upper lobe pulmonary arterial branches are then dissected free and divided using a beige load stapler through the anterior incision (**FIG 9F**).
- The fissure is then completed with the purple load stapler through the anterior incision (**FIG 9G**). The specimen is removed using a retrieval bag.
- A mediastinal lymph node dissection is performed as described in the following text.
- The hemithorax is then irrigated with warm water, and the bronchial stump is inspected for evidence of an air leak with a Valsalva to 25 cm H_2O. If there is evidence of an air leak, endoscopic or open suturing of the bronchial stump may be required using interrupted 4-0 Vicryl sutures. The vascular stumps are checked for hemostasis (**FIG 9H**).
- Prior to closure, chest tubes are placed anteriorly and posteriorly.

ALTERNATIVE APPROACHES—FISSURE DISSECTION

- If there is a complete fissure, a fissure dissection can be performed. The advantage of this approach is that the arterial branches are taken before the veins, decreasing pulmonary congestion.
- The fissure is opened sharply using thoracoscopic Metzenbaum scissors and pickups (**FIG 8A**). It is important to dissect down to the correct plane on the wall of the

pulmonary artery. The left main pulmonary artery can also be identified just posterior to the fissure and followed anteriorly (**FIG 10**).

- The pulmonary arterial branches in the fissure are then dissected free and divided individually using a beige load stapler through the anterior incision (**FIG 8B**).
- The superior pulmonary vein branches and left upper lobe bronchus are then divided as described earlier.

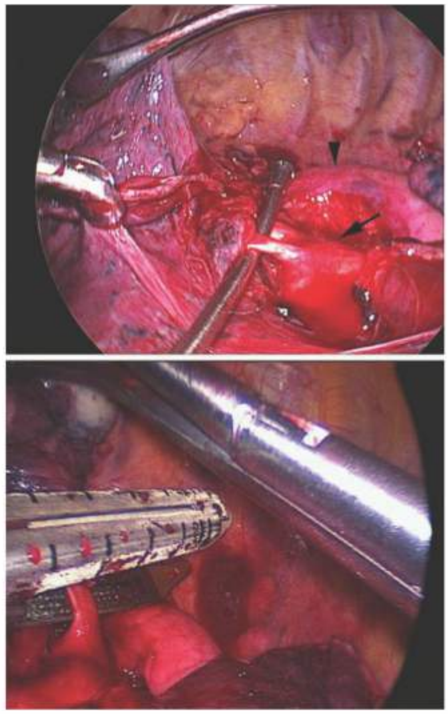

FIG 10 ● **A.** The left main pulmonary artery *(arrow)* can also be identified posteriorly behind the fissure by opening the posterior mediastinal pleura and the posterior aspect of the fissure. The *arrowhead* shows the aortic arch. Two posterior segmental arteries are being dissected free. **B.** The first branch is divided with a curved tip stapler, which can be useful in passing the stapler when there is another structure directly behind the artery; in this case, another pulmonary arterial branch.

LEFT LOWER LOBECTOMY

- A left lower lobectomy is performed in a similar fashion to a right lower lobectomy as described earlier.

MEDIASTINAL LYMPH NODE DISSECTION

- Patients undergoing resection for non–small cell lung carcinoma should have systematic mediastinal lymph node sampling or dissection performed intraoperatively.[3]
- The dissection can be performed during the lobectomy as the vessels and bronchus are taken or following lung resection.
- Paratracheal lymph nodes (levels 2R and 4R) are taken after opening the pleura superior to the azygous vein between the trachea and the superior vena cava (**FIG 11A**). Care is taken to preserve the phrenic and vagus nerves. The nodal tissue between the superior vena cava and the trachea up to the level of the innominate artery is removed.
- For the subcarinal node dissection (level 7), the pleura is incised posteriorly between the inferior pulmonary vein and the bronchus intermedius on the right and the mainstem bronchus on the left (**FIG 11B**). The nodal packet is dissected from the pericardium, bronchus, and esophagus. Care is taken to protect the esophagus and the vagus nerve.
- The inferior pulmonary ligament is divided, and level 9 lymph nodes are obtained adjacent to the inferior pulmonary vein (**FIG 11C**).
- The paratracheal lymph nodes are not easily accessible on the left where aortopulmonary window (level 5) and paraaortic (level 6) lymph nodes are obtained after incising the pleura in between the aorta and pulmonary artery. Again, care must be taken to preserve the left phrenic and recurrent laryngeal nerves (**FIG 11D**).

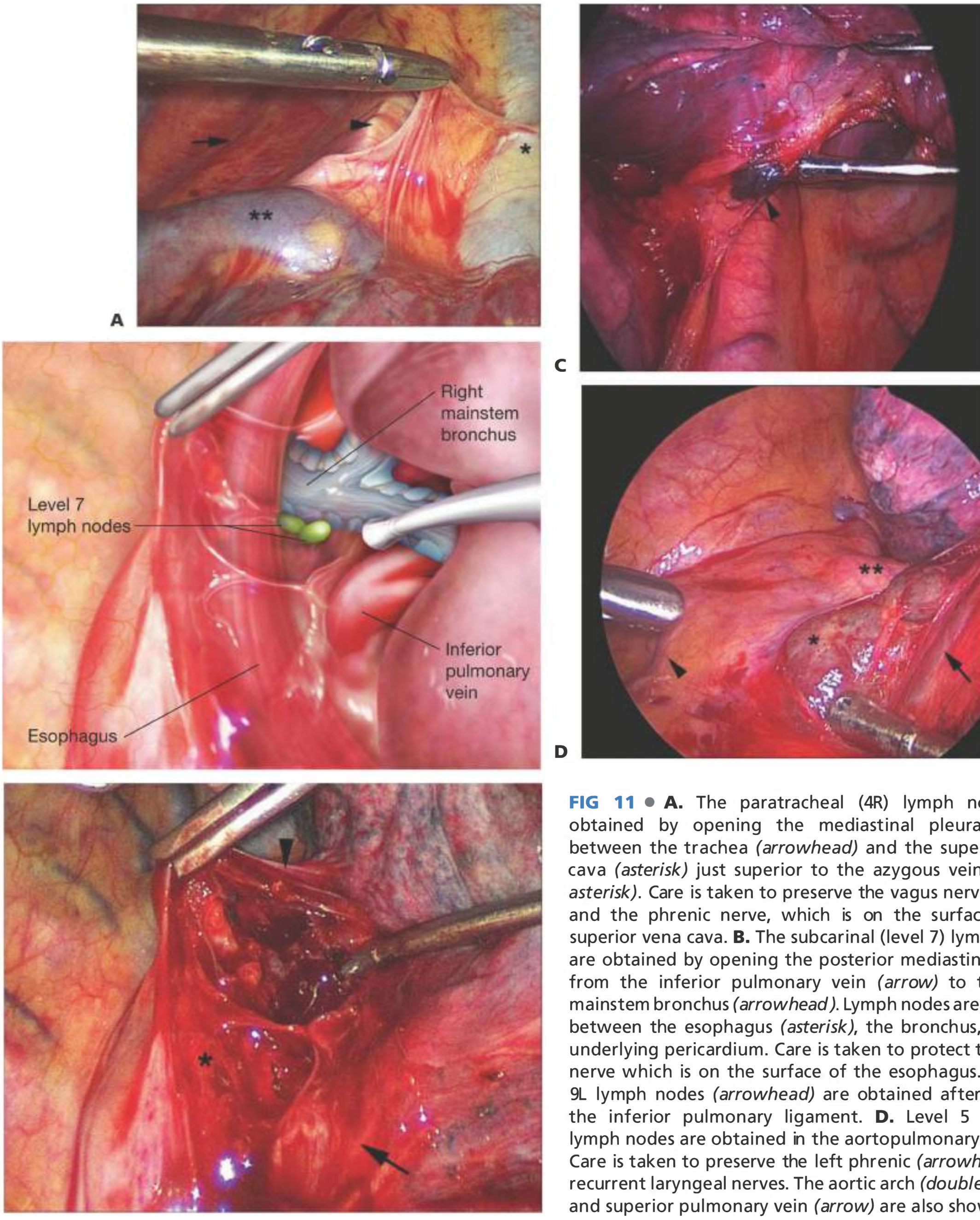

FIG 11 ● **A.** The paratracheal (4R) lymph nodes are obtained by opening the mediastinal pleura sharply between the trachea *(arrowhead)* and the superior vena cava *(asterisk)* just superior to the azygous vein *(double asterisk)*. Care is taken to preserve the vagus nerve *(arrow)* and the phrenic nerve, which is on the surface of the superior vena cava. **B.** The subcarinal (level 7) lymph nodes are obtained by opening the posterior mediastinal pleura from the inferior pulmonary vein *(arrow)* to the right mainstem bronchus *(arrowhead)*. Lymph nodes are removed between the esophagus *(asterisk)*, the bronchus, and the underlying pericardium. Care is taken to protect the vagus nerve which is on the surface of the esophagus. **C.** Level 9L lymph nodes *(arrowhead)* are obtained after dividing the inferior pulmonary ligament. **D.** Level 5 *(asterisk)* lymph nodes are obtained in the aortopulmonary window. Care is taken to preserve the left phrenic *(arrowhead)* and recurrent laryngeal nerves. The aortic arch *(double asterisk)* and superior pulmonary vein *(arrow)* are also shown.

PEARLS AND PITFALLS

Preoperative evaluation	■ Patients with a hilar mass or those unable to tolerate single-lung ventilation should undergo open lobectomy. ■ For ground glass or small nodules (<5 mm) requiring a wedge resection, localization with methylene blue injection or coil/wire placement should be considered.
Positioning	■ Patients should be flexed and positioned to drop the hip out of the way of the camera port. ■ Single-lung ventilation should be started when prepping the patient to allow time for the lung to collapse especially in patients with emphysema.
Incisions	■ Incisions should be placed to allow for optimal visualization and angles for stapler placement for vascular ligation.
Dissection	■ Careful identification and exposure of hilar structures is imperative prior to division. ■ Care must be taken to preserve the right middle lobe vein during a right upper lobectomy. ■ The phrenic and recurrent laryngeal nerves are protected during the mediastinal lymph node dissection. ■ The bronchial stump should be tested for an air leak following division. ■ The hilar structures should be examined to ensure there is no torsion of the remaining lung, particularly the right middle lobe after an upper lobectomy.
Closure	■ Placing chest tubes to water seal may result in quicker resolution of air leaks as long as the lung is well expanded on chest x-ray (CXR).

POSTOPERATIVE CARE

- Following VATS lobectomy, a chest x-ray should be obtained. The chest tubes should be placed to water seal unless the lung is not fully inflated on suction. Chest tubes may be removed on postoperative day 2 or once any air leaks have resolved and drainage has decreased to less than 100 mL per shift.
- Patients should be given an adequate pain control regimen and encouraged to ambulate and use the incentive spirometer.

OUTCOMES

- There are no large, randomized studies of VATS compared to open lobectomy. However, in the two largest series published to date, with more than 500 patients each, the conversion rate was 1.6% to 2.5%, mortality 0.8% to 1.2%, and morbidity 15.3%[5,6] The median length of stay was 3 days.
- VATS lobectomy results in less pain,[7] improved pulmonary function in the postoperative period, and an increased chance of completing adjuvant chemotherapy.[8]
- VATS lobectomy, when performed by experienced thoracic surgeons, is a safe procedure with comparable or better results than open lobectomy via thoracotomy.

COMPLICATIONS

- Prolonged air leak
- Bleeding
- Infection
- Atrial fibrillation
- Pneumonia
- Phrenic or recurrent laryngeal nerve injury
- Myocardial infarction
- Bronchopleural fistula
- Right middle lobe torsion is a rare complication following right upper lobectomy. The lung should be reinflated under direct vision to ensure that there is no lobar torsion.

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Chapter 7

Lobectomy: Robotic

Tyler Grenda Jules Lin

DEFINITION

- Robotic-assisted thoracoscopic lobectomy is defined as an anatomic lobectomy performed with the assistance of robotic technology in which bronchial and vascular ligation is performed with lymph node dissection or sampling through several small incisions while avoiding spreading of the ribs. The technique is a minimally invasive alternative to thoracoscopic lobectomy and must be performed with the same oncologic principles as an open lobectomy including vascular ligation, resection with negative margins, and appropriate lymph node dissection.

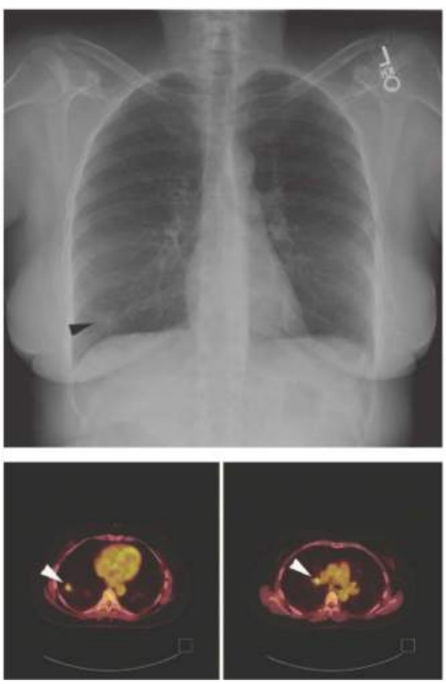
PATIENT HISTORY AND PHYSICAL FINDINGS

- A detailed history and physical must be performed including past medical and surgical history, allergies, medications, social, and family history.
- A detailed social history is important to determine the patient's previous history of tobacco use as well as any chemical or asbestos exposures. Smoking cessation for 4 weeks preoperatively should be strongly encouraged prior to surgery.
- The patient's current functional status and exercise tolerance must also be assessed to determine their fitness for surgery.
- A complete physical examination should be performed with auscultation of the heart and lungs and evaluation for any cervical or supraclavicular lymphadenopathy or peripheral edema. Any abnormal findings on physical examination should be evaluated prior to surgery.
- Routine laboratory studies including a complete blood count and basic chemistry panel should be included as part of the preoperative evaluation.

IMAGING AND OTHER DIAGNOSTIC STUDIES

- Patients generally present with abnormalities on chest radiograph (**FIG 1A**) or chest computed tomography (CT) (**FIG 1B**). The lung nodule should be compared to previous imaging when available. Nodules that have been stable for more than 2 years are generally benign. Indeterminate lesions less than 1 cm in size should be followed with serial imaging according to the recommendations of the Fleischner Society.[1]
- A chest CT (**FIG 1B**) should be obtained in all patients with a suspicious lung nodule on chest x-ray (CXR)[2,3] to evaluate the size and characteristics of the lesion; any potential involvement of the chest wall, vessels, airway, and mediastinum; additional pulmonary nodules; and hilar or mediastinal lymphadenopathy. The upper abdomen should be included to evaluate the liver and adrenal glands for any metastatic disease.
- A positron emission tomography (PET) scan (**FIG 1C**) is a functional study that evaluates the metabolic activity of the pulmonary lesion and areas of uptake that are suspicious for regional nodal or distant metastatic disease and should be obtained in patients suspected of having a non–small cell lung carcinoma.[3] Sampling of any abnormal lymph nodes

A



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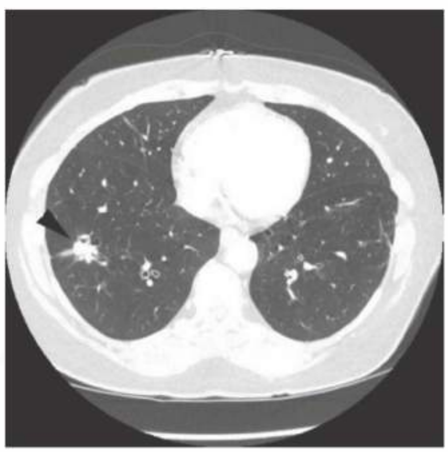


C

FIG 1 ● **A.** Chest x-ray shows a peripheral right lower lobe nodule *(arrowhead)*. **B.** Chest CT shows a spiculated right lower lobe nodule suspicious for a lung carcinoma *(arrowhead)*. **C. Left:** PET scan shows an intensely fluorodeoxyglucose (FDG)-avid right lower lobe nodule *(arrowhead)* with a hypermetabolic right hilar lymph node (**right**; *arrowhead*).

should be performed prior to lung resection by endobronchial ultrasound (EBUS) or mediastinoscopy.

- Due to the low morbidity and mortality of a thoracoscopic wedge resection, for nodules that are highly suspicious for lung carcinoma on PET or serial imaging, our preference is to perform a video-assisted thoracic surgery (VATS) wedge resection for a tissue diagnosis. CT or super dimensional needle biopsies are performed when the diagnosis is less clear or for central lesions that would require a lobectomy for diagnosis alone.
- Once the cancer diagnosis is confirmed, an anatomic lobectomy and mediastinal lymph node dissection for complete oncologic resection and staging is performed in patients who are surgical candidates.[4]
- As screening chest CTs identify smaller lesions, preoperative localization with methylene blue or coil/wire placement by CT guidance or super dimensional bronchoscopy may be useful in identifying small (<5 mm) or ground glass nodules (<1 cm) and nodules that are deep to the pleural surface intraoperatively.

SURGICAL MANAGEMENT

Preoperative Planning

- All patients undergoing lung resection should undergo preoperative pulmonary function testing (PFT) to determine if they have adequate pulmonary reserve.[5] Preoperative cardiac evaluation should be performed in patients with significant cardiovascular risk factors or symptoms.
- Patients with a preoperative forced expiratory volume in 1 second (FEV_1) of more than 60% predicted and diffusing capacity of lung for carbon monoxide (DLCO) of more than 50% predicted are candidates for lobectomy. Patients not meeting these criteria should undergo further testing with a quantitative ventilation perfusion scan to determine the postoperative predicted pulmonary function with a minimum postoperative value of 40% predicted.
- Cardiopulmonary exercise testing can be helpful in patients whose symptoms do not correlate with the severity of their pulmonary function results.
- For patients who are not candidates for an anatomic lobectomy, alternatives include a sublobar resection such as a segmentectomy or wedge resection, stereotactic body radiation therapy (SBRT), radiofrequency ablation (RFA), or definitive chemoradiation. These patients should be discussed in a multidisciplinary setting.
- In the preoperative area, the history and physical should be reviewed and consent should be obtained from the patient. The operative side should be marked.
- Once in the operating room (OR), a flexible bronchoscopy is performed to verify airway anatomy and the location of any endobronchial lesions.
- A left-sided double lumen endotracheal tube is generally preferable to a bronchial blocker in achieving single-lung ventilation, especially on the right where the mainstem bronchus is shorter.
- It is important to recognize the lack of tactile feedback when using the robot. Practice in the robotic simulator prior to the case is useful.
- The OR team must be familiar with emergency de-docking, and a sponge stick should be immediately available in case of bleeding.
- The dual console is useful when working with residents and allows both surgeons to switch instruments as needed. Pressing the camera pedal stops all the arms from moving, increasing safety.

Positioning

- The robot is draped sterilely (**FIG 2A**). The surgeon operates with arms 1 and 2 while arm 3 is used for retraction. The joint of the camera arm should be placed opposite of arm 3 to minimize bumping of the robotic arms.
- The surgeon sits at the console (**FIG 2B**), whereas an experienced bedside assistant changes the robotic instruments, passes the staplers, and suctions when needed.
- The patient should be placed in the lateral decubitus position, tilted slightly posteriorly (**FIG 3A**). The robotic camera is much larger than the standard thoracoscopic camera, and the bed is flexed taking care to drop the hips out of the way of the camera port. The patient should be secured to the bed, and all pressure points are padded. The arms are positioned in the neutral position in an arm holder.
- The position of the endotracheal tube should be confirmed again once positioning is complete.

FIG 2 ● **A.** The robot is draped sterilely. For a left-sided resection, arm 3 is placed as shown while arm 3 is moved to the opposite side for a right-sided resection. The surgeon operates with arms 1 and 2 while arm 3 is used for retraction. The joint of the camera arm *(arrowhead)* should be placed opposite of arm 3 to minimize bumping of the robotic arms. **B.** The surgeon sits at the console, whereas an experienced bedside assistant changes the robotic instruments, passes the staplers, and suctions when needed.

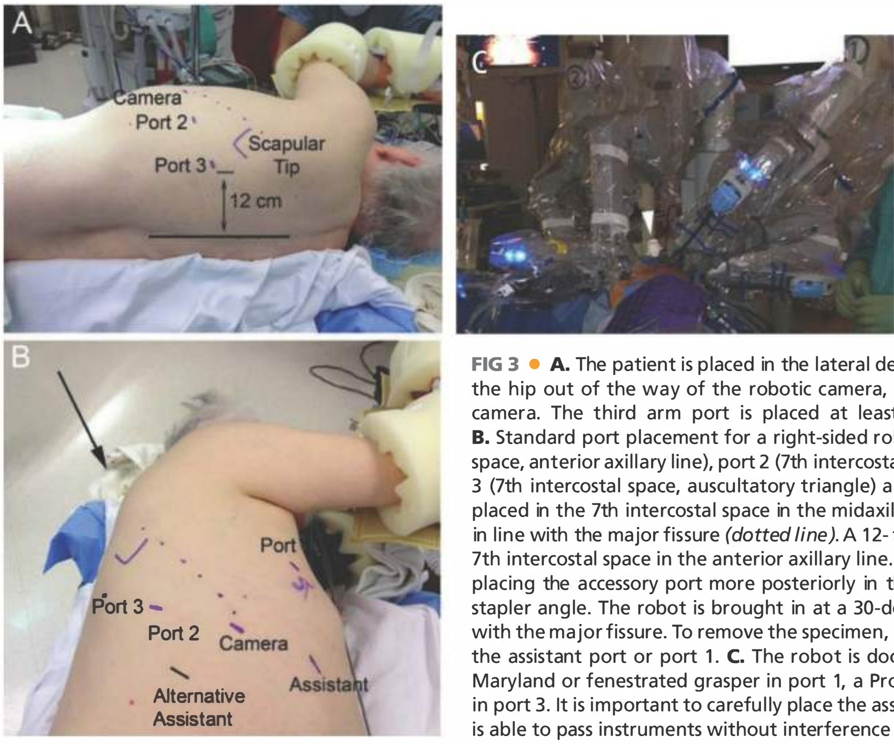


FIG 3 • **A.** The patient is placed in the lateral decubitus position. It is important to drop the hip out of the way of the robotic camera, which is larger than the thoracoscopic camera. The third arm port is placed at least 12 cm from the level of the spine. **B.** Standard port placement for a right-sided robotic lobectomy. Port 1 (5th intercostal space, anterior axillary line), port 2 (7th intercostal space, posterior axillary line), and port 3 (7th intercostal space, auscultatory triangle) are placed as shown. The camera port is placed in the 7th intercostal space in the midaxillary line, so the camera will be directed in line with the major fissure *(dotted line)*. A 12- to 15-mm accessory port is placed in the 7th intercostal space in the anterior axillary line. For a right upper or middle lobectomy, placing the accessory port more posteriorly in the 8th intercostal space offers a better stapler angle. The robot is brought in at a 30-degree angle to the back *(arrow)* in line with the major fissure. To remove the specimen, a 10-cm access incision is made at either the assistant port or port 1. **C.** The robot is docked to the ports with either a bipolar Maryland or fenestrated grasper in port 1, a ProGrasp in port 2, and a Caudier grasper in port 3. It is important to carefully place the assistant port so that the bedside assistant is able to pass instruments without interference from the robotic arms.

PLACEMENT OF INCISIONS

- Port placement is important in obtaining the ideal angles for stapler placement and avoiding the robotic arms interfering with each other or the bedside assistant's port. Our general port placement for a robotic lobectomy is shown (**FIG 3B**).
- Port 1 is placed in the 5th intercostal space in the anterior axillary line. A 5-mm, 30-degree angled standard thoracoscope is inserted, so the remaining ports can be placed under direct visualization.
- Port 2 is placed in the 7th intercostal space in the posterior axillary line. Port 3 is placed in the 7th intercostal space in the auscultatory triangle and should be placed at least 12 cm from the spine. The camera port is placed in the 7th intercostal space in the midaxillary line, so the camera will be directed in line with the major fissure.
- A 12- to 15-mm assistant port is placed in the 7th intercostal space in the anterior axillary line. It is important to carefully place the assistant port so that the bedside assistant is able to pass instruments without interference from the robotic arms (**FIG 3C**). For a right upper or middle lobectomy, placing the assistant port more posteriorly in the 8th intercostal space offers a better stapler angle. Early in the surgeon's experience, the 15-mm port is useful, so standard thoracoscopic instruments such as the Foerster clamp and long coronary tip suction can be used.
- Carbon dioxide (CO_2) insufflation to 5 mmHg can be useful for a lower lobectomy to help push the diaphragm out of the way. It is important to communicate with the anesthesiologist at the start of insufflation to watch for hypotension and adjust the CO_2 insufflation as warranted.
- A 10-cm access incision can be made instead of the assistant port at the beginning of the case. If CO_2 insufflation is used, the access incision is made at either the assistant port or port 1 at the end of the case to remove the specimen. In the event of bleeding, a sponge stick can be quickly inserted through the access incision or the 15-mm port to hold pressure.
- The robot is brought in at a 30-degree angle to the back in line with the major fissure (**FIG 3B**).
- The robot is docked to the ports with either a bipolar Maryland or fenestrated grasper in port 1 for dissection. A ProGrasp is placed in port 2 and is used to provide counter tension as vessels and other structures are dissected free. A Caudier grasper is placed in port 3 and is used to retract and position the lung. A 30-degree, 8.5-mm camera (angled down) is used to decrease compression of the intercostal nerve.
- Following port placement, a thoracoscopic exploration is performed to evaluate for any effusion, pleural lesions, or additional pulmonary nodules.
- Adequate lung isolation is important, and if the lung is not adequately collapsed, suction should be applied to the appropriate lumen of the endotracheal tube.

RIGHT UPPER LOBECTOMY

- The location of the nodule in the right upper lobe should be confirmed. The lung is retracted posteriorly to expose the hilum.
- The dissection is performed from anterior to posterior. The anterior mediastinal pleura is opened sharply to avoid injuring the phrenic nerve using scissors or the bipolar Maryland grasper (**FIG 4A**).
- The superior pulmonary vein branches are dissected bluntly with the bipolar fenestrated grasper. The division between the upper lobe and middle lobe venous branches must be identified (**FIG 4B**). The minor fissure can be followed anteriorly to ensure that the middle lobe vein is preserved. Care must be taken to avoid injury to the underlying right pulmonary artery.
- The upper lobe superior venous branches are divided using a vascular stapler (Ethicon Inc, San Antonio, TX or Covidien, Mansfield, MA; beige load Endo GIA, 2.0- to 3.0-mm stapler height) through the assistant port (**FIG 4C**). If needed, the vessels can be encircled with a silk tie for traction or a curved-tip stapler (Covidien) can be used to assist in passage of the stapler.
- The truncus anterior branch of the pulmonary artery is then dissected free and divided using a beige load stapler through the assistant port (**FIG 4D**).
- With the lung retracted anteriorly, the posterior pleura is opened. The bifurcation between the upper lobe bronchus and the bronchus intermedius is dissected free (**FIG 4E**). An 11R lymph node is often removed, and care must be taken not to injure the posterior ascending pulmonary artery branch, which is just behind this lymph node.
- The lung is again retracted posteriorly, and the right upper lobe bronchus is dissected free (**FIG 4F**). Stations 10R and 11R lymph nodes are obtained for pathology. The right upper lobe bronchus is then clamped flush with the bronchus intermedius with a purple load stapler passed from the assistant port (**FIG 4G**). The right middle and lower lobes are partially inflated to confirm that the bronchus intermedius is patent before firing the stapler.
- The posterior ascending arterial branch (**FIG 4H**) is then dissected free and divided using a beige load stapler through the assistant port.
- A purple load stapler (3.0- to 4.0-mm stapler height) through port 1 is then used to divide the minor fissure to complete the resection of the right upper lobe (**FIG 4I**).
- Once the dissection has been completed, the specimen should be removed using a protective retrieval bag (Cook Urological, Bloomington, IN; LapSac).

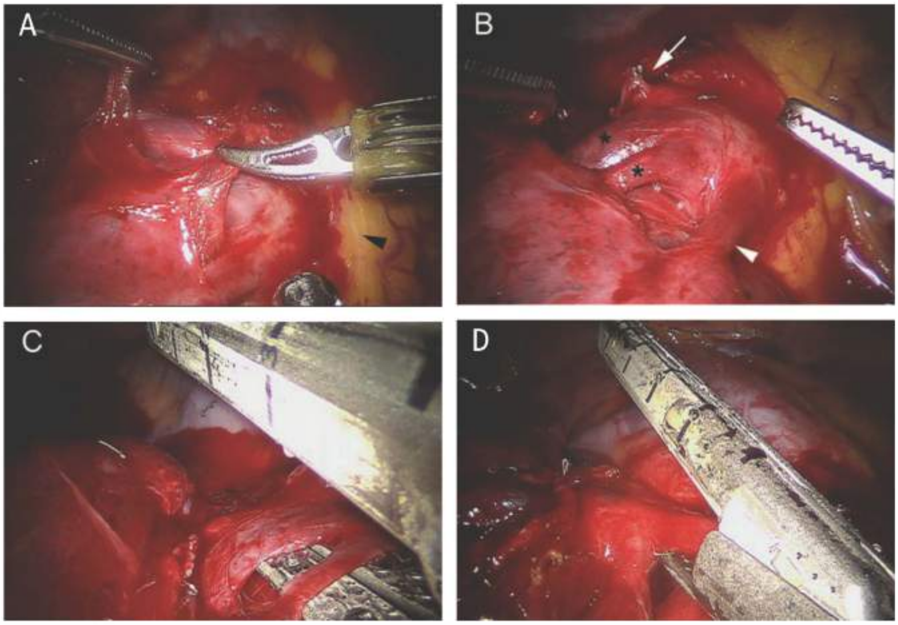


FIG 4 ● **A.** The anterior mediastinal pleura is opened with either scissors or bipolar Maryland grasper. Care is taken to preserve the right phrenic nerve *(arrowhead)*. **B.** The right upper lobe branches *(asterisks)* of the superior pulmonary vein are dissected free. The most superior branch *(arrow)* has already been divided. Care is taken to preserve the right middle lobe vein *(arrowhead)*. Attention must also be taken to avoid injuring the underlying right pulmonary artery. **C.** The upper lobe branches are divided with a beige load stapler passed from the assistant port. **D.** The truncus anterior branch of the pulmonary artery is dissected free and divided with a beige load stapler. *(continued)*

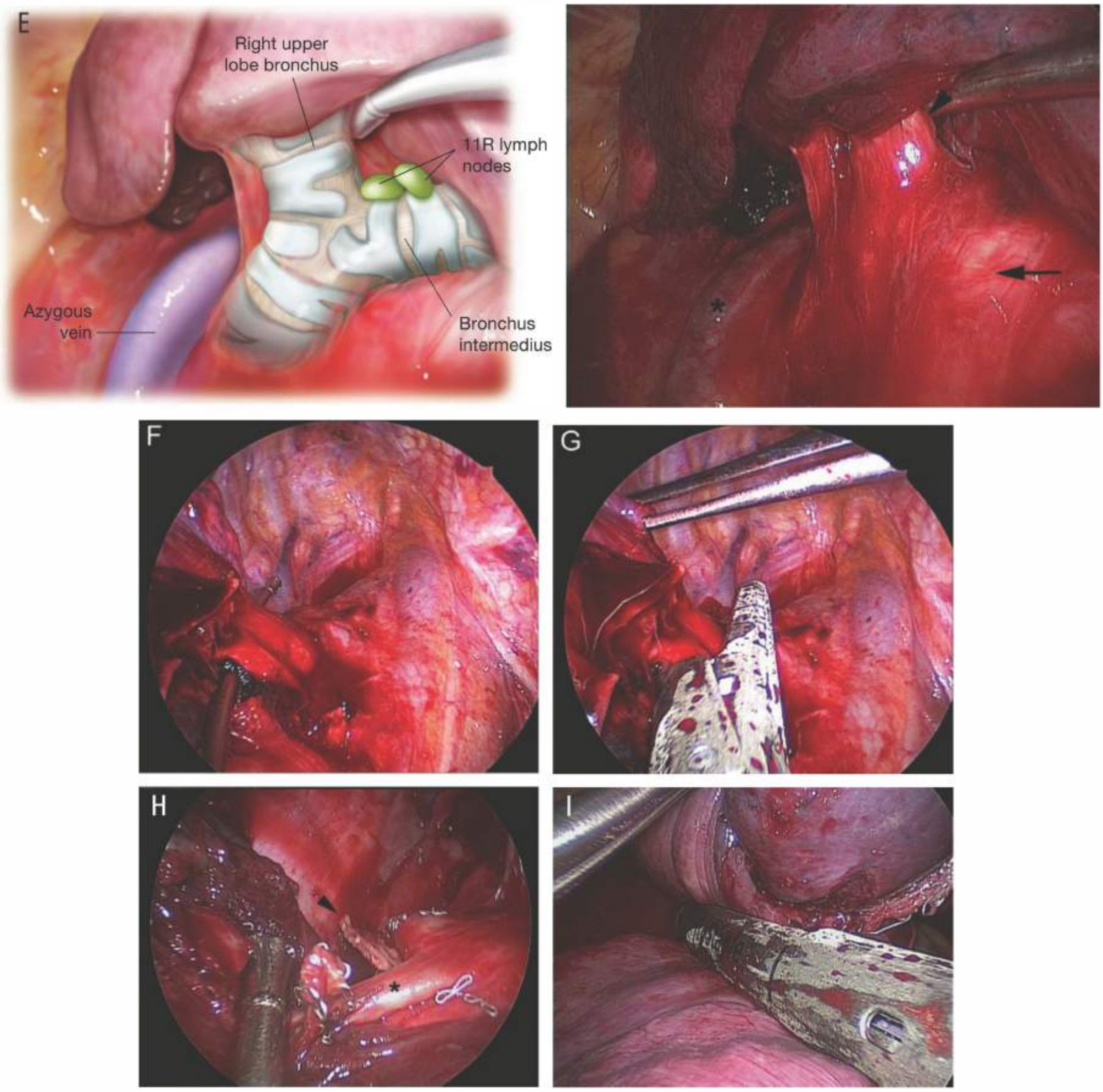


FIG 4 ● *(continued)* **E.** With the lung retracted anteriorly, the posterior pleura is opened. The bifurcation between the upper lobe bronchus *(arrowhead)* and the bronchus intermedius *(arrow)* is dissected free. An 11R lymph node is often removed, and care is taken not to injure the posterior ascending pulmonary artery branch, which is just behind this lymph node (azygous vein, *asterisk*). **F.** The right upper lobe bronchus is dissected free anteriorly, and 11R lymph nodes are sent for pathology. **G.** The right upper lobe bronchus is clamped with a purple load stapler passed from the assistant port. The right middle and lower lobe are partially inflated to confirm that the bronchus intermedius is patent before firing the stapler. **H.** The posterior ascending pulmonary artery branch *(asterisk)* is dissected free and divided with a beige load stapler passed from the assistant port. The right upper lobe bronchial stump is shown *(arrowhead)*. **I.** The fissure is completed with a purple load stapler through port 1. Care is taken to preserve the middle lobe pulmonary vein and the underlying pulmonary artery. *(continued)*

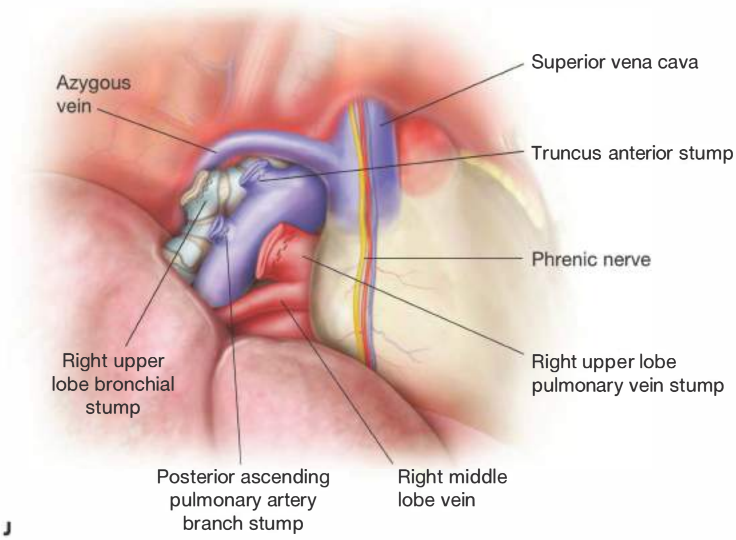


FIG 4 ● *(continued)* **J.** The right upper lobe pulmonary and bronchial veins and truncus anterior and posterior ascending pulmonary arterial stumps are checked for hemostasis. It is important to examine the middle lobe vein to confirm that there is no middle lobe torsion.

- A mediastinal lymph node dissection is performed as described in the following text.
- The hemithorax is then irrigated with warm water, and the bronchial stump is inspected for evidence of an air leak with a Valsalva to 25 cm H_2O. If there is an air leak, robotic or open suturing of the bronchial stump is performed using interrupted 4-0 Vicryl sutures. The vascular stumps are checked for hemostasis (**FIG 4J**).
- Chest tubes are placed anteriorly and posteriorly through the port 1 and camera port incisions. The lung is reinflated under direct vision to ensure that there is no torsion of the middle lobe (**FIG 4J**).
- The remaining port sites are closed in layers using running 2-0 Vicryl for the muscle and subcutaneous layers and 4-0 Monocryl to reapproximate the skin.

RIGHT MIDDLE LOBECTOMY

- The tumor location in the right middle lobe is confirmed. The right middle lobe is retracted posteriorly. The anterior mediastinal pleura is opened sharply to avoid injuring the phrenic nerve using scissors or the bipolar Maryland grasper.
- The right middle lobe vein is identified. Care is taken to preserve the right upper lobe vein branches (**FIG 5A**). The minor fissure can be followed anteriorly to ensure that the upper lobe veins are preserved. The right middle lobe vein is dissected with a bipolar fenestrated grasper and divided with a beige load stapler passed from the assistant port (**FIG 5B,C**).
- The major fissure is opened with a combination of dissection with the bipolar Maryland grasper and the purple load stapler taking care to protect the underlying right lower lobe branches of the pulmonary artery.
- The right middle lobe bronchus is dissected free with the bipolar fenestrated grasper at the branch point with the right lower lobe bronchus (**FIG 5D,E**). Any 10R or 11R lymph nodes are obtained for pathology. The right middle lobe bronchus is then clamped with a purple load stapler passed through the assistant port, flush with the origin of the lower lobe bronchus. The lung is gently reinflated to ensure that the right lower lobe bronchus is patent before dividing the middle lobe bronchus.
- The right middle lobe pulmonary arterial branches are dissected free with a bipolar fenestrated grasper and divided with a beige load stapler passed from the assistant port (**FIG 5F**). A second middle lobe arterial branch may be present and is divided in a similar fashion.
- The major and minor fissures (**FIG 5G**) are completed with a purple load stapler passed from port 1. Care is taken to preserve the upper lobe veins.
- The specimen is then removed using a retrieval bag.
- A mediastinal lymph node dissection is performed as described in the following text.
- The hemithorax is then irrigated with warm water, and the bronchial stump is inspected for evidence of an air leak with a Valsalva to 25 cm H_2O. If there is evidence of an air leak, robotic or open suturing of the bronchial stump with interrupted 4-0 Vicryl may be performed.
- Prior to closure, chest tubes are placed anteriorly and posteriorly. The lung is reinflated under direct vision to confirm that there is no lobar torsion.

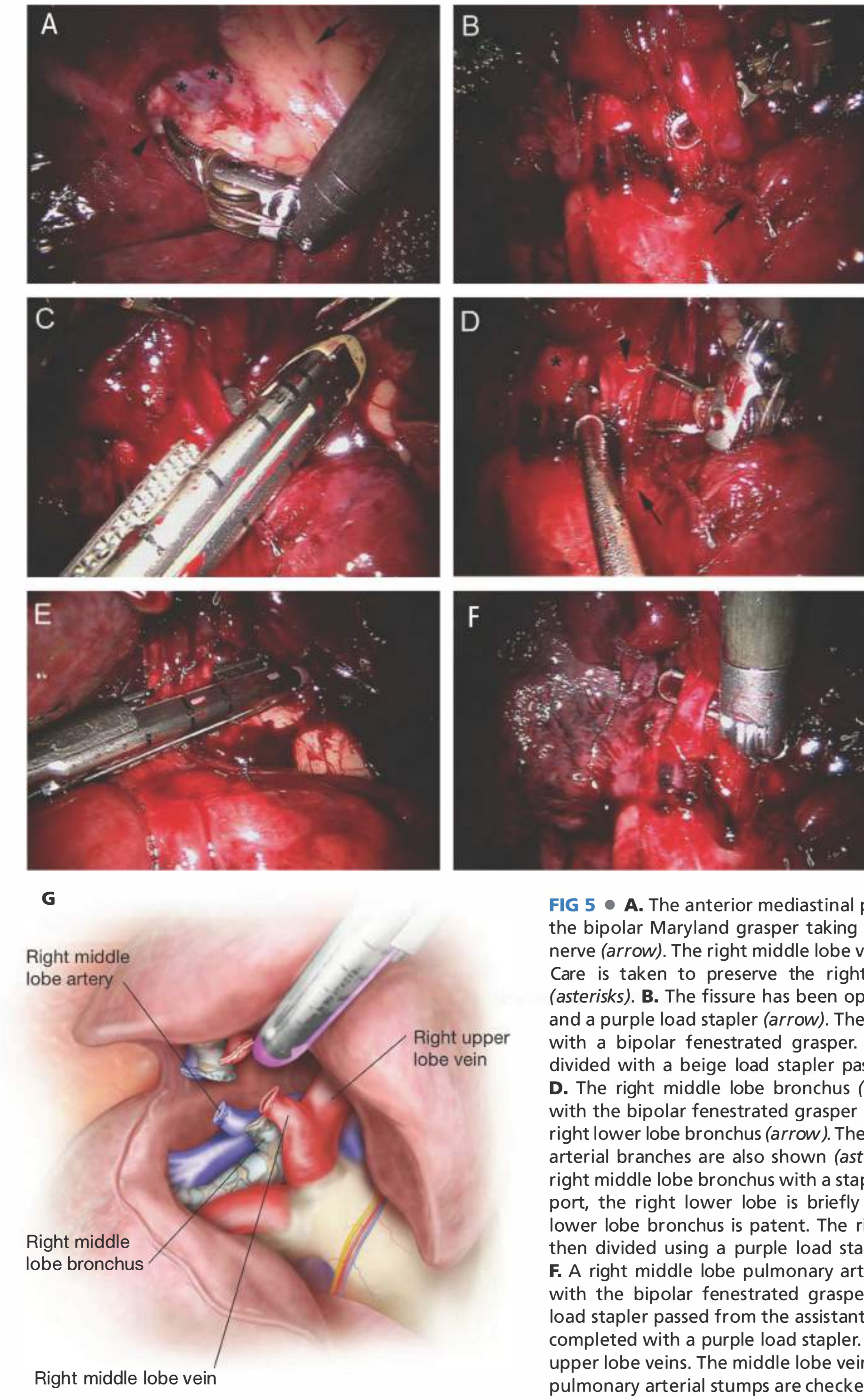


FIG 5 ● **A.** The anterior mediastinal pleura has been opened with the bipolar Maryland grasper taking care to preserve the phrenic nerve *(arrow)*. The right middle lobe vein is identified *(arrowhead)*. Care is taken to preserve the right upper lobe vein branches *(asterisks)*. **B.** The fissure has been opened with bipolar dissection and a purple load stapler *(arrow)*. The middle lobe vein is dissected with a bipolar fenestrated grasper. **C.** The middle lobe vein is divided with a beige load stapler passed from the assistant port. **D.** The right middle lobe bronchus *(arrowhead)* is dissected free with the bipolar fenestrated grasper at the branch point with the right lower lobe bronchus *(arrow)*. The right middle lobe pulmonary arterial branches are also shown *(asterisk)*. **E.** After clamping the right middle lobe bronchus with a stapler passed from the assistant port, the right lower lobe is briefly inflated to ensure that the lower lobe bronchus is patent. The right middle lobe bronchus is then divided using a purple load stapler from the assistant port. **F.** A right middle lobe pulmonary arterial branch is dissected free with the bipolar fenestrated grasper and divided with a beige load stapler passed from the assistant port. **G.** The minor fissure is completed with a purple load stapler. Care is taken to preserve the upper lobe veins. The middle lobe vein, bronchial, and middle lobe pulmonary arterial stumps are checked for hemostasis.

RIGHT LOWER LOBECTOMY

- The location of the tumor in the right lower lobe is confirmed.
- With the lower lobe retracted superiorly, the inferior pulmonary ligament is divided to expose the right inferior pulmonary vein (**FIG 6A**). The 9R lymph nodes are removed.
- The anterior and posterior mediastinal pleural are opened sharply to avoid injuring the phrenic nerve using scissors or the bipolar Maryland grasper.
- The inferior pulmonary vein is then dissected bluntly with the bipolar fenestrated grasper. With the lung retracted anteriorly, level 7 lymph nodes may be obtained. The lung is then retracted posteriorly, and the inferior pulmonary vein is divided with a beige load stapler through port 1 (**FIG 6B**).
- Performing a fissure dissection is easier using the robotic bipolar Maryland grasper compared to thoracoscopy (**FIG 6C**). Once the plane overlying the pulmonary arterial branches is identified, the parenchyma is dissected from the arterial branches with the bipolar fenestrated grasper.
- If the fissure is incomplete, a standard thoracoscopic anterior to posterior approach is performed. Working outward from the hilum, the parenchyma in the major fissure is dissected from the lower lobe bronchus and the basilar pulmonary artery branches.
- The anterior fissure is completed with a purple load stapler passed from the assistant port, exposing the right lower lobe bronchus and pulmonary arterial branches (**FIG 6D**).
- The basilar pulmonary arterial branches (**FIG 6E**) are then dissected free and divided either together or individually with a beige load stapler passed from the assistant port.
- The superior segment pulmonary arterial branch is dissected free and divided with a beige load stapler passed from the assistant port.
- The right lower lobe bronchus is dissected free at the junction with the right middle lobe bronchus (**FIG 6F**). The right lower lobe bronchus is clamped with a purple load stapler and the right middle lobe briefly inflated to ensure patency of the right middle lobe bronchus before firing the stapler.
- The posterior fissure is completed with a purple load stapler (**FIG 6G**). The specimen is then removed using a retrieval bag.
- A mediastinal lymph node dissection is performed as described in the following text.
- The hemithorax is then irrigated with warm water, and the bronchial stump is inspected for evidence of an air leak with a Valsalva to 25 cm H_2O. If there is evidence of an air leak, robotic or open suturing of the bronchial stump with interrupted 4-0 Vicryl may be performed. The vascular stumps are checked for hemostasis.
- Prior to closure, chest tubes are placed anteriorly and posteriorly.

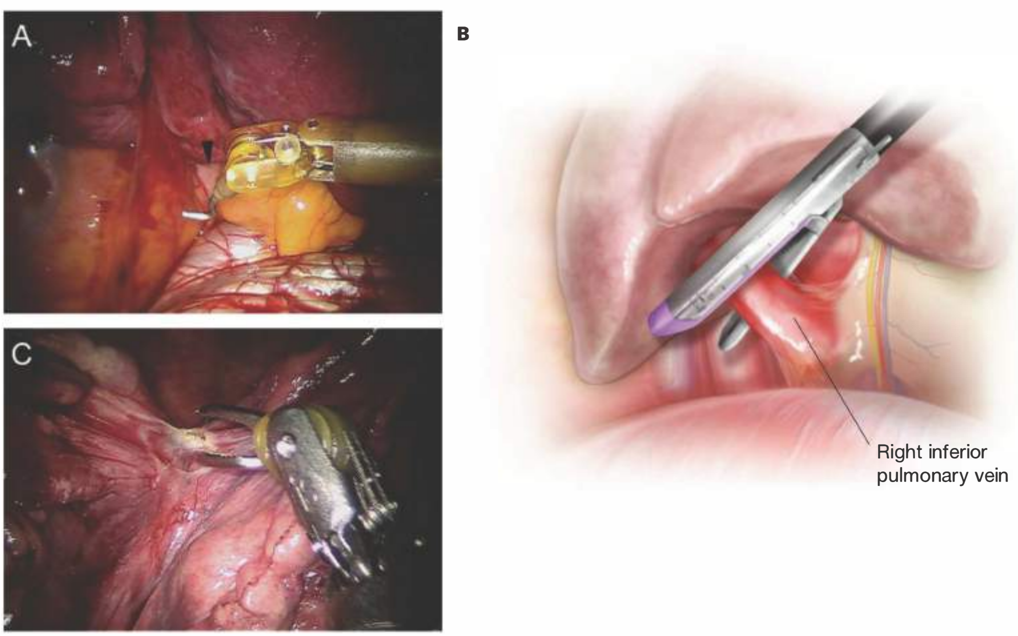
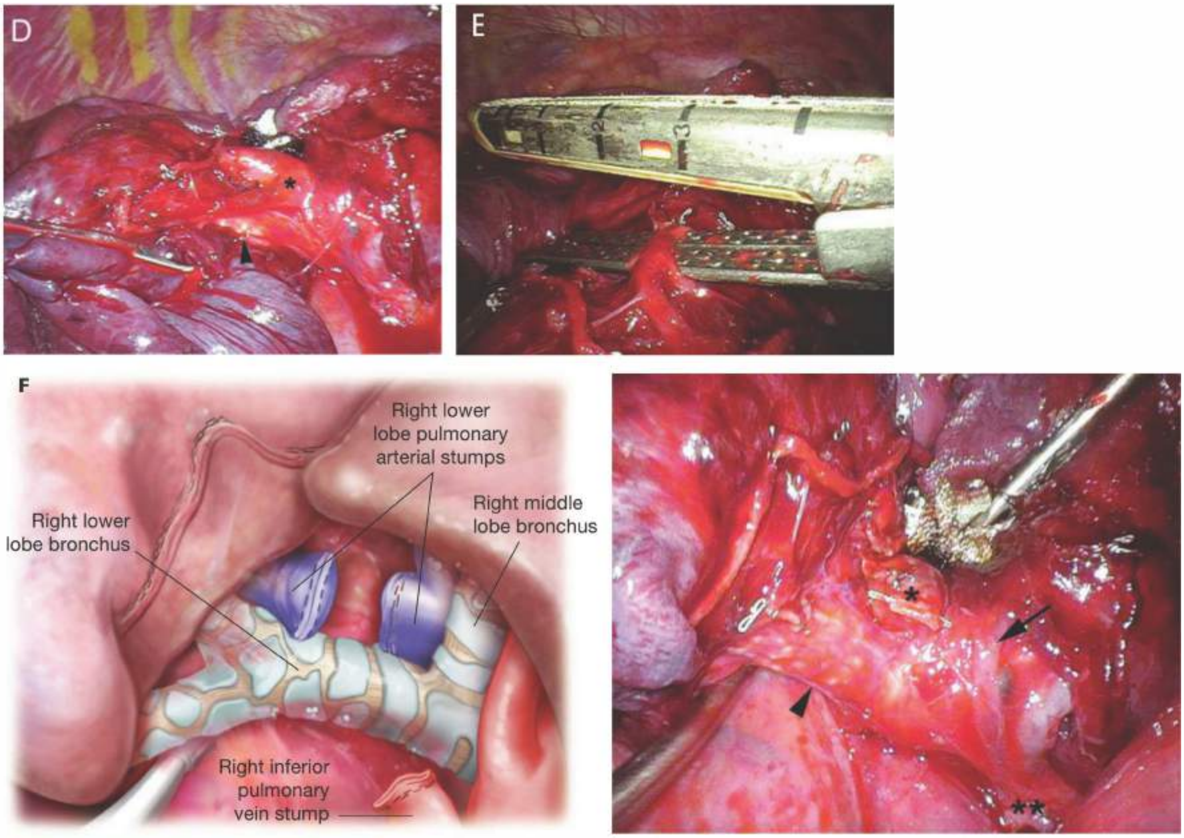


FIG 6 ● **A.** The inferior pulmonary ligament is divided to expose the right inferior pulmonary vein *(arrowhead)*. The 9R lymph nodes are removed. **B.** The inferior pulmonary vein is divided with a stapler passed from port 1. **C.** The right lower lobe fissure is opened with the bipolar Maryland grasper. *(continued)*



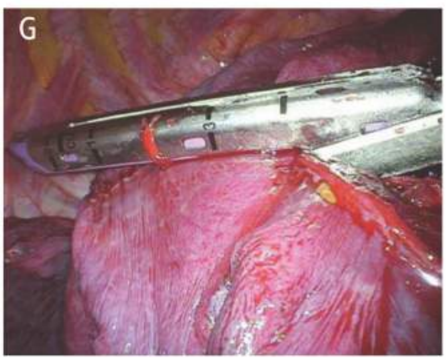


FIG 6 ● *(continued)* **D.** Staying in the plane overlying the pulmonary arterial branches, the anterior fissure has been completed with a purple load stapler passed from the assistant port, exposing the right lower lobe bronchus *(arrowhead)* and pulmonary arterial branches *(asterisk)*. **E.** A right lower lobe basilar branch is divided with a beige load stapler passed from the assistant port. **F.** The right lower lobe bronchus *(arrowhead)* is dissected free at the junction with the right middle lobe bronchus *(arrow)*. The right lower lobe bronchus is clamped with a purple load stapler and the right middle lobe briefly inflated to ensure patency of the right middle lobe bronchus before firing the stapler. The right lower lobe pulmonary arterial *(asterisk)* and inferior pulmonary vein stumps are shown *(double asterisk)*. **G.** The posterior fissure is completed with a purple load stapler.

LEFT UPPER LOBECTOMY

- The major fissure should be inspected, and the tumor should be localized in the left upper lobe.
- The left upper lobe is retracted posteriorly, and the anterior mediastinal pleura is opened sharply to avoid injuring the phrenic nerve using scissors or the bipolar Maryland grasper.
- The left superior pulmonary vein branches are dissected free and divided with a beige load stapler passed from port 2 (**FIG 7A**). There are usually three branches, although there can be more.
- The pleura superior to the hilum is then opened sharply. Levels 5 and 6 lymph nodes are obtained for pathology.
- The left upper lobe pulmonary arterial anatomy is the most variable, and there are often multiple, small branches.
- The apical pulmonary arterial branch is dissected free and divided with a beige load stapler passed from the assistant port (**FIG 7B**).
- Performing a fissure dissection is easier using the robotic bipolar Maryland grasper compared to thoracoscopy. Once the plane overlying the pulmonary arterial branches is identified, the parenchyma is dissected

from the arterial branches with the bipolar fenestrated grasper (**FIG 7C**).

- If the fissure is incomplete, the dissection is continued anterior to posterior as is generally used for a thoracoscopic lobectomy.
- Working outward from the hilum, the parenchyma in the major fissure is dissected off the lingular pulmonary arterial branches and the bronchus.
- The fissure is then divided, keeping the purple load stapler above the bronchovascular structures passing the stapler from port 1.
- The lingular pulmonary arterial branches are then dissected free and divided using a beige load stapler through the anterior incision.
- The junction of the left upper and lower lobe bronchi is dissected free while retracting the upper lobe superiorly (**FIG 7D,E**). Level 11L lymph nodes are obtained for pathology. The bronchus is then clamped with a purple load stapler passed from port 2 flush with the origin of the lower lobe bronchus. The left lower lobe is briefly inflated to confirm that the lower lobe bronchus is patent before firing the stapler.
- The remaining pulmonary arterial branches (**FIG 7F**) are divided with a beige load stapler passed from the assistant port.
- The remaining fissure is divided using a purple load stapler from port 1. The specimen is removed using a retrieval bag.
- A mediastinal lymph node dissection is performed as described in the following text.
- The hemithorax is then irrigated with warm water, and the bronchial stump is inspected for evidence of an air leak with a Valsalva to 25 cm H_2O. If there is evidence of an air leak, robotic or open suturing of the bronchial stump with interrupted 4-0 Vicryl may be performed. The vascular stumps are checked for hemostasis (**FIG 7G**). The lung is reinflated under direct vision to ensure that there is no lobar torsion.
- Prior to closure, chest tubes are placed anteriorly and posteriorly.

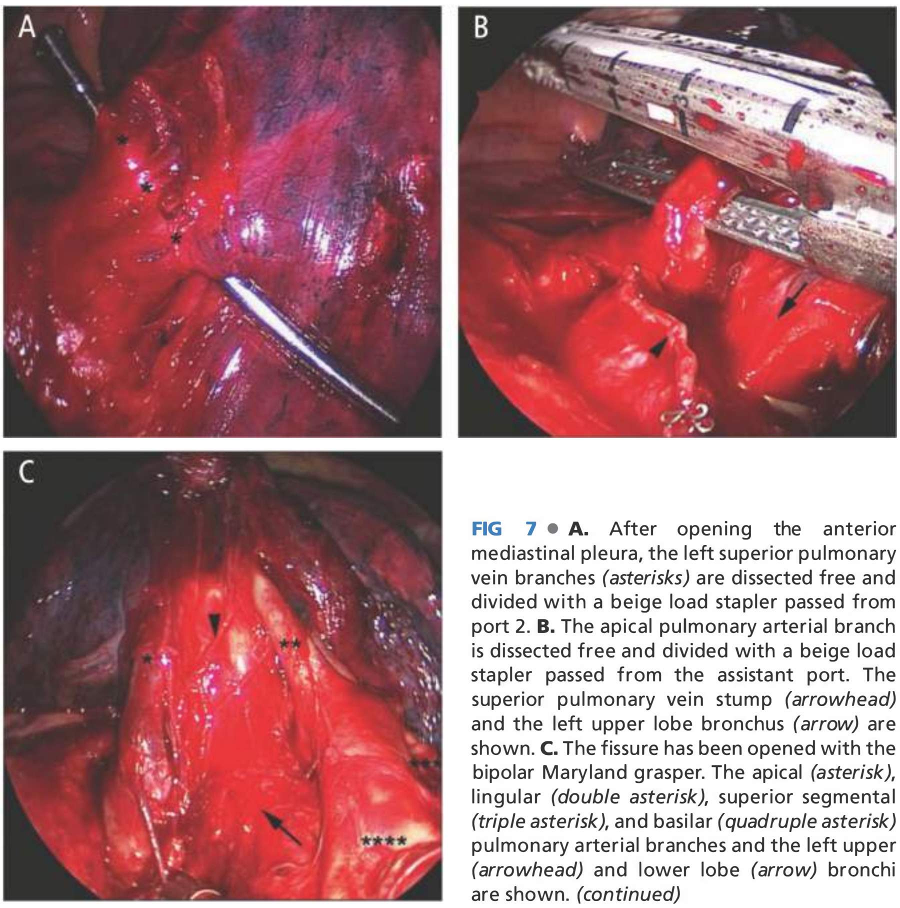


FIG 7 ● **A.** After opening the anterior mediastinal pleura, the left superior pulmonary vein branches *(asterisks)* are dissected free and divided with a beige load stapler passed from port 2. **B.** The apical pulmonary arterial branch is dissected free and divided with a beige load stapler passed from the assistant port. The superior pulmonary vein stump *(arrowhead)* and the left upper lobe bronchus *(arrow)* are shown. **C.** The fissure has been opened with the bipolar Maryland grasper. The apical *(asterisk)*, lingular *(double asterisk)*, superior segmental *(triple asterisk)*, and basilar *(quadruple asterisk)* pulmonary arterial branches and the left upper *(arrowhead)* and lower lobe *(arrow)* bronchi are shown. *(continued)*

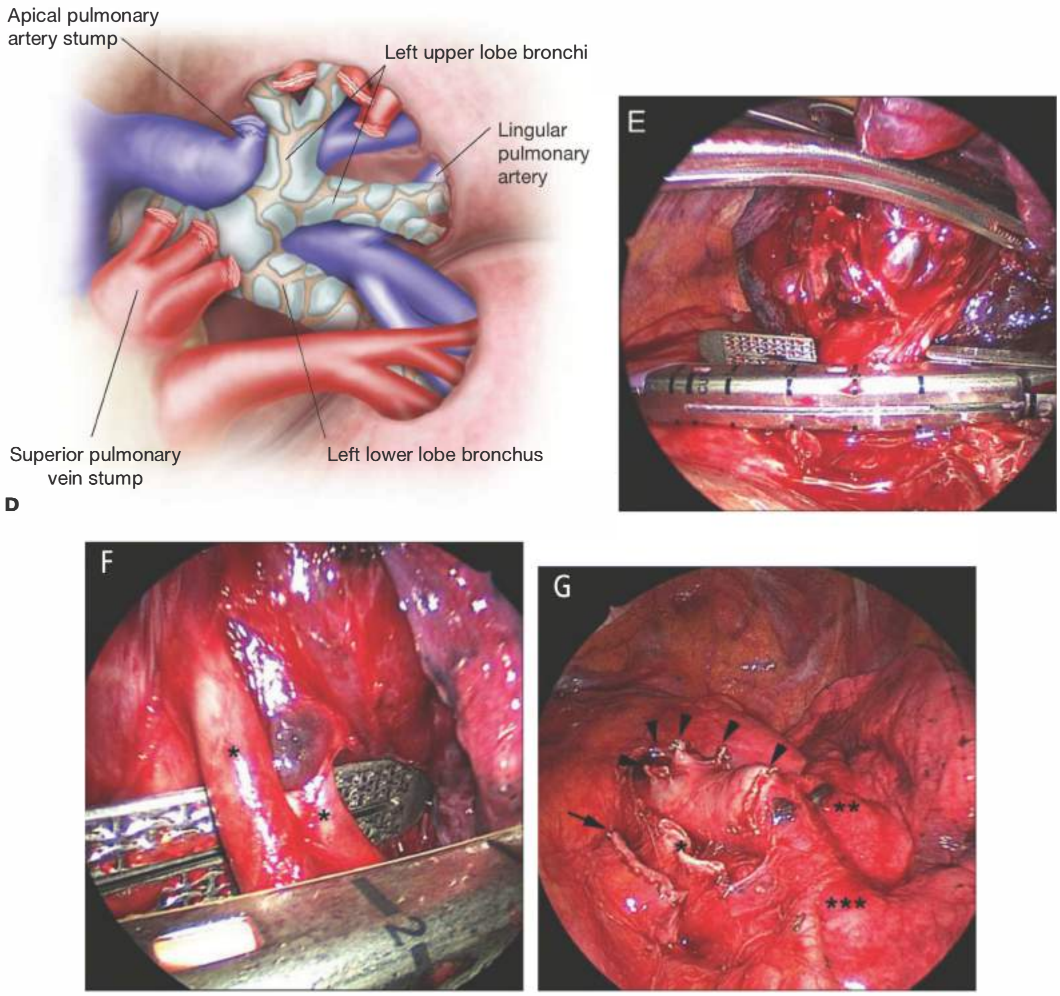


FIG 7 ● *(continued)* **D.** This illustration shows the junction of the left upper and lower lobe bronchi. The 11L lymph nodes are removed and sent to pathology. **E.** Before dividing the left upper lobe bronchus, the bronchus is clamped with a purple load stapler passed from port 2, and the left lower lobe is briefly inflated to confirm that the lower lobe bronchus is patent. **F.** The remaining pulmonary arterial branches *(asterisks)* are divided with a beige load stapler. **G.** The left upper lobe pulmonary arterial anatomy is the most variable, and there are often multiple, short branches. The pulmonary arterial *(arrowheads)*, superior pulmonary vein *(arrow)*, and left upper lobe bronchial *(asterisk)* stumps are checked for hemostasis. The superior segmental *(double asterisk)* and basilar pulmonary arterial branches *(triple asterisk)* are shown.

LEFT LOWER LOBECTOMY

- A left lower lobectomy is performed in a similar fashion to a right lower lobectomy as described earlier.

MEDIASTINAL LYMPH NODE DISSECTION

- Patients undergoing resection for non–small cell lung carcinoma should have systematic mediastinal lymph node sampling or dissection performed intraoperatively.[4]
- The dissection can be performed during the lobectomy as the vessels and airway are dissected or following lung resection.
- The paratracheal (2R and 4R) lymph nodes are obtained by opening the mediastinal pleura sharply between the trachea and the superior vena cava just superior to the azygous vein (**FIG 8A**). Care is taken to preserve the vagus and phrenic nerves. Nodal tissue is removed between the superior vena cava and the trachea up to the level of the innominate artery.

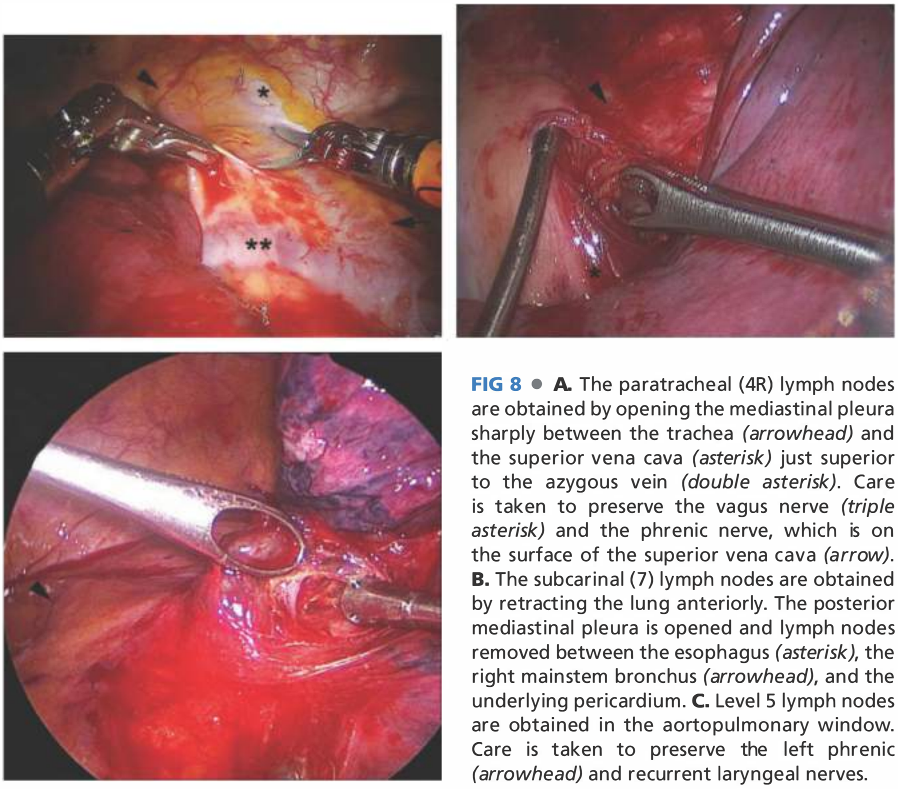


FIG 8 ● **A.** The paratracheal (4R) lymph nodes are obtained by opening the mediastinal pleura sharply between the trachea *(arrowhead)* and the superior vena cava *(asterisk)* just superior to the azygous vein *(double asterisk)*. Care is taken to preserve the vagus nerve *(triple asterisk)* and the phrenic nerve, which is on the surface of the superior vena cava *(arrow)*. **B.** The subcarinal (7) lymph nodes are obtained by retracting the lung anteriorly. The posterior mediastinal pleura is opened and lymph nodes removed between the esophagus *(asterisk)*, the right mainstem bronchus *(arrowhead)*, and the underlying pericardium. **C.** Level 5 lymph nodes are obtained in the aortopulmonary window. Care is taken to preserve the left phrenic *(arrowhead)* and recurrent laryngeal nerves.

- The subcarinal (level 7) lymph nodes are obtained by retracting the lung anteriorly. The posterior mediastinal pleura is opened and lymph nodes are removed between the mainstem bronchus, the esophagus, and the underlying pericardium (**FIG 8B**).
- Level 9 lymph nodes are obtained after dividing the inferior pulmonary ligament and are found adjacent to the inferior pulmonary vein.
- The paratracheal lymph nodes are not easily accessible on the left where aortopulmonary window (level 5) and paraaortic (level 6) lymph nodes are obtained after incising the pleura in between the aorta and pulmonary artery (**FIG 8C**). Care must be taken to preserve the left phrenic and recurrent laryngeal nerves.

PEARLS AND PITFALLS

Preoperative evaluation	■ Patients with a hilar mass or those unable to tolerate single-lung ventilation should undergo open lobectomy. ■ For ground glass or small nodules (<5 mm) requiring a wedge resection, localization with methylene blue injection or coil/wire placement should be considered.
Positioning	■ Patients should be flexed in the lateral decubitus position to drop the hip out of the way of the camera port. ■ Single-lung ventilation should be started when prepping the patient to allow time for the lung to collapse especially in patients with emphysema. ■ The robot should be brought in at 30 degrees from the back in line with the major fissure to decrease the robotic arms from interfering with each other.
Incisions	■ The third arm port should be placed at least 12 cm from the spine. ■ Placing the assistant port more posteriorly provides a better stapler angle for right upper and middle lobectomies. ■ It is important to place the assistant port so that the bedside assistant is able to pass instruments without interference from the robotic arms.

Dissection	▪ The OR team must be familiar with emergency de-docking, and a sponge stick should be immediately available in case of bleeding. ▪ The dual console is useful when working with residents and allows both surgeons to switch instruments as needed. Pressing the camera pedal stops all arms from moving, increasing safety. ▪ Careful identification and exposure of hilar structures are essential prior to division. ▪ The lobar bronchus should be test clamped prior to division and the ipsilateral lung gently inflated to confirm that the remaining airway is patent. ▪ The bronchial stump should be tested for an air leak following division. ▪ The hilar structures should be examined to ensure there is no torsion of the remaining lung, particularly the right middle lobe after an upper lobectomy.
Closure	▪ Placing chest tubes to water seal may result in quicker resolution of air leaks as long as the lung is well expanded on CXR.

POSTOPERATIVE CARE

- A CXR should be obtained immediately following the procedure.
- The chest tubes should be placed to water seal unless the lung is not fully inflated on suction. Chest tubes may be removed on postoperative day 2 or once any air leaks have resolved and drainage has decreased to less than 100 mL per shift.
- Patients should be given an adequate pain control regimen and encouraged to ambulate and use the incentive spirometer.

OUTCOMES

- Robotic technology continues to evolve and provides the advantage of three-dimensional visualization and wristed instruments with seven degrees of freedom. However, it is also important to recognize the limitations of the technology with the lack of tactile feedback and the need for an experienced bedside assistant.
- The surgeon must assess his or her comfort level and skill as he or she gains experience with the robotic simulator and performing simpler procedures such as robotic resection of a mediastinal mass prior to attempting more advanced cases, such as a robotic lobectomy. In several series, the number of robotic lobectomies felt to be needed before the surgeon and nursing teams were considered proficient was at least 20 cases.[6–8]
- When comparing long-term oncologic outcomes in 325 patients undergoing robotic pulmonary resection, overall and stage-specific survival for early non–small cell lung cancer is comparable for robotic and thoracoscopic lobectomy.[9]
- Louie et al.[10] compared 53 robotic to 35 thoracoscopic pulmonary resections and found that the postoperative outcomes were similar with significantly shorter narcotic use and earlier return to normal activities.
- Although randomized trials are not available, results after robotic lobectomy appear to be comparable to VATS lobectomy, although the costs are currently higher. In the largest series published to date with 100 to 325 patients each, the median operating time ranged from 90 to 220 minutes. The conversion rate was 0% to 13%. The median length of stay was 3 to 5 days with a morbidity rate of 21% to 27% and 30-day mortality of 0% to 3%.[6,7,9,11,12]
- Robotic lobectomy can be performed safely by experienced thoracic surgeons. However, larger series and more widespread use and experience will be required before definitive conclusions can be made regarding any benefits of robotic lobectomy in terms of length of stay or postoperative pain.

COMPLICATIONS

- Prolonged air leak
- Bleeding
- Infection
- Atrial fibrillation
- Pneumonia
- Phrenic or recurrent laryngeal nerve injury
- Myocardial infarction
- Bronchopleural fistula
- Right middle lobe torsion

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Chapter 8

Pneumonectomy: Open

Christopher R. Morse Cameron T. Stock

DEFINITION

- Pneumonectomy is the complete removal of a lung. A pneumonectomy is most often performed for bronchogenic carcinomas that are central and unable to be removed via a lesser (lobectomy, segmentectomy) resection.

PATIENT HISTORY AND PHYSICAL FINDINGS

- A thorough history should be obtained on all patients presenting with a new lung mass. Patients may have symptoms of dyspnea, cough, hemoptysis, or weight loss. Some patients, however, may present with a mass or hilar fullness discovered incidentally on routine chest x-ray.
- The history should focus on signs and symptoms of local or distant metastases. Patients should be asked about recent onset of headaches or other neurologic symptoms, which should arouse suspicion for distant metastases. Patients should also be questioned about new chest wall or back pain, suggesting local tumor invasion or distant bony metastases.
- It is essential to establish the patient's functional status prior to pneumonectomy. There are several scales that can be used to quantify a patient's performance status including the Zubrod and Karnofsky scales. Poor functional status is a contraindication to pneumonectomy. Age is not a contraindication to pneumonectomy; however, older patients must be carefully selected as increasing age has been associated with increased postoperative complications. Patients should also be asked about significant cardiac history and other medical comorbidities.
- A history of smoking or significant exposure to secondhand smoke should be noted in the patient's history or significant environmental exposures such as to silicon, asbestos, or radon. Active smokers are often not considered operative candidates.
- On physical exam, auscultation of the lungs revealing diminished breath sounds suggests a near obstructing lesion or a significant pleural effusion. Findings of Horner's syndrome suggest involvement of the sympathetic ganglion. Hoarseness can indicate invasion of the recurrent laryngeal nerve (RLN). Evaluation of the supraclavicular and cervical lymph nodes (LNs) should be performed with enlarged nodes suggesting metastatic disease.

IMAGING AND OTHER DIAGNOSTIC STUDIES

- Routine chest x-rays may reveal a hilar mass or hilar fullness. Chest x-rays are limited, however, they may show lobar collapse, pleural effusions suspicious for a malignant effusion, or elevation of the diaphragm suggesting phrenic nerve involvement.
- A computed tomography (CT) scan of the chest should be obtained for all patients being evaluated for possible pneumonectomy (**FIG 1**). If available, prior CT scans should be used for comparison. A CT scan of the chest can be used to assess staging of the primary lesion, degree of local chest wall, or mediastinal invasion. The presence of hilar or mediastinal lymphadenopathy should be noted. CT may understage mediastinal LN by missing LNs positive for metastatic disease that are not enlarged or greater than 1 cm. Therefore, a CT chest alone is not sufficient for preoperative staging.
- Positron emission tomography (PET)/CT should be performed to confirm metabolic activity in the primary lesion, to assess for distant metastases, and to increase the ability to detect nodal involvement. PET/CT has a high false-positive rate; therefore, suspicious lesions on PET should be confirmed with a tissue diagnosis.
- Magnetic resonance imaging (MRI) of the brain is used to assess for distant metastases that are not able to be imaged on PET/CT and should be obtained for all patients with central lesions.
- Pulmonary function tests (PFTs) are necessary to define the patient's ability to tolerate a pneumonectomy. In general, postoperative calculated forced expiratory volume (FEV_1) of less than 40% predicted or a diffusing capacity of the lung for carbon monoxide (DL_{CO}) less than 40% predicted are significant predictors of morbidity and mortality following pneumonectomy and should be used to guide candidate selection.
- In patients with marginal PFTs, a ventilation-perfusion (V/Q) scan should be obtained. Patients with large proximal tumors compromising lung function may have compensated through shunting and therefore may better tolerate a pneumonectomy than would be predicted based on their preoperative PFTs. Other cardiopulmonary testing such as maximum oxygen consumption (VO_{2max}) can be used to evaluate patients who are marginal candidates for resection.

FIG 1 ● CT scan of chest demonstrating a right hilar mass causing partial lobar collapse of the right upper lobe.

Patients with a Vo_{2max} less than 15 mL/kg/min and a postoperative predicted FEV_1 and DL_{CO} less than 40% are at high risk for postoperative complications.[1]

- A cardiac workup including an electrocardiogram (EKG) and an echocardiogram and stress test in patients with significant risk factors for coronary artery disease should be performed. Patients with signs of right heart failure or pulmonary hypertension are at high risk for mortality postoperatively.
- Routine lab work including liver function tests and alkaline phosphatase should be obtained.
- A tissue diagnosis of the primary lesion is helpful in the preoperative planning and staging for a lung resection. Patients with small cell lung cancer lesions are not candidates for pneumonectomy. Due to proximity to hilar structures, a CT-guided fine needle aspiration (FNA) may be technically challenging. When tumors are intraluminal and visible on flexible bronchoscopy, biopsies can easily be obtained. Other modalities such as endobronchial ultrasound (EBUS) FNA or navigational bronchoscopy can be used to biopsy a hilar mass if not visible on flexible bronchoscopy.
- Mediastinoscopy and LN biopsy should be performed on all patients considered for pneumonectomy. Patients with enlarged mediastinal LN on CT or have increased metabolic activity on PET/CT have a high likelihood of having mediastinal LN metastases. Mediastinal LN involvement (N2 disease) may lead to neoadjuvant chemoradiotherapy.

SURGICAL MANAGEMENT

Preoperative Planning

- Active smokers should be counseled to quit smoking weeks in advance, as smoking has been found to be an independent risk factor for adverse outcomes.[2]
- A thoracic epidural catheter should be placed prior to surgery unless there is a contraindication.
- Prior to surgery, all patients should undergo flexible bronchoscopy by the operating surgeon to assess resectability. On flexible bronchoscopy, the location of the tumor with respect to the trachea and main bronchus should be assessed (**FIG 2**). Copious respiratory secretions may warrant a course of antibiotics to treat pneumonia prior to pneumonectomy.
- CT chest images should be reviewed, and final planning for the procedure should occur.
- The patient should have an active type and screen and have blood available in the blood bank, and antibiotics should be administered prior to skin incision.
- An arterial line should be placed prior to incision.
- Communication between the surgeon and anesthesiologist is critical. Excessive intravenous (IV) fluid administration in the perioperative period (particularly intraoperative and postoperative) is associated with acute lung injury in patients undergoing pneumonectomy.
- High tidal volumes during single-lung ventilation have been linked to increased rates of respiratory failure postoperatively. Low tidal volume ventilation (5 to 6 mL/kg) to prevent barotrauma is preferred with peak inspiratory pressures not to exceed 35 cm H_2O and plateau pressures to remain below 25 cm H_2O.[3]

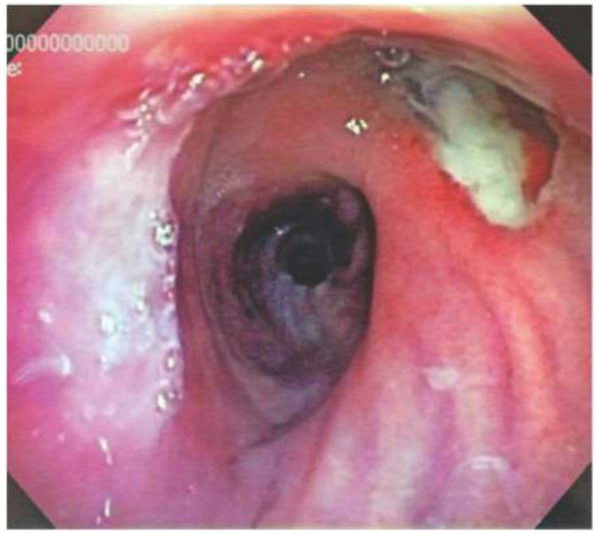

FIG 2 • Preoperative flexible bronchoscopy demonstrating an adenocarcinoma involving the right upper lobe bronchus.

Positioning

- Patients are intubated with a double lumen tube and positioned in the lateral decubitus position with the surgery side up. Rolled blankets or a "beanbag" are used to hold the patient upright. An arm board or ether screen can be used to support the arms. All pressure points should be well padded with particular attention paid to the common peroneal nerve. An axillary roll may be used to support the axilla. The bed is flexed and the patient should be secured to the bed with heavy tape and a belt (**FIG 3**).

FIG 3 • Patient positioned in the left lateral decubitus position for a right pneumonectomy.

RIGHT PNEUMONECTOMY

Posterolateral Thoracotomy

- A standard posterolateral thoracotomy incision is made 1 to 2 cm below the scapula. The latissimus dorsi muscle is divided. The serratus is mobilized along its posterior border and retracted anteriorly. The 4th intercostal space is entered on top of the 5th rib. If an intercostal muscle flap will be used to cover the bronchial stump, it should be created during the entry into the pleural space. The 5th rib is shingled by dividing it at the border of the paraspinous muscles and removing a small segment. A chest retractor is placed in the rib space and the lung hilum is exposed.

Assessment of Resectability

- The visceral and mediastinal pleura are examined initially for signs of pleural spread. The right lower lobe is grasped and retracted cephalad and the inferior pulmonary ligament is divided with cautery. Level 9 LNs are excised during this step or are swept into the specimen. Assessment of the lung hilum is performed by identifying the phrenic nerve and dividing the mediastinal pleura lateral to the nerve (**FIG 4**). The landmarks for dissection are the inferior border of the azygous vein to the inferior pulmonary vein. The lung is retracted caudally and medially, and dissection of the mediastinal pleura is carried over the superior aspect of the hilum and posterior to the bronchus. Care is taken to separate the right main bronchus from the esophagus. Resection of the subcarinal LN packet can be performed at this time. The tumor should be readily palpated at this point, and the degree of vascular invasion as well as invasion of surrounding structures should be assessed. The need for pneumonectomy should be reassessed and consideration should be given to a lesser pulmonary resection if oncologically feasible. Tumor that extends onto the pulmonary artery or the pulmonary veins and cannot be safely taken with a stapler may require an intrapericardial ligation of the vascular structure. This should be determined at this time.

Division of Pulmonary Veins

- There is no specific order to the division of the lung hilar structures, and division of the vascular structures may proceed according to which are most convenient for division. With the mediastinal pleura open and the inferior pulmonary ligament divided, the inferior and superior pulmonary veins are readily visualized. The lung is retracted cephalad and laterally, exposing the inferior pulmonary vein. Careful blunt dissection is used to dissect the inferior vein from the mediastinum. Prior to division of the veins, they should be reassessed for tumor involvement. Division of the vein is most commonly accomplished using a vascular stapler. The superior pulmonary vein is exposed by lateral retraction of the lung. The superior vein lies in close proximity to the pulmonary artery and this must be accounted for during dissection of the posterior aspect of the vein. Once the vein is completely dissected and able to be encircled, it is divided with a vascular stapler (**FIG 5**). If either the superior or inferior veins are invaded by the tumor, the pericardium can be entered and an additional 1 to 2 cm of vein can be exposed.

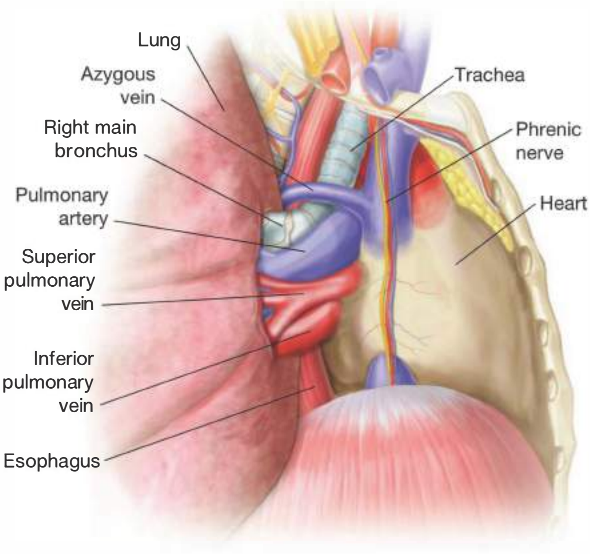

FIG 4 ● Right pneumonectomy. Exposure of the right hilar structures. Initial dissection of the right hilum proceeds with division of the mediastinal pleura lateral to the phrenic nerve.

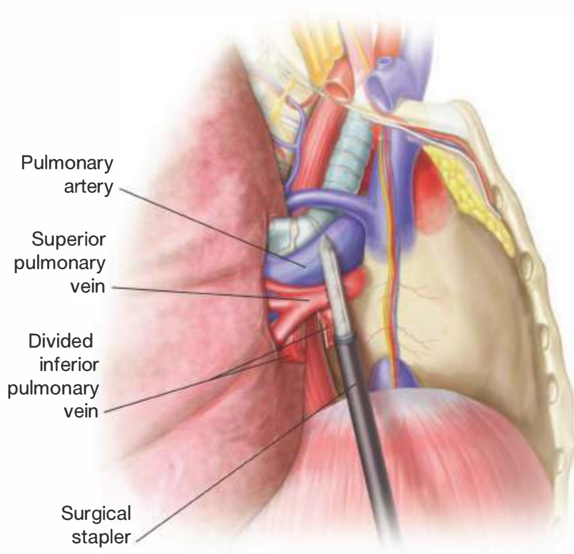

FIG 5 ● Right pneumonectomy. Division of the superior pulmonary vein is performed using a vascular stapler. The inferior pulmonary vein has already been divided.

Division of Pulmonary Artery

- With the mediastinal pleura divided and the lung retracted laterally, the pulmonary artery is visible cephalad and posterior to the superior pulmonary vein. The artery should be assessed for tumor invasion by palpation after it is carefully dissected. The pulmonary artery must be handled carefully during dissection as it is relatively thin walled compared to the pulmonary veins and can tear easily resulting in potentially catastrophic hemorrhage. Therefore, all dissection should be blunt around the artery and cautery should be used sparingly if at all. In patients who are borderline candidates for resection, that is, those who have elevated pulmonary arterial pressures, we prefer to dissect the pulmonary artery first and perform a test clamp of the artery prior to division of any hilar structure. If the patient has significant negative hemodynamic changes with the test clamp, the procedure is aborted. In our institution, we typically use a vascular stapler to divide the artery (**FIG 6**); however, some surgeons prefer to clamp the artery with a vascular clamp and oversew the artery with a nonabsorbable suture after it has been divided. As with the pulmonary veins, if the tumor invades or is adherent to the artery and it is unclear if a margin can be obtained on the vessel, the pericardium can be entered away from the tumor to provide an extra 1 to 2 cm of length to safely divide the artery.

Division of Bronchus

- The lung is retracted medially to reveal the membranous trachea (**FIG 7**). From the right side, the carina is visible after excision of the subcarinal LNs. When preparing to divide the bronchus, it must be remembered to minimize proximal dissection on the trachea and to divide the bronchus as close to the carina as possible. This serves to preserve the blood supply to the bronchial stump and prevents the pooling of secretions leading to stump breakdown and bronchopleural fistula formation. In our institution, we typically divide the bronchus using a thick tissue surgical stapler. Alternately, the bronchus may be divided sharply and the trachea closed with a series of interrupted 4-0 absorbable sutures (**FIG 8**). The right

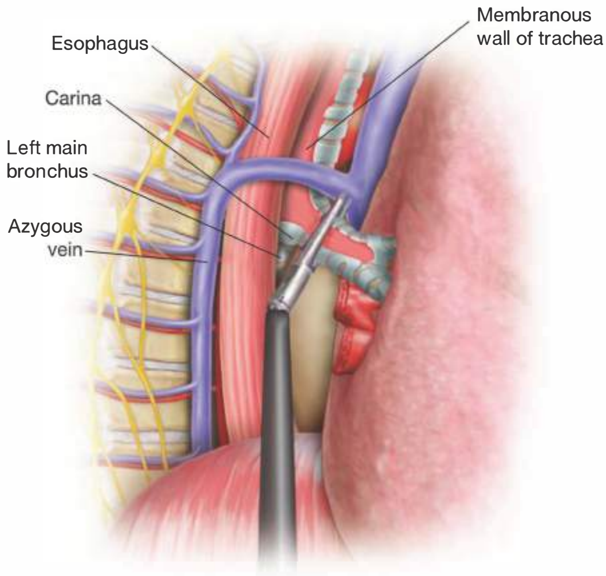

FIG 7 • Right pneumonectomy. Division of the right main bronchus. The lung is retracted medially and the membranous trachea is exposed. A thick tissue stapler is used to divide the bronchus as close to the carina as possible.

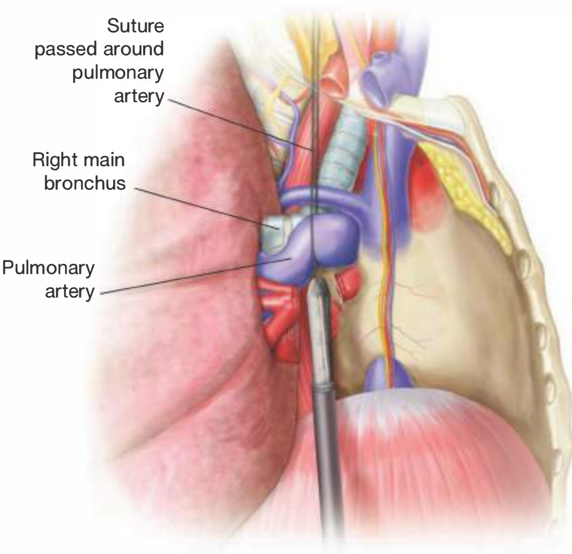

FIG 6 • Right pneumonectomy. The pulmonary artery is carefully dissected and encircled with a tie. After palpating the artery for involvement with tumor, it is divided using a vascular stapler.

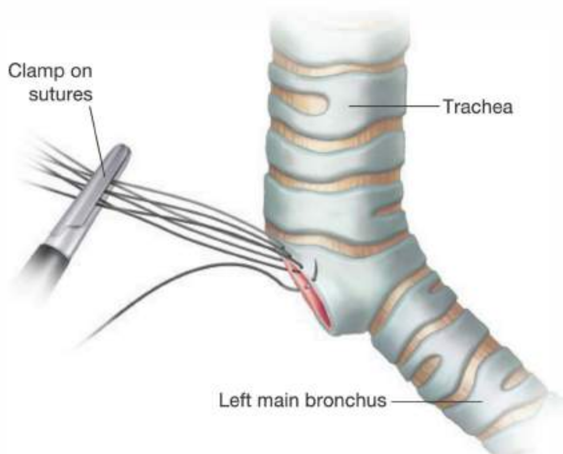

FIG 8 • Right pneumonectomy. Suture closure of the right bronchus. The bronchial stump may be alternatively closed with a series of interrupted 4-0 absorbable sutures.

bronchial stump is at high risk for stump breakdown and fistula formation. This is thought to be due to the lack of soft tissue coverage on the right side as compared to the left. In our institution, we cover all bronchial stumps with vascularized tissue. Due to its robust vascular supply, we prefer to use an intercostal muscle flap, although others have described using pericardial fat, parietal pleura, or pericardium to cover the bronchial stump. The pleural cavity should be filled with warm saline and the stump tested for a leak under water at pressures of 20 to 25 cm H_2O.

LEFT PNEUMONECTOMY

Exposure and Assessment of Resectability

- The exposure and dissection for a left pneumonectomy proceeds in a similar sequence as for a right pneumonectomy. The patient is placed in the right lateral decubitus position and a standard left thoracotomy is performed. During dissection, consideration must be made for the course of the left RLN. On the left side, the RLN passes around the arch of the aorta from anterior to posterior (**FIG 9**). When mobilizing the hilum or removing the aortopulmonary window LNs, care must be made to avoid injury to the nerve. During the initial assessment, it should be noted if there is invasion of the nerve by the tumor. The mediastinal pleura is divided lateral to the phrenic nerve and the inferior pulmonary ligament is divided. The hilum is exposed and the tumor should be assessed for resectability by palpating the hilar structures.

Division of Pulmonary Veins

- With the mediastinal pleura divided, the lung is retracted laterally. The pulmonary veins are identified and, after careful blunt dissection, are divided using a vascular stapler.

Division of Pulmonary Artery

- The pulmonary artery is visualized cephalad to the superior pulmonary vein. It is divided using a vascular stapler after careful blunt dissection.

Division of Bronchus

- The left main bronchus is longer than the right bronchus, and exposure of the carina is often challenging due to the presence of the heart on the left side. However, the same principles are applied to dividing the left bronchus as to the right. Proximal dissection is minimized to preserve blood flow to the bronchial stump. The bronchus is divided as close as possible to the carina using a thick tissue stapler. The stump should be covered with well-vascularized tissue to facilitate healing. The pleural cavity should be filled with warm saline and the stump tested for a leak under water at pressures of 20 to 25 cm H_2O.

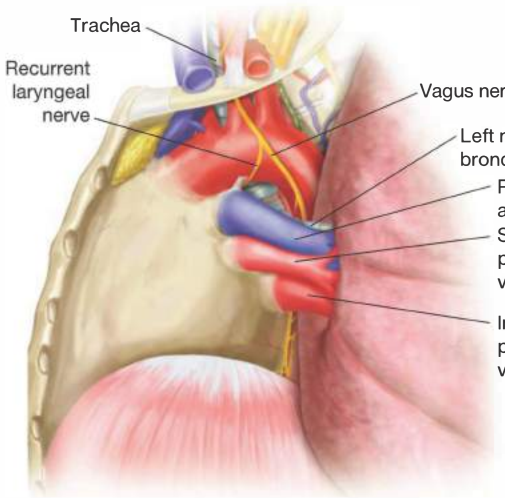

FIG 9 ● Left pneumonectomy. Division of the mediastinal pleura exposes the left hilum. Care should be exercised to avoid injuring the left RLN during dissection of the hilum.

PEARLS AND PITFALLS

Patient selection	▪ Pneumonectomy is associated with a high rate of postoperative morbidity. ▪ Consideration should be given to a lesser pulmonary resection if oncologically feasible. ▪ There is no one test to determine if a patient is able to tolerate a pneumonectomy but is a clinical decision based on a patient's performance status and PFTs.
Intraoperative management	▪ IV fluid should be restricted intraoperatively. ▪ Test clamp the pulmonary artery prior to division. ▪ Low tidal volume ventilation should be used when the patient is intubated. ▪ Early extubation should be the goal for all patients.
Bronchial stump closure	▪ Bronchial stump should be flush with the carina. ▪ All bronchial stumps should be reinforced with pedicled soft tissue coverage. ▪ The bronchial stump should be tested under water for leaks after it is divided at a pressure of 20 to 25 cm H_2O. ▪ The right bronchial stump is at increased risk for breakdown compared to the left side.

Avoidance of RLN damage	■ During dissection of the left hilum need to be alert to the presence of the RLN at the arch of the aorta.
Management of the postpneumonectomy space	■ If a chest tube is inserted into the postpneumonectomy space, it should be placed on water seal and removed within the first 48 hours.
Postoperative management	■ Patients should be fluid restricted for the first 48 hours with IV fluids titrated to urine output. ■ Aggressive pulmonary toilet should be performed and a low threshold for bronchoscopy should be maintained for clearance of respiratory secretions.

POSTOPERATIVE CARE

- Patients should be extubated, if possible, in the operating room and transferred to an intensive care unit immediately postoperative.
- If a chest tube is inserted into the pneumonectomy space, it should be placed on water seal and removed within 48 hours. Suction applied to a chest tube may induce a mediastinal shift into the postpneumonectomy space causing significant hemodynamic changes.
- Daily chest x-rays should be obtained with attention paid to the level of pleural fluid on the pneumonectomy side and the position of the mediastinum. By 2 weeks, the postpneumonectomy space should be 80% to 90% filled with pleural fluid and complete opacification should occur by 4 weeks postoperatively.
- Patients should be fluid restricted over the first 24 to 48 hours postoperative, and IV fluids should be judiciously adjusted to maintain adequate renal function as acute lung injury is associated with patients who receive more than 3 L of crystalloid in the first 24 hours.[4] Diuretics should be administered to patients demonstrating signs of fluid overload or respiratory distress.
- Pneumonectomy patients need aggressive pulmonary toilet and should ambulate within 48 hours of surgery. Physical therapy should be involved early in the postoperative course of debilitated patients.
- A low threshold to perform bronchoscopy for pulmonary toilet should be maintained for those patients who are unable to generate a cough, clear their respiratory secretions, or have a change in respiratory status.

OUTCOMES

- In general, a pneumonectomy is well tolerated among carefully selected patients. However, pneumonectomy is a procedure associated with significant postoperative morbidity and mortality. Rates of major postoperative adverse events vary depending on the series but ranges from 30% to 59%.[5] Pneumonectomy is generally associated with a mortality of 4% to 8%.
- Right-sided pneumonectomies are associated with higher rates of postoperative morbidity and mortality. This is thought to be due to an increased incidence of bronchopleural fistulas in this patient population.[6]
- Increasing age has a negative effect on outcome, with patients older than 65 years having a significantly higher risk of having an adverse event than younger patients.

COMPLICATIONS

- Respiratory failure
- Pulmonary edema/acute respiratory distress syndrome (ARDS)
- Pneumonia
- Atelectasis
- Chylothorax
- Postpneumonectomy syndrome
- Bronchopleural fistula
- Empyema
- Arrhythmias: most commonly supraventricular arrhythmias
- Myocardial infarction
- Wound infection
- Deep vein thrombosis/pulmonary embolism
- Vocal cord paralysis

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Chapter 9

Thymectomy

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DEFINITION

- Thymectomy is defined as resection of the thymus gland.
- The most common indications for thymectomy are myasthenia gravis and thymoma. Less common indications for thymectomy include thymic carcinoma, neuroendocrine tumors of the thymus, ectopic parathyroid glands, and thymic cysts.
- Thymectomy has been most commonly performed through a median sternotomy, as described by Alfred Blalock. Alternate approaches include video-assisted thoracoscopic surgery (VATS), robotic-assisted thoracoscopic surgery (RATS), and transcervical approach.[1]

DIFFERENTIAL DIAGNOSIS

- Differential diagnosis of anterior mediastinal mass includes thymoma, thymic carcinoma, lymphoma, and germ cell tumor.
- Thymomas have cytologic features of malignancy in less than 10% of cases. However, thymomas lacking malignant features cytologically can express malignant behavior by recurring locally and metastasizing even after resection; thus, the term "benign" thymoma should not be used.[2]
- The most widely accepted and clinically applicable staging system for thymoma is the Masaoka staging system, which is based on microscopic or macroscopic invasion into mediastinal structures.[3]

PATIENT HISTORY AND PHYSICAL FINDINGS

- One-third of patients with thymoma are asymptomatic.
- Among patients symptomatic from thymoma, about 40% present with local symptoms directly related to the mass itself, including chest pain, cough, and dyspnea, but can include superior vena cava syndrome.[2]
- The parathymic syndrome most commonly associated with thymoma is myasthenia gravis, which occurs in approximately 45% of patients with thymoma (reported ranges from 10% to 67%). Other associated autoimmune conditions include pure red cell aplasia and hypogammaglobulinemia, which can occur in up to 5% of people with thymoma.[2]
- Approximately 10% to 15% of patients with myasthenia gravis have a thymoma.
- Fevers, night sweats, and other constitutional symptoms may indicate lymphoma rather than thymoma.

IMAGING AND OTHER DIAGNOSTIC STUDIES

- Computerized tomography is the most useful imaging modality for thymoma. Thin-slice cuts will improve preoperative planning.
- Thymomas can have variable uptake on positron emission tomography, so it is not routinely recommended. Magnetic resonance imaging can also provide helpful information about invasion into vessels or adjacent structures (**FIG 1**).[4]
- Masses larger than 5 cm (not including thymus gland itself) in maximal diameter or those invading mediastinal structures either warrant specialized surgical planning or possibly enrollment into a neoadjuvant treatment protocol.[5]
- Fine needle aspiration or core biopsy of the anterior mediastinal mass is recommended preoperatively in most cases to rule out lymphoma or germ cell tumor. If the biopsy is consistent with thymoma, resection of the entire thymic gland is indicated.[4]
- Myasthenia gravis can be diagnosed with serum testing for the acetylcholine receptor antibody or through clinical improvement in symptoms with administration of edrophonium chloride.

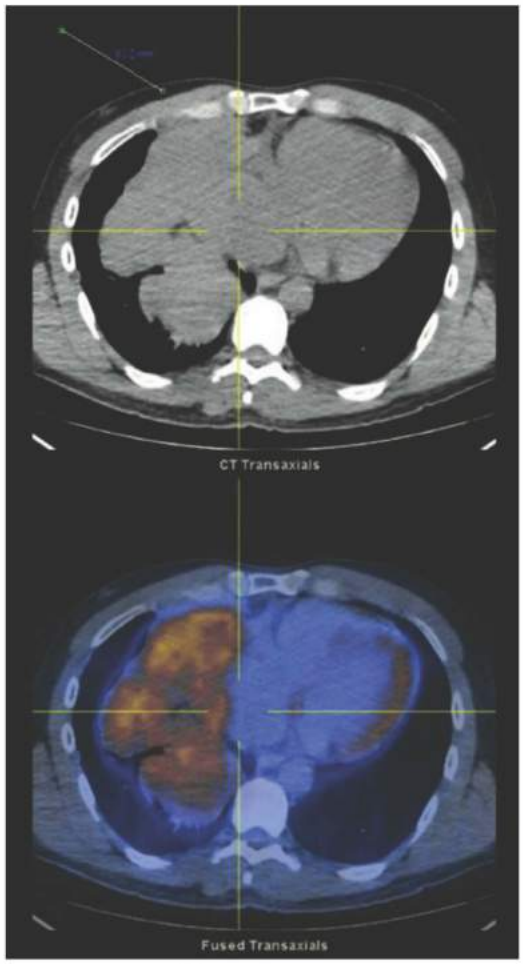

FIG 1 • Positron emission tomography (PET) scan. Standard uptake value (SUV) of 6.5 in biopsy-proven thymoma measuring 14 cm × 8.3 cm in 38-year-old male.

SURGICAL MANAGEMENT

Preoperative Planning

- The decision to perform thymectomy for treatment of myasthenia gravis must involve the patient, the treating neurologist, the anesthesiologist, and the thoracic surgeon. Preoperative optimization of the patient's myasthenia gravis symptoms with pyridostigmine, steroids, and in some cases, plasmapheresis is critical.
- Special anesthetic requirements may be necessary for patients with myasthenia gravis, taking care to avoid anticholinergics. The anesthetic team should be notified preoperatively of the patient's medical condition and the severity of their symptoms in appropriate time to make accommodations.[6]
- All patients who will undergo single-lung ventilation (VATS or RATS) should have preoperative pulmonary function testing to ensure they will be able to tolerate single-lung ventilation during resection. If the patient is deemed unable to tolerate single-lung ventilation, resection via sternotomy or transcervical approach is indicated. All patients with myasthenia gravis need pulmonary function testing preoperatively.
- Central venous access should be obtained prior to beginning procedure.
- A sternal saw should always be present in the operating suite and readily available in the event emergent conversion to sternotomy for bleeding is necessary.

Positioning

- For median sternotomy or transcervical approach, a single lumen endotracheal tube is adequate.
- For VATS or robotic-assisted thoracoscopic approach, we strongly prefer the use of double lumen endotracheal tube placement to single lumen endotracheal tube with bronchial blockers. If the patient needs to be repositioned intraoperatively, we feel that the double lumen endotracheal tube is much less likely to be dislodged than a bronchial blocker and provides more reliable lung isolation.
- We confirm the placement of the double lumen endotracheal tube with bronchoscopy before positioning the patient.
- Each time the patient is repositioned, proper placement of the double lumen endotracheal tube is confirmed with bronchoscopy.

TECHNIQUES

THYMECTOMY BY STERNOTOMY

Positioning

- Place patient in supine position.
- We prefer arms tucked at the patient's side and use an axillary roll placed laterally under the scapulae.
- Use clippers to remove hair from sternal notch to below xiphoid process. Prep and drape skin in sterile fashion from the sternal notch to below xiphoid process.

Boundaries of Dissection

- The boundaries of dissection for radical thymectomy are the innominate veins superiorly, the phrenic nerves bilaterally, and the diaphragm inferiorly (**FIG 2**).
- Preservation of the phrenic nerve is of the upmost importance and it should never be sacrificed unless the diagnosis of thymic carcinoma is confirmed and tumor grossly invades the nerve. Even in these cases, the surgeon must consider the implications of diaphragmatic paralysis on a patient who may need adjuvant chemotherapy and radiation. Both phrenic nerves should never be divided.[1]
- With invasive thymoma, involved structures should be resected en bloc with the thymic mass at the time of initial operation, always sparing at least one phrenic nerve.[7]
- Mark areas of dissection for invasive thymoma with surgical clips to help direct future radiation therapy.[7]

Median Sternotomy Incision

- Partial or "mini-sternotomy" can be used as long as entirety of thymus tissue can accessed and phrenic nerves visualized bilaterally. Visualization must not be sacrificed for cosmesis (**FIG 3**).[7]
- Incise skin from 1.5 cm below the sternal notch to level of 4th or 5th intercostal space for partial sternotomy or to xiphoid process for full sternotomy.
- Use a sternal saw to separate the sternum down the midline.
- Mind adhesions that could be present from the underlying thymoma itself or from previous sternotomy.

Right Inferior Pole Dissection

- The order of dissection with regard to thymectomy by sternotomy is surgeon preference, with regard to starting on the right or left or from the superior or inferior. We choose to start at the right inferior pole for both open and minimally invasive approaches.
- The right phrenic nerve is identified.
- The right inferior pole is identified and dissected from the pericardial fat pad, dividing attachments to non-thymic tissue.
- Arterial blood supply to the inferior pole is from the pericardiophrenic branches. These small vessels are well suited for ligation with a bipolar energy source such as LigaSure (Covidien, Mansfield, Massachusets) or an ultrasonic vessel-sealing device such as the Harmonic Ace (Ethicon Endo-Surgery, Blue Ash, Ohio). These devices are also useful for dividing the mediastinal pleura and connecting tissue.
- The mediastinal pleura is incised 1 cm medial to the right phrenic nerve and division is carried cranially along the lateral aspect of the thymus toward the superior pole. Be mindful of lateral energy transfer from electrocautery or bipolar energy source that could damage the phrenic nerve.
- The major arterial blood supply to the thymus is lateral, from branches of the internal mammary artery. These vessels can be tied, clipped, or divided with advanced vessel-sealing devices as mentioned earlier.

Right Superior Pole Dissection

- Continue dissection of the mediastinal pleura cranially toward the right superior pole.

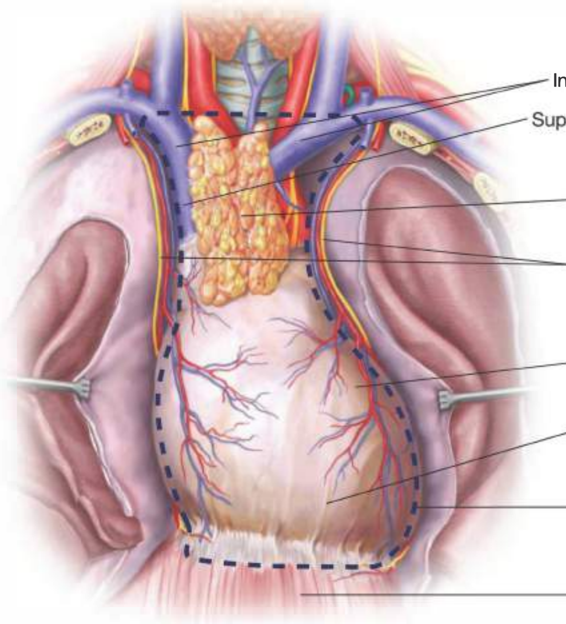

FIG 2 ● Boundaries of dissection for radical thymectomy. Innominate veins superiorly, phrenic nerves laterally, and diaphragm inferiorly. Sternum is anterior to the thymus and the pericardium is posterior to the thymus.

- Gently use the divided thymic tissue as a handle for downward retraction to expose the right superior pole.
- The arterial blood supply to the superior pole branches off the inferior thyroid artery. These vessels can be divided between ties or clips or using advanced vessel-sealing devices.
- Divide the right thyrothymic ligament between clamps or using an advanced vessel-sealing device. Once vessels or tissue attached to the superior pole are divided, they can retract cranially, making gaining control of bleeding difficult.
- Occasionally, a vein draining into the right innominate vein may be encountered. Divide it if present.

Left Inferior Pole Dissection

- Redirect attention to the right inferior pole. Divide the mediastinal pleura from the right lateral pole to the left lateral pole just above the level of the diaphragm, taking care to include all inferior thymic tissue with the thymus.
- Identify the left phrenic nerve and avoid damage to it when dividing laterally across the inferior aspect of the thymic tissue.
- Dissect the left inferior pole away from the pericardial fat pad and divide the left inferior pole from its attachments.
- Incise the mediastinal pleura 1 cm medially from the left phrenic nerve and continue division cranially.
- Divide the left lateral branches of the internal mammary artery.

Left Superior Pole Dissection

- Gently use divided thymic tissue for downward retraction.
- Proceed with division of lateral attachments of thymic tissue toward the left superior pole. Divide remaining attachments of the left superior pole, including branches of the left inferior thyroid artery supplying it.
- There are usually one or two veins that drain the thymus. These are most often encountered at the left superior pole, emptying from the thymus into the left innominate vein. Uncontrolled division of these veins will result in significant hemorrhage, with the superior end of the vein retracting cranially, often out of view. We use a surgical clip or tie proximally and distally when dividing these veins. This vein can also be torn inadvertently with excessive downward retraction on the thymus.
- Small lymphatic branches entering the thoracic duct may be encountered and should be clipped if inadvertently divided. The appearance of chyle may signify division of lymphatic vessels.
- Divide any attachments, if present between left superior and right superior poles.
- Divide the posterior attachments of the thymus to the pericardium.

Specimen Removal

- Remove specimen.
- If thymoma is present, avoid disruption of the capsule.

Sternal Closure

- Place mediastinal drain. If the pleural spaces have not been violated, chest tubes are not necessary.
- Close sternum with sternal wires. Larger patients may benefit from contemporary sternal closure devices to prevent dehiscence, such as sternal plating or use of the Synthes ZipFix System (Synthes Incorporated, West Chester, Pennsylvania). Close overlying skin in preferred manner. We use skin adhesive over all incisions.

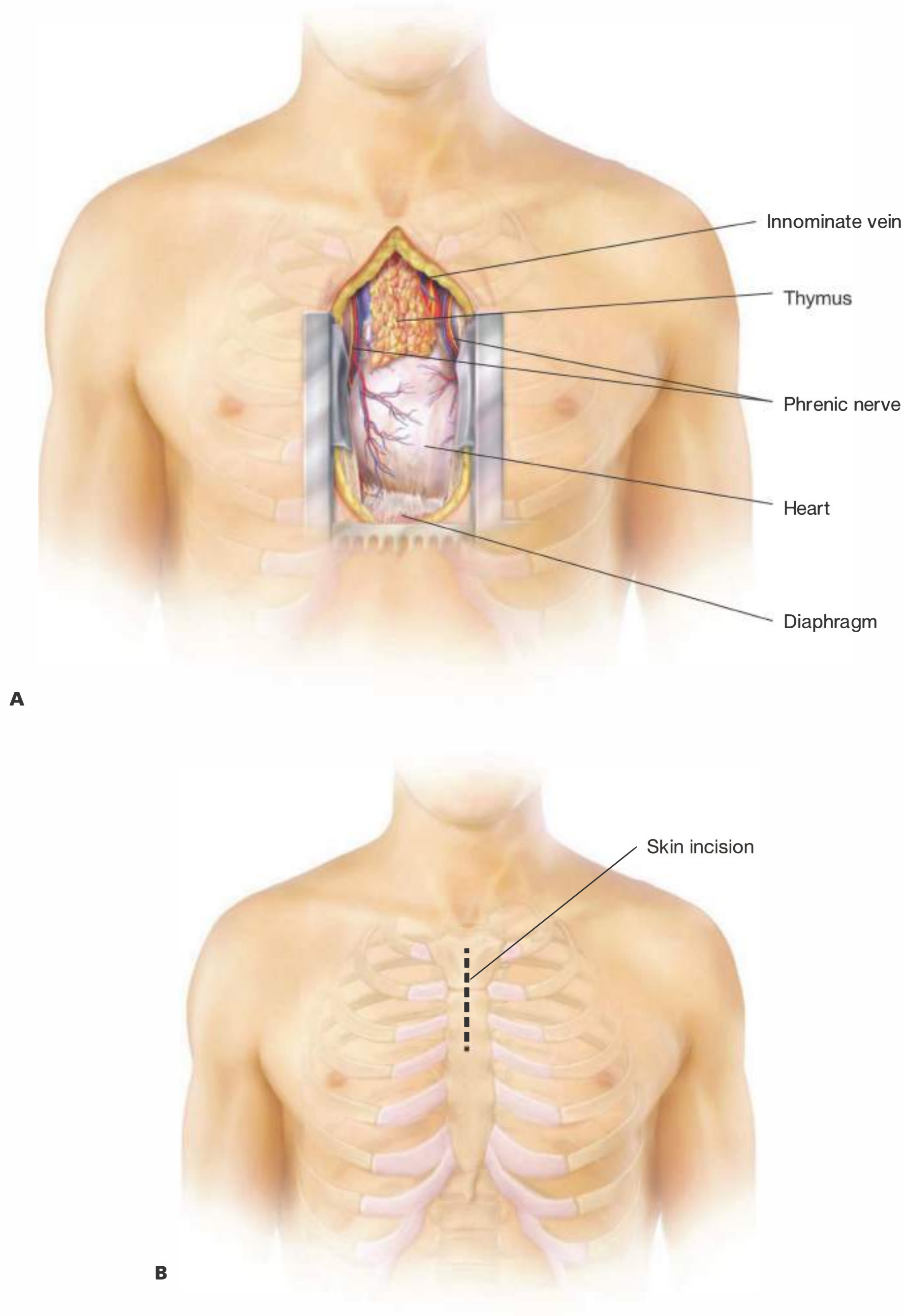

FIG 3 ● **A.** Traditional median sternotomy. **B.** Partial or "mini" sternotomy with incision extending to the level 4 or 5 intercostal space.

VIDEO-ASSISTED THORACOSCOPIC SURGERY THYMECTOMY

Positioning

- Because thymic tissue left behind at time of resection for thymoma or myasthenia gravis can be devastating, we advocate a bilateral approach to thymectomy for VATS and some selected robotic-assisted thymectomy to ensure that all thymic tissue is visualized and removed. When working from one side alone, we feel that the contralateral phrenic nerve cannot always be adequately visualized and is therefore risk of injury when trying to divide the lateral-most attachments. In those cases, a contra lateral VATS check is appropriate.
- For VATS or robotic-assisted approach, the right side should be approached first because of physical constraints from the heart on the left.
- For VATS thymectomy, position the patient in left lateral decubitus, on a beanbag and with an axillary roll in place.
- The patient's anterior superior iliac spine should be at a break in the bed, and the bed should be broken at the hips to at least 30 degrees. This opens the interspaces of the ribs to facilitate port insertion and allows the lung to fall away posteriorly.
- Place the right arm on a support brace over the left arm.
- Pad all pressure points.
- The monitors are placed on each side of the patient near the head. The surgeon and assistant stand on the posterior side of the patient.

Port Insertion

- For VATS approach, 5-mm thoracoscopic instruments can be used for throughout the case but one port site will need to be enlarged for specimen removal at the end of the case (**FIG 4A**).
- If needed, a 12-mm working port can be added on either side to insert a ring clamp for retracting the thymus downward.

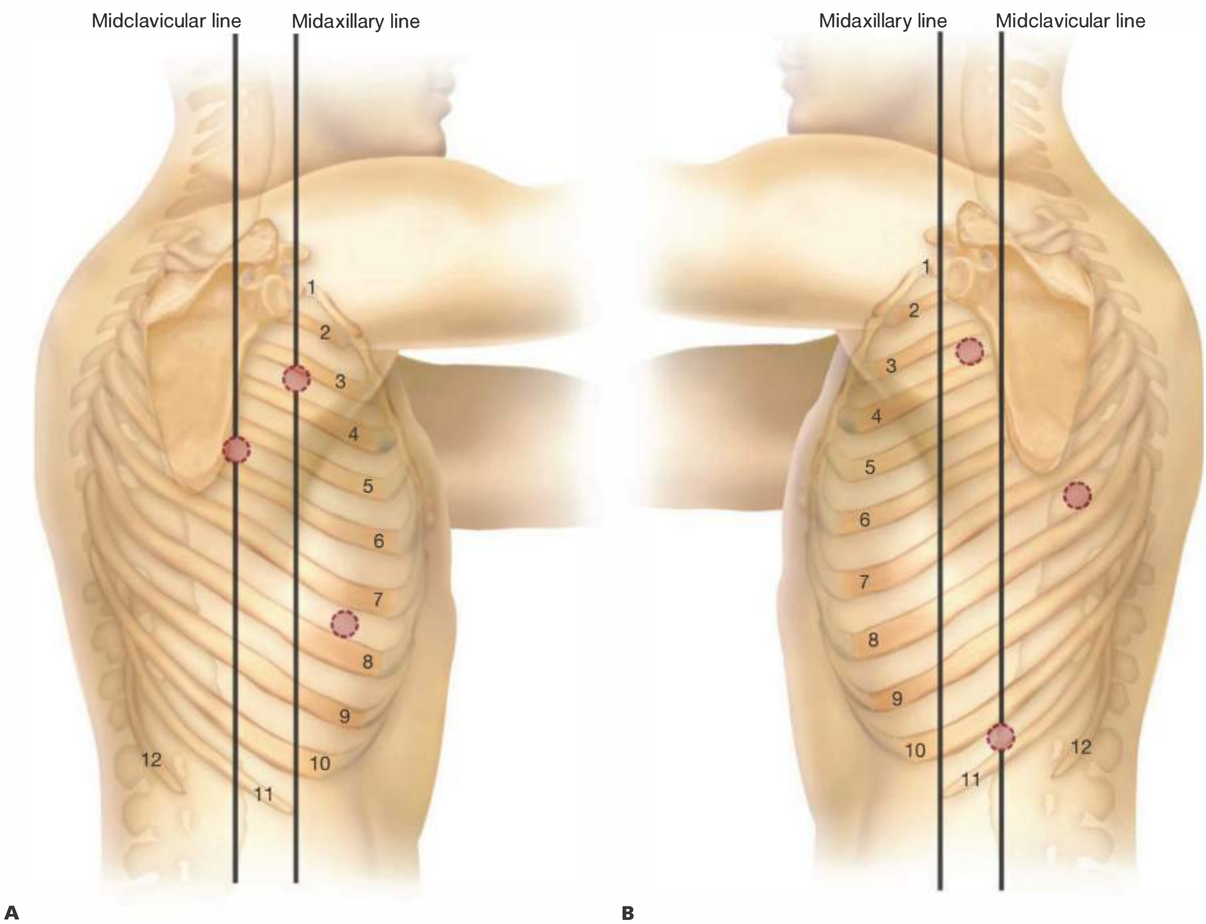

FIG 4 ● **A.** Port placement for right-sided dissection during VATS thymectomy. **B.** Port placement for left-sided dissection during VATS thymectomy.

- Always use protected ports during thymectomy for thymoma, as seeding of the thoracic wall from malignancy has been reported.
- Before inserting the first port, ask the anesthesiologist to stop ventilation to the lung on the side that you will be working on. Confirm adequate single-lung ventilation.
- If starting on the right side, insert the first port between at the 5th or 6th intercostal space along the posterior axillary line. Insert the thoracoscope and inspect the thoracic cavity for suspicious lesions or effusions signaling malignant disease. Biopsy any suspicious lesions and send any suspicious fluid to pathology (**FIG 4A**).
- Under direct intrathoracic visualization from the first thoracoscopic port, taking care to avoid any adhesions or adherent lung parenchyma, insert the second port at the 3rd or 4th intercostal space along the midaxillary or anterior axillary line. This will serve as the camera port for most of the dissection (**FIG 4A**).
- Similarly, insert the third thoracoscopic port at the 5th or 6th intercostal interspace along the anterior axillary line (**FIG 4A**).
- Port location can be varied according to surgeon preference, and additional ports should be used if visualization is not optimal.
- The left-sided ports will need to be placed slightly more posterior in comparison to the right-sided ports to account for the pericardium and heart (**FIG 4B**).
- Insufflation with 8 to 10 mmHg of carbon dioxide gas can facilitate dissection of the thymus away from the sternum anteriorly and pericardium posteriorly, but we do not routinely use insufflation in the thoracic cavity for thymectomy.
- We place bupivacaine or exparel (liposomal bupivacaine) intercostal nerve blocks to the port sites under direct visualization at the time of thoracoscopy, being especially generous around port site where the thoracostomy tube will exit.

Division of Right Inferior Pole

- Identify the right phrenic nerve.
- Proceed with division of right inferior pole from the pericardial fat pad using an advanced vessel-sealing device.
- Using electrocautery at low settings in cutting mode, the mediastinal pleura can be scored 1 cm medially from the right phrenic nerve. This can facilitate lateral dissection.

Division of Right Superior Pole

- Proceed cranially to the right superior pole as described previously using advanced vessel-sealing device to divide attachments.
- Divide right superior pole and right thyrothymic ligament.

Medial Dissection

- From the right side, proceed with dissection toward the patient's left side, dividing superior and inferior attachments of the thymus past midline.
- You will be able to accomplish most of the thymectomy from the right side. However, once it becomes difficult to see the leftmost aspect of the thymus and you cannot safely divide tissue without ensuring that left phrenic nerve is protected, stop dissection from the right side.
- Confirm hemostasis of previously divided tissue. An absorbable hemostatic agent such as Surgicel (Ethicon, Bridgewater, New Jersey) can be used at the superior pole for minor oozing.
- Place a small-bore chest tube on the right under direct visualization and ensure the right lung inflates adequately as positive pressure is administered by the anesthesiologist.
- Remove the other ports and confirm hemostasis from port sites. Close intercostal muscles in one layer with interrupted absorbable sutures and close overlying skin in preferred manner.

Repositioning

- Reposition the patient in right lateral decubitus position with the bed flexed to 30 degrees at hips, using a beanbag and axillary roll as mentioned previously.
- For the left-sided approach, the ports are rotated slight posterior to account for the heart and pericardium. The surgeon and assistant again stand on the patient's posterior side.
- Insert thoracoscopic ports on the left in the same manner as on right.
- Inspect the left thoracic cavity.

Division of Left Inferior Pole

- Identify the left phrenic nerve.
- Dissect and divide left inferior pole and any remaining attachments medially.
- Divide right superior pole and right thyrothymic ligament.
- Score the mediastinal pleura 1 cm medially to the left phrenic nerve and proceed cranially with dissection and division.

Division of Left Superior Pole

- Dissect and divide the left superior pole and any remaining attachments medially.
- Use a laparoscopic clip applier to apply clips to the proximal and distal aspects of the vein or veins that drain from the thymus into the left innominate vein. Divide the vein between the clips using an energy source.

Specimen Removal and Closure

- Place the specimen in a specimen bag and remove through a protected port. For larger thymomas, a port site that will not be used as the chest tube site will need to be enlarged for specimen removal.
- Place a small-bore chest tube on left side and confirm inflation of left lung.
- Close intercostal muscles and overlying skin.

ROBOTIC-ASSISTED THYMECTOMY

Positioning

- Position the patient in the supine position with an axillary roll, or bump and to the right side of the bed.
- Arm maybe placed hanging within a padded towel off the right side of the bed. Tuck the arms at the patient's side.
- Prep skin from above sternal notch to below xiphoid process and to as far laterally as possible on both sides.
- Patients with large, pendulous breasts may require retraction of breast tissue medially using 4-in silk tape. Expose the entire inframammary crease bilaterally.
- The spine of the robot will be on the patient's left and the assistant on the patient's right.
- Place thoracoscopic/VATS tower above the patient's left shoulder.

Port Placement

- Discontinue ventilation to right lung.
- The first incision will be for a 5-mm port, and this will be 2 cm lateral to the midclavicular line at the 6th intercostal space. Through this port, insert a 5-mm thoracoscope. Inspect the thoracic cavity. The VATS thoracoscope will be used to confirm safe placement of subsequent ports.
- Place the next port 2 cm lateral to the midclavicular line at the 2nd intercostal space. This will accommodate one of the working arms of the robot. At this time, we use 8-mm metal trocars designed for the robot.
- Place the robotic camera port 4 cm lateral to the midclavicular line at the 4th intercostal space. This port should be 10 or 12 mm and will accommodate the 10-mm robotic camera head.
- Exchange the 5-mm thoracoscope to one of the other two port sites, and under visualization, replace the 5-mm port at the 6th intercostal space with an 8-mm trocar designed for the robotic arm. This trocar will accommodate the other working arm of the robot.

Docking the Robot

- Dock the robot at the table, with the robotic spine on the patient's left and the robotic arms on the patient's right.
- Using the 5-mm thoracoscope inserted through one of the 8-mm ports, insert the robotic camera into the 12-mm port site at the 4th intercostal space. The 30-degree robotic camera will start in the "up" configuration. This will be placed on arm number "2" of the robot.
- Insert the working arms of the port into the chest under direct visualization. We usually start with a robotic Cadiere dissector at the 2nd intercostal port site, which will be robot arm number "1." The Cadiere can be connected to bipolar energy if needed. A robotic LigaSure arm is inserted at the 6th intercostal port site, at robotic arm number "3." This arm configuration can be varied per surgeon preference.
- An assistant's port can be added wherever necessary for additional downward retraction. The assistant may insert a grasper or a ring clamp into the thoracic cavity to assist as needed.

Dissect the Right Inferior and Superior Poles

- Dissect the right inferior and superior poles in the same manner as described during the VATS approach.
- Divide lateral and medial attachments of the thymus.
- When complete, place a right-sided chest tube, confirm inflation of the lung, and remove the ports under direct visualization.
- Close overlying intercostal muscles and skin as desired.
- If the left phrenic nerve can be visualized from the right, or if right phrenic nerve can be visualized from the left if starting on the right, then the surgeon may be able to complete the thymectomy from one side. If both phrenic nerves cannot be adequately visualized from the same side, then a bilateral approach is warranted. The contralateral side can be approached with VATS or RATS approach.

Reposition the Robot

- Reposition the robotic spine to the patient's right side with the robotic arms on the patient's left side.
- Insert ports on left side in same manner as inserted on the right using a thoracoscope connected to a VATS tower initially for assistance with port placement.
- Avoid damage to the heart when inserting the ports at the 4th and 6th intercostal space.

Dissect the Left Inferior and Left Superior Poles

- Dissect the left inferior and left superior poles in the same manner as described during the VATS approach.
- Clip the vein or veins draining the thymus to the left innominate vein. This will require the assistant to load a clip applier onto one of the robotic arms.
- Place the specimen in a specimen bag and remove from the 12-mm port site.
- Place a right-sided chest tube, confirm inflation of the lung, and remove the ports under direct visualization.
- Close overlying intercostal muscles and skin as desired.

TRANSCERVICAL THYMECTOMY

Positioning

- Place the patient in the supine position, with the head maximally hyperextended using an inflatable bag and a rolled sheet behind the patient's shoulders. Inability to hyperextend the patient's neck must be considered preoperatively.
- Place the back of the head in a doughnut at the very edge of the operating table.
- Tuck the arms at the patient's side. Avoid having any cords or sheets covering the attachment rails of the table, as a retractor will be mounted there later in the case.
- Prep the skin of the anterior neck and chest to the sternal notch in preparation for sternotomy if needed.

- The anesthesiologist will be positioned on the patient's side, and the tubing should be allowed to drop down and not be suspended with a "Christmas tree."[8]

Incision and Isolation

- Make transverse incision just over the sternal notch, below the level where an incision would be made for a mediastinoscopy.
- Elevate superior and inferior subplatysmal flaps. Carry the superior flap to the level of the thyroid cartilage, and the inferior flap is carried to just below the suprasternal notch. Insert two handheld self-retaining retractors to separate the skin flaps.
- Dissect down to and separate the median raphe between the sternohyoid and sternothyroid muscles.
- Incise the ligamentous attachment within the sternal notch and develop the substernal plane using a finger to dissect. The cervical portion of the thymus appears salmon-pink and this color distinguishes it from the surrounding cervical fat.[8]
- The right lobe of the gland often comes up higher than the left and will be identified first. The thymus is anterior to the inferior thyroid vein. Once the inferior thyroid vein is identified, separate it posteriorly.

Division of Superior Poles

- Sit at the head of the bed and use a headlight. The assistant will be positioned on the opposite side of the anesthesiologist at the patient's head.
- Place another self-retaining retractor between the strap muscle.
- Dissect and divide attachments to the right superior and left superior poles. Place a silk traction suture around each pole to use as a handle. Do not cut these sutures; leave a hemostat clamped to their ends (**FIG 5A**).
- Dissect downward toward the innominate vein, which the thymus usually lies anterior to. Small venous branches can be divided between clips or with an advanced vessel-sealing device.
- When the dominant vein emptying into the innominate vein is identified, place ligatures proximally and distally and divide it.
- Use a peanut for dissection initially. Once the dominant vein is divided, further dissection can be carried out with a tonsil sponge.
- Divide lateral attachments to the right and left lobes of the thymus.

Placement of Retractor

- The Cooper thymectomy retractor (Pilling Surgical Instruments, Teleflex Medical, Research Triangle Park, North Carolina) is designed for transcervical thymectomy. Alternatively, the Rultract retractor (Rultract Inc, Cleveland, Ohio), designed for taking down the internal mammary arteries, can be used if a blade of appropriate size for the sternal notch is used. A Thompson retractor (Thompson Surgical Instruments, Inc, Traverse City, Michigan) with an appropriately sized blade can be used if both arms of the retractor are joined together arching over the patient (**FIG 5B**).
- Clamps are applied to the over drapes on each side of the table. Place the sidebars of the Polytract retractor (Pilling Surgical Instruments, Teleflex Medical, Research Triangle Park, NC) into the clamps and place the crossbar of the retractor between the clamps.
- The positioning of the table clamps and crossbar must be adjusted so that patient's entire body can be lifted and suspended off of the table using the Cooper thymectomy retractor (**FIG 5B**).
- Insert the blade of the Cooper thymectomy retractor behind the sternum and lift toward the ceiling. Connect the Cooper thymectomy retractor to the crossbar (**FIG 5B**).
- Insert an Army-Navy retractor on each side of the wound and attach each laterally to the sidebars using Penrose drains or sterile rubber bands.
- Deflate the beanbag behind the shoulder. Now, the patient's entire body weight is being suspended by thymectomy retractor.
- Drape the silk ligatures affixed to the left superior and right superior poles over the top of the crossbar, weighed by hemostats.

Division of the Inferior Poles

- Sweep the right lobe away from right pleural reflection with a tonsil sponge first, then sweep the left lobe away from the left pleural reflection.
- The left lobe is more difficult to dissect than the right because of extension of the thymus into the aortopulmonary window. Avoid traction injury to the phrenic nerves, whose location cannot be seen.[8]
- Proceed caudally with dissection on each side; divide any pericardial attachments sharply.

Removal of Specimen and Closure

- Sweep away the inferior attachments and retract the thymus cranially. After inferior and lateral tissues are swept away and the thymus is freed, it is often attached to small pedicle at the superior aspect of the gland posteriorly. This is likely a previously unidentified vein draining the thymus into the innominate vein. It should be divided between clips.
- Remove the specimen and confirm hemostasis in the mediastinum. Topical hemostatic agents can be used here for minor oozing.
- If any pleural violation occurred, insert a red rubber catheter into the violated pleural place and perform a Valsalva maneuver to evacuate the hemithorax of air just before the wound is closed.
- Close the platysma with absorbable suture and close the skin with absorbable subcuticular suture.
- Obtain a chest radiograph postoperatively. Pneumothoraces that are not large or symptomatic do not need to be addressed because there is no ongoing air leak and thus will resolve spontaneously.[8]

Division of superior poles

- Step-by-step description, with at least one surgical photo or sample drawing for artist to illustrate surgical technique. Photos and illustrations may be used side-by-side.

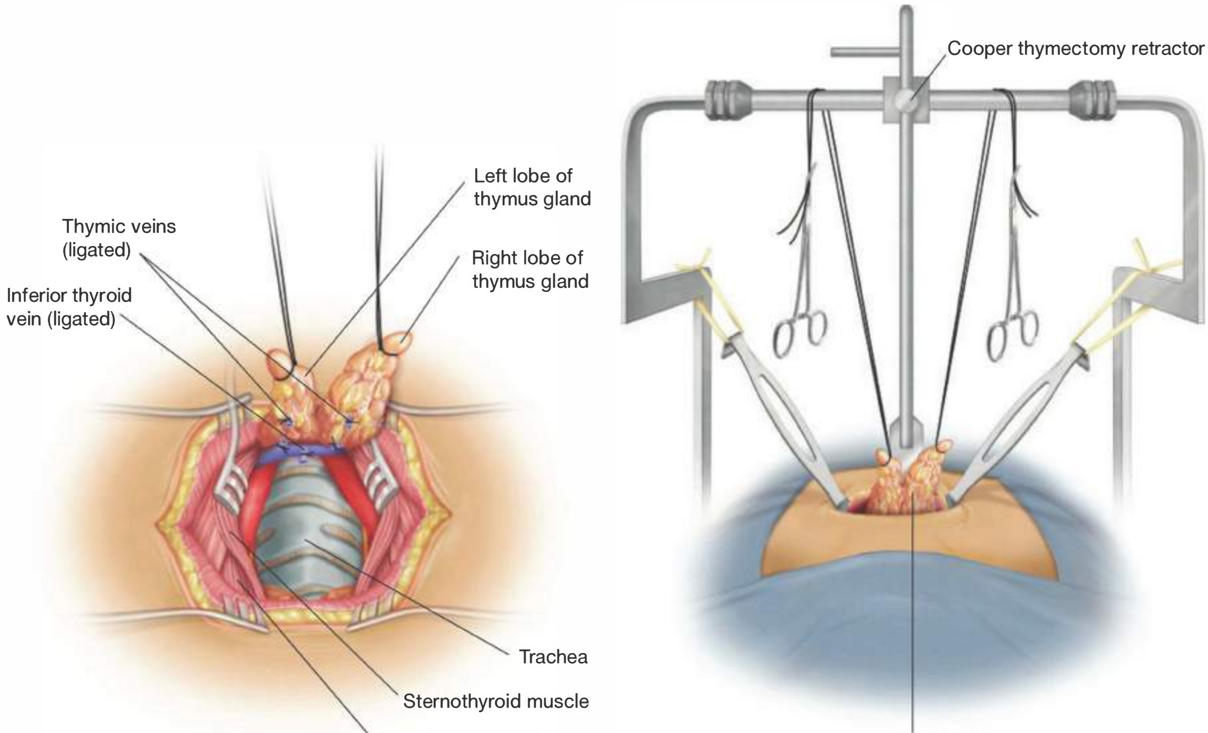

FIG 5 ● **A.** Identify and ligate right and left poles of thymus gland, using them as a handle for superior retraction. **B.** Cooper thymectomy retractor or other fixed blade retractor placed substernally and used to lift the entire patient off of operating table.

PEARLS AND PITFALLS

Imaging and workup	■ Thin-slice computed tomography (CT) of chest with intravenous (IV) contrast is most often used. ■ In almost all cases, biopsy of lesions in anterior mediastinum is warranted preoperatively.
Anesthesia	■ Special anesthetic requirements may be necessary for myasthenia gravis patients, and the anesthesia team should be notified well in advance to make accommodations, if needed. ■ Plasmapheresis may be indicated preoperatively in patients with myasthenia gravis. ■ Double lumen endotracheal tubes are strongly recommended in patients undergoing VATS or RATS thymectomy. ■ Central venous access should be established preoperatively.
Technique	■ The ipsilateral phrenic nerve must be visualized and preserved before initiating resection of thymic tissue on that side. ■ The phrenic nerve must be identified and preserved on at least one side. A phrenic nerve should only be sacrificed if grossly invaded by tumor. ■ Troublesome bleeding can occur if a thymic vein near the left superior or right superior pole tears and retracts cephalad. ■ Doubly ligate thymic veins. ■ Bipolar devices such as LigaSure or Harmonic scalpel can be of assistance with dissection around poles of thymus. ■ Protected ports and EndoCatch bags should be used.
Pitfalls	■ If performing robotic thymectomy and the contralateral phrenic nerve cannot be visualized from the same side the case was started on, the surgeon must operate on the contralateral side as well. ■ Complete resection of all thymic tissue is necessary to obtain cure in myasthenia gravis.

POSTOPERATIVE CARE

- Obtain chest radiograph postoperatively.
- Inpatient observation and patient-controlled anesthetics are recommended for patients undergoing thymectomy by sternotomy, VATS, or robotic-assisted approaches. Patients undergoing transcervical thymectomy can often be discharged home on the day of operation.
- For patients undergoing thymectomy by sternotomy, VATS, or robotic-assisted approaches, obtain a hemogram and electrolyte panel including magnesium and phosphorus levels the first morning postoperatively. Correct any electrolyte imbalances.
- Plasmapheresis or medical may be necessary initially postoperatively, with the guidance of the referring neurologist, when there is difficulty weaning from ventilation or if myasthenic crisis occurs.

OUTCOMES

- Complete stable remission, pharmacologic remission, or improvement of manifestation status of myasthenia gravis occurs in 97.9% of patients undergoing thymectomy by sternotomy and 95.8% in patients undergoing thymectomy by VATS approach.[9]
- Complete remission of myasthenia gravis is between 15% and 35%, depending on literature reviewed.

COMPLICATIONS

- Bleeding from the innominate vein
- Damage to the phrenic nerve, especially devastating in patients with myasthenia gravis
- Pneumothorax with persistent air leak from damage to lung parenchyma
- Chylothorax if thoracic duct or branch of thoracic duct is damaged during takedown of the poles of the thymus
- Inability to wean from mechanical ventilation in patients with more extreme symptoms from myasthenia gravis
- Failure of thymectomy to resolve symptoms of myasthenia gravis (percentage)
- Local recurrence of thymoma if incomplete resection performed
- Metastasis to surgical site
- Death

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Chapter 10 Thoracoscopic Sympathectomy

Brett Broussard Douglas Minnich Benjamin Wei

DEFINITION

- Hyperhidrosis is a medical condition that involves the overproduction of sweat/perspiration in the palms, axillae, face, or feet.
- Diagnostic criteria include focal sweating of greater than 6 months and two of the following characteristics: bilateral and symmetric nature, impairs daily activities, occurs weekly at a minimum, onset at younger than 25 years of age, significant family history, and no evidence of focal sweating during sleep.
- Eccrine glands innervated by the sympathetic nervous system are responsible for hyperhidrosis. Acetylcholine is the primary neurotransmitter carried by cholinergic autonomic neurons.
- Hyperhidrosis can be related to an abnormal central response to emotional stress but also occurs spontaneously and intermittently. Eccrine glands appear histologically and functionally normal under microscopic examination.[1] The pathophysiologic basis of hyperhidrosis remains unclear.

DIFFERENTIAL DIAGNOSIS

- Generalized, or secondary, hyperhidrosis can be caused by a wide variety of systemic and metabolic reasons. Excessive heat exposure and obesity are the most common causes of generalized hyperhidrosis. Other causes include endocrine disorders, neuroendocrine tumors, infection, malignancy, and toxins. Hodgkin's disease and tuberculosis are common causes of nocturnal hyperhidrosis.
- Localized unilateral, or segmental, hyperhidrosis is rare and can be attributed to gustatory stimuli; eccrine nevus; eccrine angiomatous hamartoma; glomus tumor; polyneuropathy, organomegaly, endocrinopathy, monoclonal gammopathy, and skin changes (POEMS) syndrome; and pachydermoperiostosis.

PATIENT HISTORY AND PHYSICAL FINDINGS

- Patients typically present with history of palmar and plantar sweating since childhood. The onset of sweating may be associated with stress or occur during a time of calmness. The timing of palmar and plantar sweating is synchronous.
- The presentation of sweating is intense in nature. Patients may complain of puddles of sweat around bare feet, saturation of paper while writing, or the need to change clothes multiple times a day.[2]
- Hyperhidrosis may have a significant impact on the patient's self-image, occupation, and social interactions.

IMAGING AND OTHER DIAGNOSTIC STUDIES

- The diagnosis of primary hyperhidrosis is obtained through a thorough history and physical examination.
- If secondary or unilateral hyperhidrosis is suspected, further evaluation is warranted including laboratory studies and imaging.

SURGICAL MANAGEMENT

- Various nonoperative treatments such as application of aluminum chloride alcohol solutions (Drysol), iontophoresis (placing of hands and feet in water through which electric current flows), botulinum toxin injections, and oral anticholinergics such as glycopyrrolate and oxybutynin are usually tried prior to consideration of sympathectomy.
- The Society of Thoracic Surgeons (STS) expert consensus committee has adopted a nomenclature when describing sympathectomy. For example, R3 refers to a sympathectomy above the 3rd rib space.[1]
- In preparation for sympathectomy, it is important to consider the anatomic presentation of the patient's symptoms for operative planning.
- *Palmar hyperhidrosis*: Disruption of the sympathetic chain above both the 3rd and 4th ribs (R3 and R4) results in the driest hands but carries an increased risk of compensatory hyperhidrosis (CH). R4 disruption alone decreases the risk for CH but may lead to suboptimal dryness of the hands. The consensus committee therefore recommends R3 disruption alone for palmar hyperhidrosis.
- *Palmar and plantar hyperhidrosis* is best treated with R4 and R5 sympathectomy. R4 disruption alone may decrease the probability of CH, but dividing both R4 and R5 results in an excellent reduction in sweating symptoms.
- *Axillary hyperhidrosis* (including palmar-axillary and palmar-axillary-plantar) is best treated with R4 and R5 sympathetic chain disruption. Simultaneous R3 and R4 disruption was found to increase the incidence and severity of CH.
- *Craniofacial hyperhidrosis* needs to be distinguished from blushing. These patients benefit from R3 chain disruption alone. Studies have shown that R2 chain disruption is associated with an increased incidence of Horner's syndrome and CH.[1]
- There are different methods in which the sympathetic chain can be disrupted. Options include the following:
  - Sympathectomy: removal of sympathetic ganglion by transection of chain above and below ganglion
  - Sympathicotomy: simple transection of sympathetic chain
  - Clipping: clip placed at indicated level of sympathetic chain
  - Blocking: Clips are placed above and below ganglion.[2]
- There is no clear advantage to any particular method used to disrupt the chain.
- Proponents of clip application believe that sympathectomy can be reversed in the case of intolerable hyperhidrosis by removal of the clip; however, one study has shown that only about 50% of patients experience a significant decrease in CH after clip removal.[3] Experimental studies suggest that the damage inflicted on the nerve with clip application leads to degeneration of the nerve within 10 days of clip application.[4] It is more important that the correct level is identified and that enough of a gap is created when the nerve bundle is transected to prevent regrowth of the nerve.[1]

Preoperative Planning

- Patients can be intubated with either a double lumen or single lumen endotracheal tube. We prefer a double lumen endotracheal tube, which allows for single-lung ventilation.
- If a single lumen endotracheal tube is used, carbon dioxide (CO_2) insufflation or intermittent apnea is necessary to displace the lung and gain access to the sympathetic chain.

Positioning

- The patient is placed in a supine position on the operating room table with both arms abducted and placed at a 90-degree angle or greater if tolerated (**FIG 1**).
  - The arms should be padded for the full length of the arm board and safely secured with a strap proximal and distal to the elbow.
- The table is then maneuvered into a semi-Fowler's position.
- The chest is then prepped from the base of the neck to the upper abdomen and includes bilateral axillae in the field.

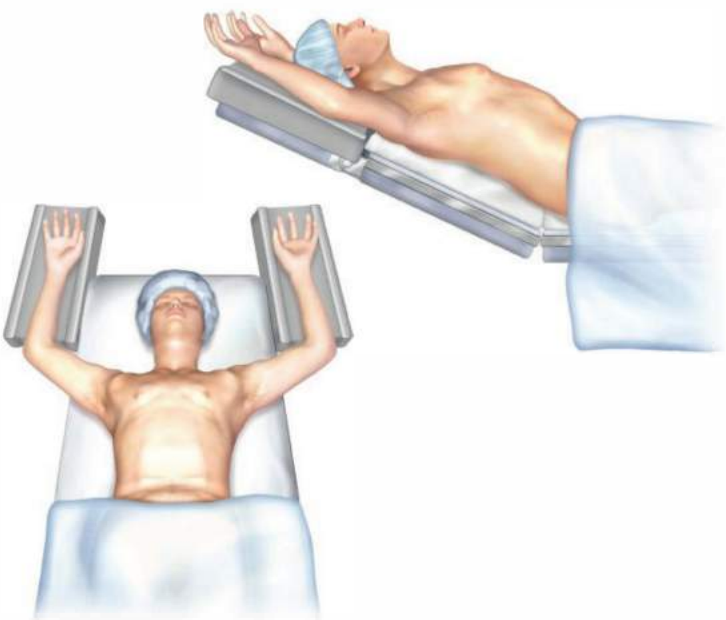

FIG 1 ● The patient is positioned in a semi-Fowler's position, elevated to 30 to 45 degrees. Arms are abducted to 90 degrees or greater to ensure both axillae are exposed.

TECHNIQUES

THORACOSCOPIC SYMPATHECTOMY

Incision and Trocar Placement (Two-Incision Technique)

- A 5-mm incision is made just lateral to the pectoralis major muscle in the anterior axillary line in the 3rd intercostal rib space (**FIG 2**).
- The subcutaneous tissue is then spread bluntly with a hemostat.
- Single-lung ventilation is then performed in the contralateral lung.
- A 5-mm trocar is then placed through the incision with special care to stay just superior to the 3rd rib. Insufflation of CO_2 into the chest may help with deflation of the lung and visualization of the upper sympathetic chain.
- A second 5-mm incision is made approximately 5 cm lateral to first incision.
- The subcutaneous tissues are again bluntly spread and a second 5-mm trocar is placed.

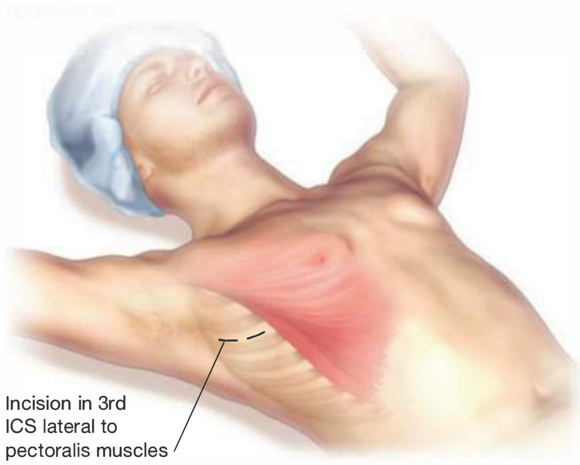

FIG 2 ● An incision is made lateral to the pectoralis major in the anterior axillary line. A second incision is made in the same interspace in the midaxillary line.

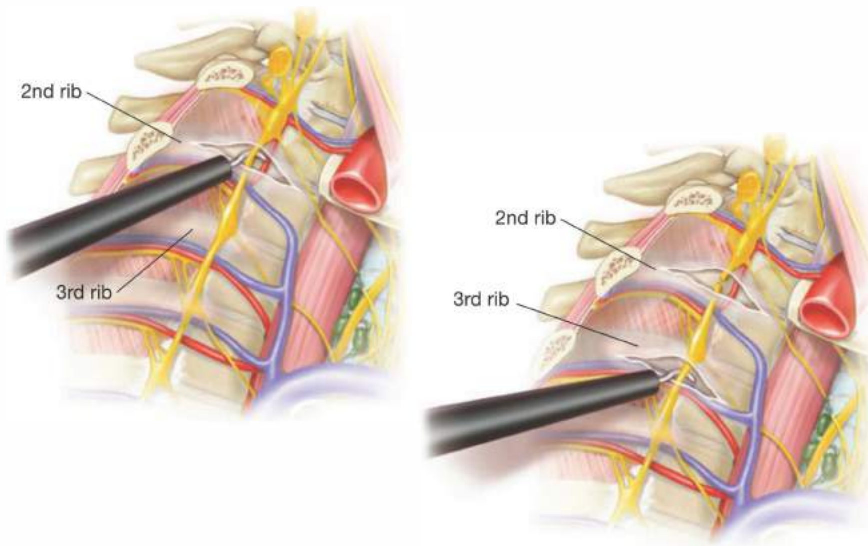

FIG 3 ● The sympathetic chain is identified lateral to the vertebral column. The desired intercostal space for sympathectomy is identified. The parietal pleura is opened medial and lateral to the chain and the hook cautery is passed behind the chain. The nerve is then cauterized and transected.

Rib Identification

- A 30-degree 5-mm scope is then placed in the lateral trocar site.
- The ribs are then correctly identified. The 2nd rib is typically the most proximal rib visualized in the chest. The 2nd rib can also be identified by a descending arterial branch from the subclavian artery that typically crosses the rib 1 cm lateral to the sympathetic chain.

Sympathetic Chain Disruption

- The sympathetic chain is then identified near the rib heads at the desired interspace(s) (e.g., above the 3rd rib for a so-called R3 sympathectomy) (**FIG 3**).
- Using a hook cautery, the parietal pleura is then cauterized on the medial and lateral side of the sympathetic chain.
- The hook is then bluntly placed around the sympathetic chain and transected by electrocautery. The distance between the transected ends of the nerve should be one rib space. Special care is made to avoid adjacent blood vessels.

Hemostasis and Pneumothorax Evacuation

- Once the appropriate chain levels have been transected, the chest should be thoroughly inspected to ensure hemostasis. This includes port sites.
- The lung is then reinflated under direct visualization to ensure proper expansion.
- A 16-Fr chest tube is then placed through a trocar while positive pressure ventilation is performed. Assuming that the surgeon is confident that the lung was not injured during the procedure, the chest tube is placed on suction and the trocar and chest tube are removed together during positive pressure ventilation.
- The incision is then closed with a continuous 3-0 Vicryl running suture and biologic glue.
- The procedure is repeated on the contralateral side.

SINGLE-INCISION THORACOSCOPIC SYMPATHECTOMY

Incision and Instrument Placement

- A 1-cm incision is made in the anterior axillary line in the 3rd intercostal space just lateral to the pectoralis major. The subcutaneous tissue is bluntly spread with a hemostat.
- A 5-mm trocar is inserted. The operative site is visualized either by single-lung ventilation or by CO_2 insufflation.
- A thoracoscope is inserted and the desired level of sympathetic chain is identified.
- The trocar is withdrawn and the hook cautery is placed adjacent to the thoracoscope into the thoracic cavity.
- The same steps as outlined above for sympathectomy via two incisions are followed.
- Alternatively, an operating thoracoscope (**FIG 4**) can be used to perform single-incison thoracoscopic sympathectomy.
- If significant adhesions are encountered, conversion to a two-port technique will allow greater maneuverability of the hook cautery for pneumolysis.

FIG 4 ● Operative thoracoscope.

PEARLS AND PITFALLS

History of breast augmentation	■ Special consideration must be made during the placement of trocars to avoid damage to implants.
Nerve of Kuntz	■ A nerve that can join the 2nd intercostal nerve to the 1st intercostal nerve and has been associated with persistent hyperhidrosis after sympathectomy.[5] Fibers that travel slightly lateral to the main sympathetic nerve below the 2nd rib should not be technically referred to as the nerve of Kuntz; however, they should be divided if encountered at the level of the sympathectomy.

POSTOPERATIVE CARE

- In the postoperative care unit, a chest radiograph is performed to ensure proper lung inflation and no residual pneumothorax. A small pneumothorax may be observed with chest radiograph repeated a few hours later. A large pneumothorax may be better treated with aspiration or small-bore catheter placement.
- Narcotic oral pain medication is typically sufficient for pain control.
- If adequate pain control is achieved and chest radiograph is satisfactory, the patient may be discharged home from the postoperative care unit. Alternatively, patients may feel more comfortable with a single-night stay in the hospital.

OUTCOMES

- Evaluating outcomes after thoracoscopic sympathectomy has been difficult due to variable reporting methods and inconsistent reporting of success rates.
- Immediate success rates following thoracoscopic sympathectomy have been reported at 90% to 100% in the literature.
- Multiple randomized clinical trials comparing R3 disruption versus R2 to R4 or R4 alone show that R3 disruption gives a superior result with less severe CH for palmar hyperhidrosis alone.[6–8]
- For axillary hyperhidrosis, randomized clinical trials show R4 chain disruption and R3 to R4 disruption to have a 100% immediate success rate but R4 disruption to have a superior CH rate, 42% versus 100%.[9,10]

COMPLICATIONS

- Complications after thoracoscopic sympathectomy can be divided into immediate and chronic.
- Immediate complications include the following:
  - *Postoperative pain* can include incisional pain related to port placement and pleuritic retrosternal pain. This can typically be controlled with oral narcotic pain medications.
  - *Bleeding* is a rare complication and can be the result of intra- or extrathoracic sources. The risk for bleeding can be greatly reduced by careful port placement to avoid intercostal vessels and avoiding crossing vessels near the sympathetic chain during transection of the nerve.
  - *Horner's syndrome* can occur due to improper identification of the 2nd rib or proximal transmission of heat from cautery causing injury to the stellate ganglion. Risk of injury is greatly reduced for sympathectomy below the 2nd rib.
  - *Pneumothorax* can be avoided by close attention to avoid parenchymal injury during port placement and proper technique when reinflating the lung and evacuating the chest.
- Chronic complications include the following:
  - CH is cited as occurring from 3% to 75% in the literature and is classified as mild, moderate, and severe. Mild CH is triggered by ambient heat, psychological stress, and exercise where sweat is tolerable and does not flow. Moderate CH is described as sweat that accumulates into droplets but does not require a change of clothes. Severe CH includes sweat that flows profusely and requires multiple changes of clothes in 1 day. It is physically and emotionally debilitating. CH has a higher incidence with interruption of the T2 ganglion.[1]
  - *Bradycardia* can result from transection of sympathetic fibers that innervate the heart. Careful consideration of the desirability of the procedure should be made for those patients who have a resting heart rate of less than 55 beats per minute.
  - *Recurrent hyperhidrosis* can mainly be attributed to inadequate surgery. This may be due to anatomic variants, including increased adipose tissue around sympathetic chain, increased vascularity, or possible reinnervation. The results of reoperative sympathectomy are comparable to initial sympathectomy in terms of symptom control; however, reoperative sympathectomy is associated with increased likelihood of requiring postoperative pleural drainage, longer hospital stay, greater difficulty of operation (e.g., adhesions), and a higher risk of CH.[11]

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Chapter 11

Mediastinoscopy

James Wiseman Shanda Haley Blackmon

DEFINITION

- Mediastinoscopy is the evaluation of the anterior mediastinum through endoscopic means.
- Video mediastinoscopy is the current technique discussed in this chapter.
- It remains the gold standard for mediastinal exploration in lung cancer staging and can be applied to the sampling of any tissue of the anterior mediastinum for diagnostic purposes.
- Through traditional video mediastinoscopy, levels 2, 4, 7, and 10 lymph nodes can be reached (**FIG 1**). Through an extended cervical mediastinoscopy (ECM), the paraaortic and aortopulmonary lymph nodes can be reached.
- Additionally, but less frequently, mediastinoscopy can be used in the setting of mediastinal disease for therapeutic purposes.

IMAGING AND OTHER DIAGNOSTIC STUDIES

- Patients being considered for mediastinoscopy frequently present following identification of either mediastinal or pulmonary pathology on plain film radiography. A minimum of two views is required to differentiate between abnormalities of the anterior, middle, and posterior mediastinum, including either a posteroanterior view or an anteroposterior projection and a lateral projection. Lymphadenopathy is rarely visible on plain films, typically necessitating the use of alternative imaging modalities in assessing for lymph node enlargement.
- Computed tomography (CT) of the chest is a critical tool in the early evaluation of patients with known or suspected lung cancer or other diseases involving mediastinal structures. The primary use of CT is the radiographic visualization of abnormalities of the mediastinum (i.e., neoplasm, abscess, lymphadenopathy). In the setting of lung cancer, CT is most useful in identification of mediastinal adenopathy. Lymph nodes are considered to be positive if they demonstrate a short-axis diameter larger than 1 cm. Using this threshold, however, the negative predictive value (NPV) of CT scan ranges from 77% to 90%, with a positive predictive value (PPV) of 41% to 74%.[1–3] Despite these limitations, the use of CT has allowed some centers to implement a selective approach to mediastinoscopy.
- Considerable attention has been given to the use of positron emission tomography (PET) in the evaluation of primary mediastinal pathology and, in particular, assessment of the mediastinum for lymphadenopathy in the evaluation of the lung cancer patient. Several studies have reported NPV in excess of 95% with the use of PET to evaluate for metastatic disease to mediastinal lymph nodes.[4–6] False-positive findings are frequent with PET, however, and the identification of PET-avid nodes demands confirmation.

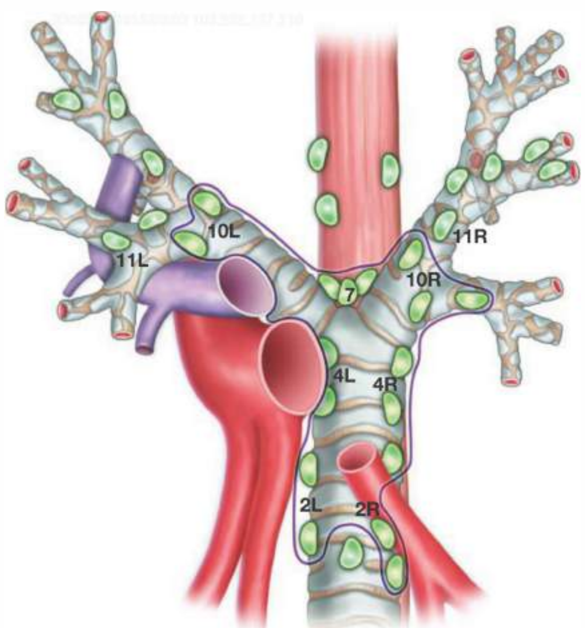

FIG 1 ● Mediastinal lymph node anatomy, as seen from the perspective of the surgeon.

SURGICAL MANAGEMENT

- The most common indication for mediastinoscopy is for staging in the setting of lung cancer. Some institutions employ mediastinoscopy routinely in the evaluation of these patients. Others advocate for a selective approach, informed by the findings of other imaging modalities. In this setting, centrally located tumors, known as adenocarcinoma, nodes larger than 1 cm on CT scan, and PET-avid nodes should prompt the use of invasive means of obtaining tissue for diagnosis.
- Mediastinoscopy is also a valuable diagnostic tool in the evaluation of nonneoplastic causes of mediastinal lymphadenopathy as well as other masses found in the mediastinum for which identification cannot be accomplished through noninvasive means.
- Absolute contraindications to mediastinoscopy include innominate artery aneurysms and the presence of a tracheostomy.[7]
- The presence of a thyroid goiter, depending on size, may present technical difficulties for the surgeon, and very large goiters may preclude performance of the procedure altogether.
- Repeat mediastinoscopy, although challenging, is usually possible and safe.

Preoperative Planning

- A complete history and physical, focusing specifically on previous mediastinal operations, should be obtained. Although prior mediastinal surgery (coronary artery bypass graft [CABG] surgery, esophagectomy, etc.) does not preclude mediastinoscopy, it is essential to be aware of such history during the planning phase.
- All patients with planned mediastinoscopy should have coagulation studies done preoperatively. In general, a target international normalized ratio (INR) of 1.2 should be achieved to minimize risk of intraoperative and postoperative bleeding. Antiplatelet therapy should be stopped prior to an elective procedure such as mediastinoscopy.

Positioning

- Following induction of general anesthesia, the patient is placed supine with the head close to the top edge of the operating table. The procedure can be facilitated through extension of the neck by placement of a rolled towel or beanbag device horizontally from shoulder to shoulder. Some patients may not tolerate complete neck extension due to prior cervical spine surgery or degenerative disease.
- The entire neck and chest should be sterilely prepped and draped in the event that an emergent sternotomy is required to address intraoperative complications.

INCISION

- The typical location of the incision is centered along the midline, approximately 1 cm superior to the sternal notch. We favor a horizontal incision, with a length of approximately 1.5 to 2.5 cm (**FIG 2**).
- The incision is carried through the platysma and subcutaneous tissue until the vertically oriented sternohyoid muscles are identified. The avascular plane separating these muscles can then be opened, revealing the underlying sternothyroid muscles.
- The surgeon will occasionally encounter engorged anterior jugular veins or their tributaries at this level of the dissection. These represent a significant bleeding risk and can be ligated if hemorrhage is encountered or anticipated. Clips should be avoided as they are prone to dislodgement with advancement of the mediastinoscope.
- The neck muscles are similarly spread vertically at the midline, at which point the pretracheal fascia and anterior wall of the trachea can be identified.
- A well-placed incision will usually access the pretracheal fascia inferior to the thyroid gland (**FIG 3**). However, the thyroid gland may occasionally require gentle cephalad retraction for adequate exposure of the trachea. The use of a tracheal hook can often be used to gain exposure in this area without interfering with the operative field.
- The pretracheal fascia is then incised and the pretracheal space bluntly developed digitally. A useful cue indicating complete development of the plane is the palpation of the innominate artery anteriorly at the fingertip following this maneuver.

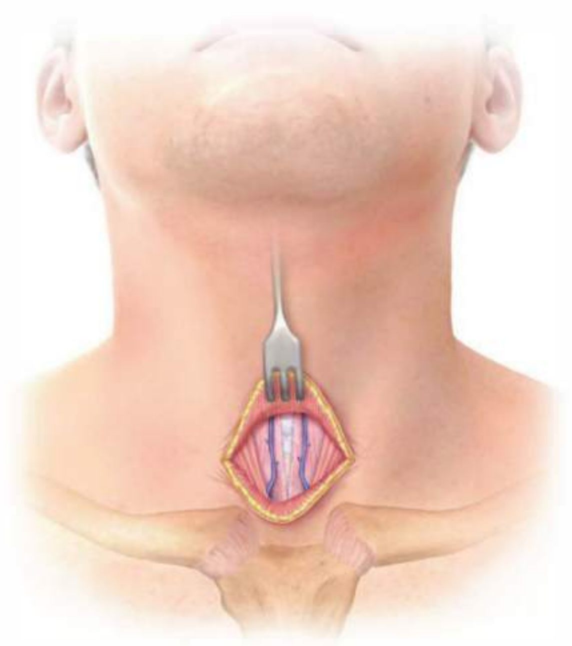

FIG 2 ● Mediastinoscopy is conducted via a horizontal incision one fingerbreadth above the sternal notch.

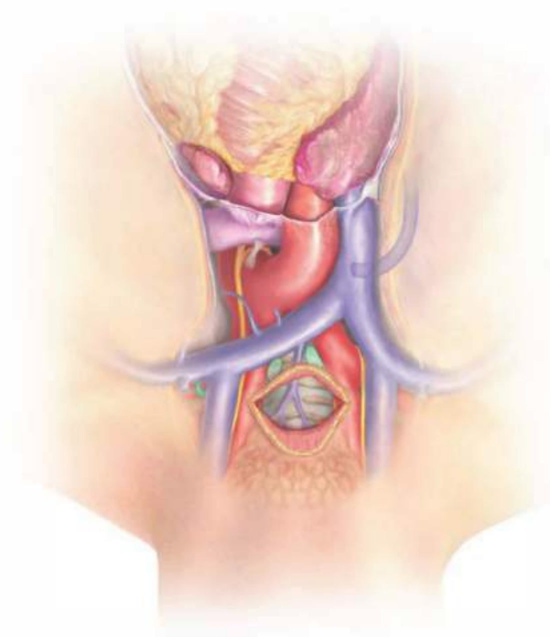

FIG 3 ● Mediastinal anatomy.

INTRODUCTION OF THE MEDIASTINOSCOPE

- The mediastinoscope is then placed into the created tunnel and advanced. Full advancement to the level of the carina can be accomplished using blunt dissection with a suction catheter.

SAMPLING OF TISSUE

- In the setting of a mediastinal mass where only tissue diagnosis is required, blunt biopsy forceps are adequate to obtain tissue. Hemostasis can be established following biopsy using pressure by packing the mediastinum with gauze, careful application of low-energy cautery connected to a suction device, or the use of commercial hemostatic factors such as Surgicel® or Arista®.
- Lymph nodes can be identified by their color and consistency. Any nodes targeted for removal should be dissected away from surrounding tissues. Dissection should be done primarily bluntly, using the suction catheter, Kittner dissector, or blunt biopsy forceps.
- Once mobilized, target nodes should be easily removable with gentle traction and twisting while grasping the tissue with biopsy forceps. Difficulty in removing a node may suggest the need for further dissection.
- For completeness of lung cancer staging, every effort should be made to obtain nodes from levels 2 and 4 bilaterally and level 7. Level 2 nodes will be encountered almost immediately upon entering the pretracheal space superior to the innominate artery, with level 4 nodes found more caudally. Level 7 nodes are found inferior to the carina. If grossly positive tissue is seen at higher stations, further sampling is unnecessary.[8]

WITHDRAWAL OF THE MEDIASTINOSCOPE

- The mediastinoscope is withdrawn slowly to assess hemostasis. Minor bleeding can be controlled by packing the tunnel with gauze. Bioabsorbable hemostatic agents can also be introduced into the space and left in place. Occasionally, bleeding vessels may require clip application at the end of the case for adequate hemostasis.
- It is advisable to use electrocautery sparingly, but it can be safely used at low energy. Cautery should be avoided at all times in the area of station 4 on the left side of the surgical field, as this poses unnecessary risk of injury to the recurrent laryngeal nerve.
- Violation of the pleural space can be identified by filling the tunnel with saline. Loss of the saline suggests disruption of the pleura. Bubbling of the fluid may imply pleural or pulmonary injury, occasionally requiring the placement of a chest tube.
- Standard mediastinoscopic techniques are limited in their ability to access many nodal stations. ECM was initially described by Specht and colleagues[9] in 1967 and was subsequently popularized for accessing nodes of the aortopulmonary (AP, stations 5 and 6) and subaortic lymph nodes (**FIGS 4** and **5**).
- The same incision as for standard mediastinoscopy is used for ECM. Using digital dissection, the plane between the left carotid artery and innominate artery is developed. This allows passage of the mediastinoscope over the aortic arch, with access then gained to the subaortic nodal basins. If the scope is then rotated slightly in a medial fashion, paraaortic lymph nodes can be accessed.

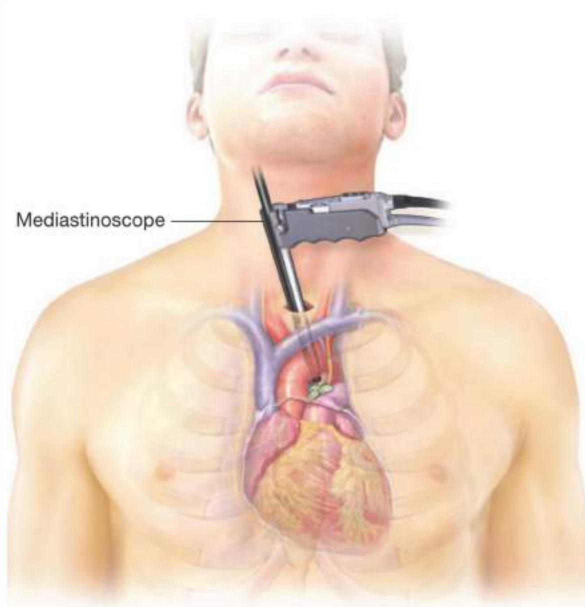

FIG 4 ● Technique of passing the mediastinoscope obliquely over the aortic arch in the performance of ECM.

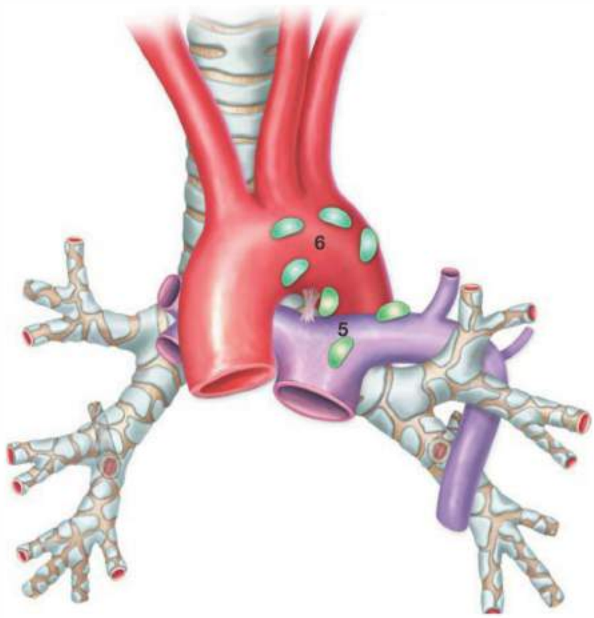

FIG 5 ● Additional lymph node basins accessible through ECM.

CLOSURE

- The sternohyoid muscles are reapproximated in the midline using absorbable sutures.
- Subcuticular closure of the skin using 4-0 Monocryl sutures in an interrupted fashion is generally preferred.

PEARLS AND PITFALLS

Anatomy	■ Always identify the innominate artery and azygous vein prior to nodal sampling. ■ Beware of crossing branch of the bronchial artery at level 7, as this represents a significant bleeding risk.
Node sampling	■ The appearance of venous structures approximates that of anthracotic lymph nodes. Care should be taken to appropriately and definitively identify structures before attempts are made to remove them.
Node presentation	■ Always label the station from which a node was sampled immediately upon retrieval. ■ If tuberculosis is suspected, touch preparation of the specimen is required. ■ If lymphoma is suspected, the specimen must be immediately treated with RPMI-1640 media and submitted for flow cytometry. ■ If a staged operation is planned, sampled lymph nodes can be submitted for permanent analysis. It is advisable, however, to submit a sample for frozen analysis to confirm the presence of nodal tissue. When resection and staging are planned for the same day, all mediastinal samples should be submitted for frozen evaluation. ■ If a mediastinal mass is encountered, at least one biopsy should be submitted for frozen analysis to confirm the presence of adequate tissue for diagnosis. ■ Our practice is for the surgeon to deliver all specimens to the pathology lab for the purposes of providing history and clarifying orientation.

POSTOPERATIVE CARE

- A postoperative chest radiography should be obtained to ensure that no pneumothorax is present.
- Mediastinoscopy, unless done as a precursor to immediate lobectomy, can be safely done on an outpatient basis. Patients may be discharged once standard discharge criteria are satisfied.

OUTCOMES

- Mediastinoscopy has a reported sensitivity of 87% to 95% and a specificity of 100% (Table 1).
- Although mediastinoscopy remains the gold standard for mediastinal staging in the setting of newly diagnosed lung cancer, endobronchial ultrasound (EBUS) or endoscopic

Table 1: Benchmark Figures for Mediastinoscopy

Sensitivity	87%–95%
Specificity	100%
Negative predictive value	96%–99%

From Anraku M, Miyata R, Compeau C, et al. Video-assisted mediastinoscopy compared with conventional mediastinoscopy: are we doing better? Ann Thorac Surg. *2010;89(5):1577–1581, with permission.*

ultrasound (EUS) via an esophageal approach with fine needle aspiration is gaining in popularity.
- In certain populations (multiple comorbidities, previous mediastinal operations), ultrasound-guided approaches to mediastinal sampling are preferred.

COMPLICATIONS

- Complication rates associated with mediastinoscopy are as high as 3%.[9] These include pneumothorax (0.5%), bleeding requiring reoperation (0.1%), and recurrent laryngeal nerve paralysis (0.4%).[10] Video mediastinoscopy appears to be safer than the traditional approach of merely using a tunneled visualization device.
- Major hemorrhage from injury to vascular structures should occur in less than 0.1% of procedures. This can result from damage to the aortic arch or its branches, superior vena cava, azygous vein, or pulmonary artery. Less commonly, hemorrhage is caused by injury to the innominate or jugular veins. In the event of a major bleeding event, clear communication with the anesthesiologist is critical to ensuring timely response to changing physiologic demands and preventing adverse outcomes.
- Hemorrhage from the innominate artery can be temporarily halted by insertion of a digit into the cervical incision and gently pressing the vessel against the posterior aspect of the sternum (**FIG 6**).
- If major bleeding cannot be controlled through the existing cervical incision, sternotomy is often the quickest and most effective approach for gaining exposure to vulnerable vascular structures. The mediastinum should be packed with gauze and resuscitation initiated, although preparations are made for conversion. If the bleeding can easily be controlled with pressure, anesthesia should be given time to prepare for the sternotomy prior to beginning the repair.
- Tracheal or bronchial injuries are infrequent and can usually be managed with packing if small. Larger injuries may require primary closure after appropriate surgical exposure.
- Esophageal perforation can occur, usually in the subcarinal area. If recognized immediately, this can be repaired primarily. A right thoracotomy provides the best exposure and allows for the surgeon to buttress the repair with an intercostal muscle flap when appropriate. Adequate treatment may require esophagectomy with diversion and staged reconstruction if diagnosis of a perforation is delayed by more than 48 to 72 hours.

FIG 6 ● Schematic drawing demonstrating emergent maneuver for hemorrhage control. A finger is inserted through the incision and advanced to the level of the innominate artery. The artery is then compressed to the underside of the sternum while the patient is being prepped for sternotomy. Packing is eventually placed to control hemorrhage when possible.

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Chapter 12

Cricopharyngeal Diverticulum: Open Repair

William R. Carroll Kirk P. Withrow

DEFINITION

- Diverticula of the hypopharynx have been recognized for over 200 years. Zenker's diverticulum is by far the most common, with an annual incidence rate of 2/100,000 individuals.[1] The disorder is acquired rather than congenital and typically occurs in older adults. Men are more commonly affected than women. There are two types of pharyngoesophageal diverticula. *Traction diverticula*, resulting from a pulling force on the outside of the alimentary tract, are more commonly seen in the mid- to distal esophagus and often result from inflammatory or neoplastic processes adjacent to the muscularis. *Pulsion diverticula*, such as Zenker's, result from an internal pushing force causing the mucosa and submucosa to herniate through the muscular wall. Zenker's diverticula occur where increased intraluminal pressure causes herniation through a deficiency in the muscular layer at Killian's dehiscence. Killian's dehiscence is located at the junction of the inferior constrictor and the cricopharyngeus muscles (**FIGS 1** and **2**).
- The history of Zenker's diverticulum is rich. The anatomy of the pharyngoesophageal junction was first detailed by Antonio Valsalva in 1704. The diverticulum was first described by Abraham Ludlow[2] (mentor of Edward Jenner of smallpox fame) in 1764. Sir Charles Bell (Bell's palsy, Bell's nerve) described the pathophysiology of uncoordinated hypopharyngeal contraction against a closed cricopharyngeus muscle. The disorder is named for Friedrich von Zenker, a German physician and pathologist, who catalogued 27 cases in 1877.[3,4]

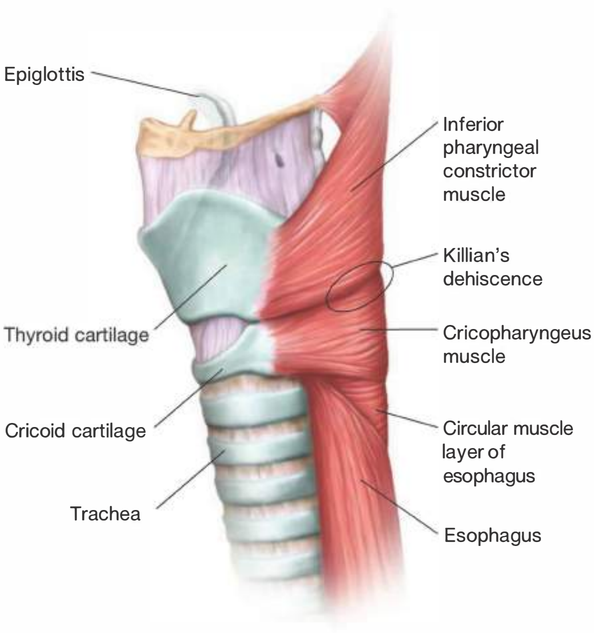

FIG 1 • Anatomy of the junction of the hypopharynx and esophagus. Killian's dehiscence is located between the inferior pharyngeal constrictor and the cricopharyngeus muscles.

DIFFERENTIAL DIAGNOSIS

- Zenker's diverticulum typically presents with dysphagia, regurgitation of undigested food, and occasionally, aspiration pneumonia. Causes for cervical dysphagia in adults may be grouped into three categories: *internal*, *external*, and *motility*. Internal disorders include inflammation and edema, stenosis, and neoplasm. External disorders produce extrinsic compression of the pharyngoesophageal segment and may include thyroid disease, adenopathy, abscess, and congenital cysts. Motility disorders include achalasia, stroke, esophageal spasm, myasthenia, and bulbar palsy.

PATIENT HISTORY AND PHYSICAL FINDINGS

- Cervical dysphagia is the most common presenting symptom of Zenker's diverticulum. Symptoms may be quite subtle and include chronic cough and unexplained weight loss. As the patient swallows, food and liquids preferentially enter the wide mouth of the diverticular pouch rather than passing through the inappropriately closed upper esophageal sphincter. As food and liquid accumulate, the patient develops a sense of neck fullness and may hear gurgling sounds in the lower neck. A pathognomonic type of regurgitation is common in which the patient regurgitates food minutes or even hours after eating that is completely undigested and not mixed with gastric contents. The pouch may fill and empty spontaneously during deglutition. When the pouch empties, the contents may spill into the airway, causing aspiration with coughing or pneumonia. The aspiration may be subtle and lead to recurrent respiratory infections and eventually chronic respiratory insufficiency. Death due to untreated Zenker's diverticulum typically results from pulmonary complications.
- Physical findings of Zenker's diverticulum include neck fullness or a mass in the tracheoesophageal groove that may gurgle or decompress with palpation (Boyce's sign). Audible gurgling may be detected over the same region with swallowing. Inspection of the hypopharynx may reveal pooling of secretions.[1] The pouch is typically not visible unless the patient undergoes esophagoscopy.

IMAGING AND OTHER DIAGNOSTIC STUDIES

- Barium swallow is usually needed to definitively diagnose Zenker's diverticulum. The study characteristically reveals a diverticular sac originating just superior to the prominent and poorly relaxing cricopharyngeus muscle. Radiologists describe this prominent muscle as a cricopharyngeal "bar."
- Computed tomography (CT) or magnetic resonance (MR) imaging of the neck is unnecessary if barium swallow

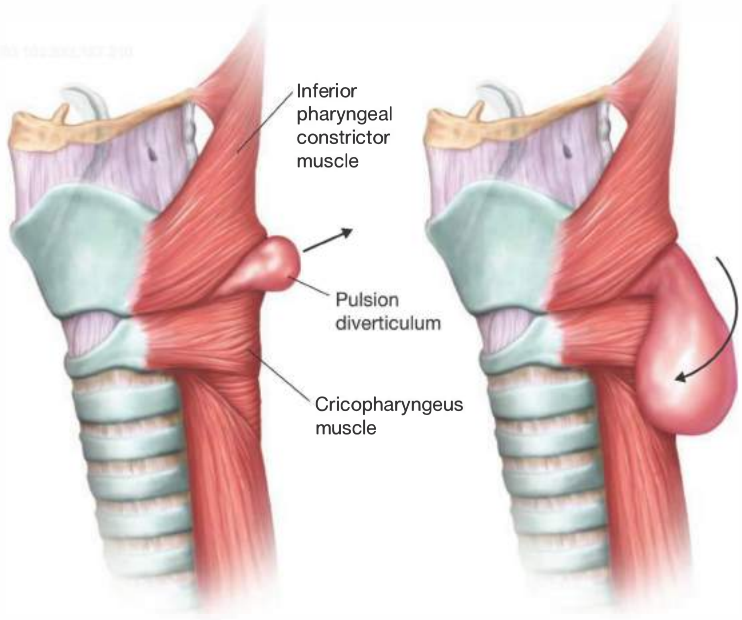

FIG 2 ● As intraluminal pressure increases due to spasticity of the cricopharyngeus muscle, the pulsion diverticulum forms.

confirms a Zenker's diverticulum. These studies would typically reveal a fluid-filled, cyst-like density adjacent to the level of the cricopharyngeus muscle.

- Chest imaging may reveal evidence of chronic aspiration pneumonitis.

SURGICAL MANAGEMENT

- Surgery is the mainstay of treatment for Zenker's diverticulum. Initially, surgeons sought to control the lesions by creating a controlled pharyngocutaneous fistula. In 1884, Niehans performed the first resection of a Zenker's diverticulum in Bern, Switzerland, but the patient died within 2 weeks of hemorrhage.[4] Wheeler[5] in Ireland completed the first successful resection in 1886. Until the mid-1900s, most operations were performed in two stages. In 1945, Harrington[6] at the Mayo Clinic reported a series of 107 cases repaired by a single-stage procedure that soon became the standard of care.
- Medical therapy with Botox injection of the cricopharyngeus muscle may provide *temporary* improvement of symptoms.
- Contemporary surgeons typically choose between an open and an endoscopic approach. When feasible, most prefer an endoscopic approach initially, citing faster recovery, lower complications, and success rates that are comparable, if not superior, to the open approach.
- The most common indication for the open approach is poor endoscopic exposure due to trismus, macroglossia, or spine disorders including osteophytes, kyphosis, or ankylosing spondylitis. Another indication for an open approach is failure of a prior endoscopic approach. Ironically, the most fragile patients are occasionally better candidates for an open approach. When the pulmonary status is particularly poor, the authors and others have used an open approach with local anesthesia successfully.[7]
- Whether open or endoscopic, a complete cricopharyngeal myotomy is the most important component of the operation.
- A diagnosis of Zenker's diverticulum does not always mandate intervention. These lesions are commonly found during routine esophagoscopy for other indications. The lesions may be observed if the patient is asymptomatic (no dysphagia, weight loss, chronic aspiration) and the lesion is relatively small (<2 cm) on barium swallow.

- The open approach includes two components: a cricopharyngeal myotomy and management of the diverticular sac. The myotomy is performed as described in the following discussion. The sac may either be resected or mobilized and suspended. The authors prefer resection, but the suspension option will be briefly illustrated as well.

TECHNIQUES

ENDOSCOPY AND DILATOR PLACEMENT

- Endoscopic evaluation of the diverticulum precedes the open approach if feasible. The diverticulum is visualized and the pouch is packed lightly with strip gauze to allow easier identification transcervically. A Maloney dilator (36 to 40 Fr) is placed into the cervical esophagus to simplify the myotomy.

POSITIONING

- The patient is placed in a supine position with the neck extended and head turned toward the nonoperative side. A shoulder roll may be helpful with a low-lying larynx or short neck.

SKIN INCISION

- A transverse incision is made in a natural skin crease at approximately the level of the cricoid cartilage (**FIG 3**).

FIG 3 ● Surgical approach is typically via a transverse incision in the left neck at the level of the cricoid cartilage.

APPROACH

- Subplatysmal flaps are developed. The investing fascia is opened along the anterior border of the sternocleidomastoid muscle and the muscle is rotated posteriorly. The plane of approach lies between the carotid sheath and the central compartment fascia. The central compartment contains the strap muscles, thyroid gland, larynx, trachea, and pharyngoesophageal segment. The plane is relatively avascular but is crossed at this level of the neck by branches of the thyroid vein and the omohyoid muscle.
- The omohyoid muscle can usually be mobilized superiorly or inferiorly without dividing but causes little morbidity if divided. The carotid artery is typically located more medial and deep to the jugular vein. The vagus nerve travels within the sheath but is often located posterior to the carotid artery and may not be seen.
- The recurrent laryngeal nerve, however, will commonly be at risk. The nerve lies in the tracheoesophageal groove within the central compartment at this level of the neck. To avoid damaging the nerve, the surgeon can either directly identify the nerve or approach the retropharyngeal space from a position well lateral to the central compartment. The authors prefer *not* uncovering the nerve but dissecting adjacent to the anterior edge of the carotid artery as the retropharyngeal space is approached (**FIG 4**). Once this space is reached, dissection can safely proceed medially while placing the nerve at very little risk. The authors do not typically employ laryngeal nerve monitoring during this procedure.

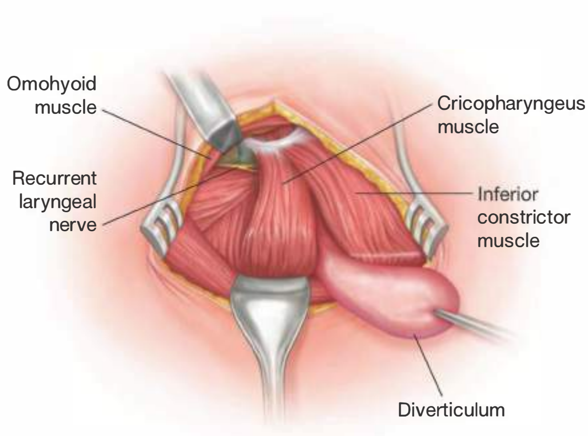

FIG 4 ● The diverticulum presents through Killian's dehiscence, with the inferior constrictor muscle cephalad and the muscle caudal.

MOBILIZING THE DIVERTICULAR SAC

- The most challenging portion of the procedure may be identifying and safely mobilizing the diverticular sac. Killian's dehiscence is located near the inferior border of the cricoid cartilage.
- The mouth of the sac exits the hypopharynx posteriorly. Depending on the size of the sac and the degree of associated fibrosis, the remainder of the sac is typically positioned to the left of midline.
- The wall of the diverticular sac should be carefully separated from the adjacent fibrofatty tissue. If there has been acute inflammation or previous surgery, this dissection may be tedious.
- Gauze packing previously placed within the sac may help delineate the wall of the sac from surrounding inflammatory tissue. The entire sac should be mobilized up to the junction with the back wall of the hypopharynx.

CRICOPHARYNGEAL MYOTOMY

- A myotomy is performed prior to transecting the diverticulum. The back wall of the pharyngoesophageal segment is identified, and the myotomy is positioned 1 to 2 cm to the left of the posterior midline (**FIG 5**).
- A hemostat is used to define the muscle and separate it from the underlying mucosa. The muscle is then divided sharply over the hemostat.
- A typical myotomy will be longer than 2 cm in length and should extend downward onto the cervical esophageal segment.
- The dilator placed in the esophagus will simplify this step. The color of the dilator should be visible through the esophageal wall as the underlying mucosa is approached.

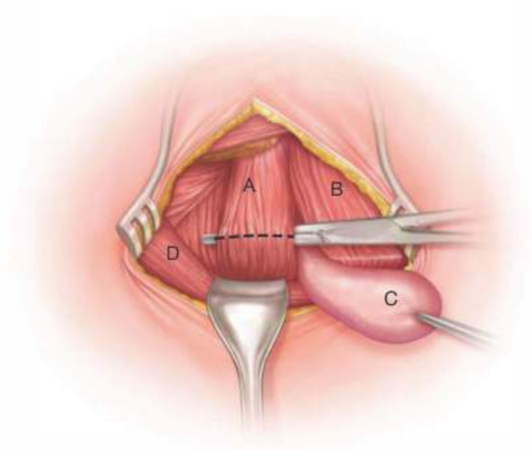

FIG 5 ● A complete cricopharyngeal myotomy is performed to relieve increased intraluminal pressure causing outflow obstruction. *A*, cricopharyngeus muscle; *B*, inferior constrictor muscle; *C*, diverticulum; *D*, omohyoid muscle

DIVISION OF THE DIVERTICULUM SAC AND MUCOSAL REPAIR

- Once fully mobilized, the sac can be resected or simply suspended. If suspension is preferred, the sac should be tacked upward so that the mouth of the diverticulum is dependent (**FIG 6**).
- The distal end of the sac is tacked to central compartment fascia with absorbable suture.
- The authors prefer to resect the diverticulum at this point. The dilator within the esophagus helps distinguish the neck of the diverticulum from the normal pharyngeal segment. Be aware that resection of normal pharynx

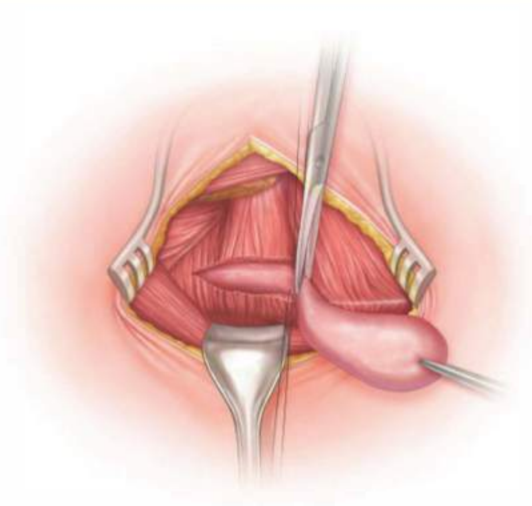

FIG 6 ● The neck of the diverticulum is transected at the junction with the pharyngeal wall, taking care not to resect normal pharyngeal lumen.

TECHNIQUES

and esophagus is surprisingly easy to do if the diverticular opening is wide-mouthed.

- Stay sutures are placed 180 degrees apart at the mouth of the diverticulum to help identify the line of closure.
- The sac is then transected with scissors or a stapling device.
- If cut sharply, a two-layer, imbricating closure is performed to minimize the chance of leak (FIG 7).
- Suction-assisted drains are placed after thorough irrigation, and the wound is closed in two layers.

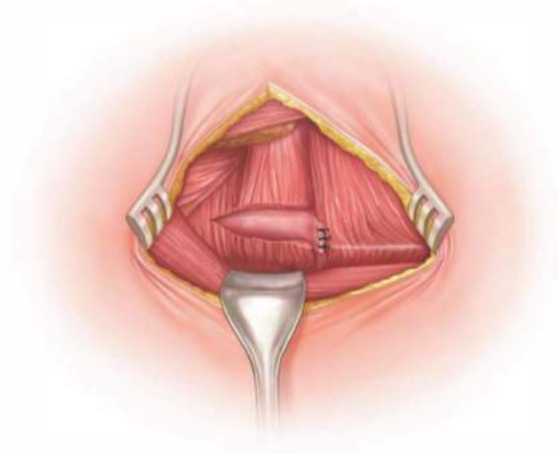

FIG 7 ● Closure of the pharyngotomy.

PEARLS AND PITFALLS

Indications	■ Symptoms may be subtle. Most patients have dysphagia. ■ Pulmonary complications of Zenker's diverticulum are common.
Workup	■ Barium swallow is necessary and sufficient for diagnosis.
Procedure	■ Begin with esophagoscopy. Consider gauze packing in diverticulum and dilator in esophagus to help delineate diverticulum from normal mucosa. ■ Approach retropharyngeal space from a lateral position to minimize risk to the recurrent laryngeal nerve. ■ A complete cricopharyngeal myotomy is essential. ■ The sac may be resected or suspended.

POSTOPERATIVE CARE

- If the diverticulum has been resected, patients are kept NPO for 3 days and an enteral feeding tube is used for nutrition. The authors typically repeat a modified barium swallow on day 3 to detect a potential leak and to determine adequacy of myotomy and efficacy of the swallow. If appropriate, patients are allowed to swallow full liquids and are discharged from the hospital. The diet is advanced to soft foods as tolerated.

OUTCOMES

- A review of the literature finding 1,696 cases of Zenker's diverticulum repaired by an external approach revealed 95% improvement in initial symptoms.[8] Another report compared patients treated by external approach ($n = 101$) with patients treated by an endoscopic approach ($n = 86$) and concluded that significantly more patients have symptomatic relief after external (open) approaches.[9] Open and endoscopic approaches for treatment of Zenker's diverticulum have not been compared in prospective clinical trials. Most surgeons today prefer the less invasive endoscopic approach when feasible.[1] Following an external approach to Zenker's diverticulum, the surgeon can anticipate that approximately 90% of patients will have improved symptoms and radiologic findings.

COMPLICATIONS

- As noted, many patients with Zenker's diverticulum are older and chronically debilitated. The surgeon should carefully weigh operative risk and frankly inform the patient and family accordingly.
- Complications from open repair of Zenker's diverticulum result from damage to adjacent structures during the approach and from infectious complications related to salivary fistula and chronic aspiration. In a literature review, Engel and

Panje[10] reported these complication rates from an external approach to Zenker's diverticulum: fistula (6.3%), recurrent laryngeal nerve injury (3.6%), mediastinitis (3.1%), pneumomediastinum (0.8%), and death (2%). Gutschow et al.[9] reported fistula in 8.6% and mediastinitis in 3.6% (0% in patients with external approach). Chang et al.[8] reported overall complication rates of 11.8% for external approaches and 5.5% for combined endoscopic approaches.

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Chapter 13

Cricopharyngeal Diverticulum: Endoscopic Repair

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DEFINITION

- Diverticula of the hypopharynx have been recognized for over 200 years. Zenker's diverticulum (ZD) is by far the most common with an annual incidence rate of 2/100,000 individuals.[1] Specifically, ZD is an outpouching of hypopharyngeal mucosa that occurs at the junction of the inferior constrictor and cricopharyngeus (CP) muscle through a weak area known as Killian's dehiscence (**FIG 1**). As it is essentially just a mucosal sac, it is technically considered a "false" diverticulum. This is an acquired disorder that most commonly presents between the sixth and eighth decade of life and affects more men than women. In rare cases, there is a family history of ZD and evidence of genetic predisposition toward its development.[2] Although the exact etiology of ZD remains debatable, most agree that it represents a pulsion diverticulum occurring due to a rise in intraluminal pressure relative to the resistance of the esophageal wall. Although manometry data from available studies provide conflicting information about CP muscle activity in ZD patients, clinical observation as well as less favorable swallowing outcomes in patients who did not have a CP myotomy as part of their treatment strongly implicate abnormal CP function in the formation of ZD.
- Historically, ZD was first recognized by Abraham Ludlow in 1796 and was named after Friedrich Albert Zenker who reported a series of ZD patients in 1877. The first successful open repair of a ZD was reported by Wheeler in 1882.[3] In 1917, Mosher first introduced the concept of endoscopic treatment of ZD that has now seen tremendous advances with respect to both instrumentation and technique.[4] The most common method used for treatment of ZD, the endoscopic staple-assist approach, was first reported by Collard in 1993.[5]

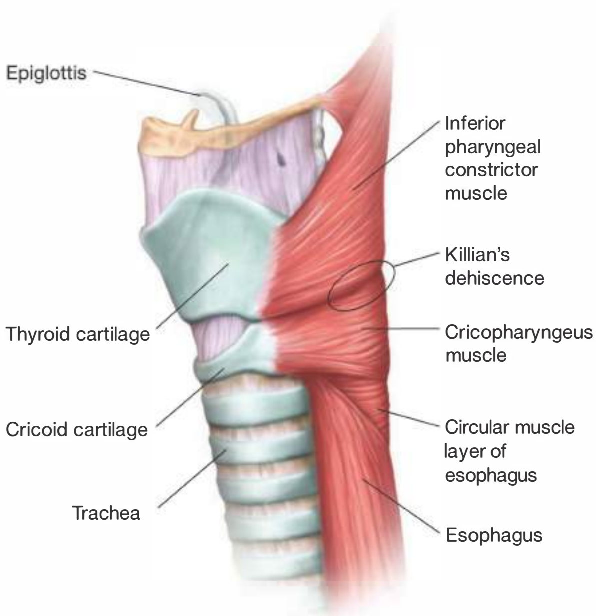

FIG 1 ● Anatomy of the junction of the hypopharynx and esophagus. Killian's dehiscence is located between the inferior pharyngeal constrictor and the CP muscle.

DIFFERENTIAL DIAGNOSIS

- Achalasia
- Esophageal cancer
- Esophageal dysmotility
- Esophageal spasm
- Esophageal stricture
- Gastroesophageal reflux disease (GERD)
- Thyroid goiter
- Myasthenia gravis
- Bulbar palsy

PATIENT HISTORY AND PHYSICAL FINDINGS

- Cervical dysphagia is the most common presenting symptom of ZD. Other symptoms may be quite subtle and include chronic cough, unexplained weight loss, and halitosis. As the patient swallows, the bolus preferentially enters the relatively wider mouth of the diverticular pouch rather than passing through the inappropriately closed upper esophageal sphincter into the esophagus. This in turn may lead to a sense of neck fullness and may be associated with a gurgling sound in the lower neck referred to as cervical borborygmi. Regurgitation of completely undigested food ingested minutes to hours previously is considered near pathognomonic for ZD. The pouch may fill and empty spontaneously during deglutition leading to coughing, choking, and possibly aspiration. Many patients report significant negative psychological and social impact due to a fear of suffering from choking and regurgitation during a meal.
- Most commonly, ZD patients present with a normal physical exam. When an abnormality is present, it is generally a neck mass in the tracheoesophageal groove that may gurgle or decompress with palpation (Boyce's sign). Audible gurgling may be detected over the same region with swallowing. Inspection of the hypopharynx may reveal pooling of secretions. Visualization of the pouch is generally only possible via esophagoscopy.

IMAGING AND OTHER DIAGNOSTIC STUDIES

- Barium swallow is the primary study used in the diagnosis of ZD. A characteristic sac is noted just posterior to the esophagus (**FIG 2**). It arises just superior to a prominent

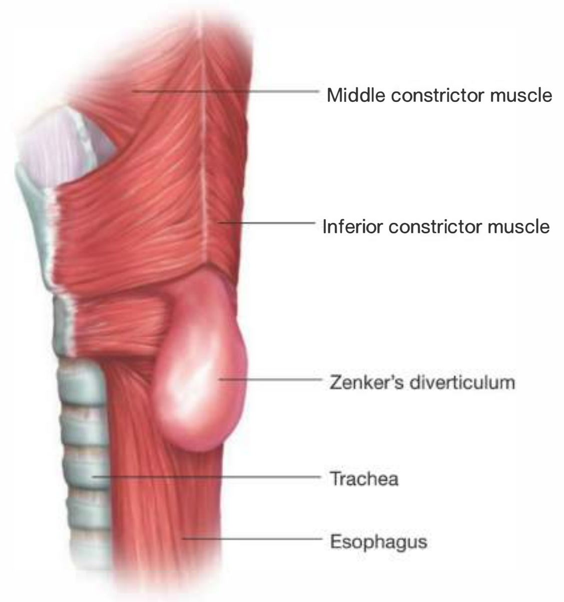

FIG 2 ● Zenker's diverticulum. The increase in intraluminal pressure during deglutition in face of relative cricopharyngeal hypertonia leads to the formation of a mucosal outpouching just superior to CP muscle (pulsion diverticulum).

CP muscle often termed a CP "bar." With this study, the surgeon can accurately size the sac and determine its location. Some authors recommend obtaining manometry testing on all ZD patients; however, that is not the practice of the authors. Computed tomography (CT) and magnetic resonance imaging (MRI) are not generally needed in these patients.

SURGICAL MANAGEMENT

Preoperative Decision Making

- The first decision a ZD surgeon has to make is whether to offer the patient surgery at all. If a patient is minimally symptomatic and of advanced age, then continued observation may be the best course of action. Medical therapy with botulinum toxin aimed at treating CP muscle achalasia is another option, although the benefit of this in ZD is much more limited than that seen in CP dysfunction without diverticulum. On the other hand, if surgery is to be offered to the patient, the surgeon should be capable of performing both open and endoscopic approaches and should clearly delineate the pros and cons of each. With an open approach, there is a cervical scar, longer surgical time, longer recovery, and longer delay to eating but potentially higher rates of symptom improvement and a lower rate of recurrent symptoms. With an endoscopic approach, there is no cervical scar, there is shorter surgical time, and most patients can resume eating the same day. Unfortunately, it is associated with a rate of recurrence as high as 10% in some reports.[6] The increased rate of recurrence is understandable as the act of dividing the common wall between the diverticular sac and the esophagus, and thus the CP muscle contained therein, does not always result in a complete CP myotomy. It is the belief of the authors that the rate of recurrence after an endoscopic repair may, at least in part, be directly related to the amount of CP muscle left intact.
- The primary anatomic considerations for an endoscopic repair include (1) factors related to exposure and (2) size of the diverticulum. Bloom et al.[7] reported unsuccessful exposure in 30% in a series of 30 patients in 2010. Shorter neck, shorter hyomental distance, and increased body mass index (BMI) showed significant correlation with failed exposure, whereas the presence of maxillary teeth trended toward significance. Further diminished cervical mobility and trismus may also hinder successful endoscopic exposure. With respect to the size, it is generally felt that very small (<2 cm) and very large (>4 cm) diverticulum may be best treated via an open approach. In the case of a small diverticulum, this is due to difficulty in engaging and grasping the common wall between the ZD and esophagus. Various modifications to the endoscopic technique address this and include using carbon dioxide (CO_2) laser or Harmonic scalpel, modifying the tip of the stapler to allow the blade and staples to be deployed closer to the tip of the device, and using traction sutures to pull the diverticulum into the jaws of the stapler.[8] The concern with a very large diverticulum is that the large, redundant, hypotonic sac may lead to persistent symptoms of dysphagia, although this is only anecdotal at present. Visosky et al.[9] reported a series 61 ZD patients who underwent endoscopic treatment and noted the main risk factors for recurrence were size larger than 3 cm and the associated amount of redundant mucosa noted after repair.

Operative Management—Endoscopic Approach

- The successful treatment of ZD via an endoscopic approach, much like the open counterpart, includes two components: a cricopharyngeal myotomy and management of the diverticular sac. In contrast to an open repair in which a myotomy is performed followed by management of the diverticulum itself, these occur simultaneously when performing an endoscopic repair. Essentially, the "common wall" or septum between the diverticulum and esophagus is divided, leading to the creation of a "common cavity." Structurally, the common wall is composed of the CP muscle with the herniated mucosa draped over it. In this sense, the two primary goals of ZD surgery can be achieved via an endoscopic approach, but they cannot be separated from one another.

- Patients are placed under general anesthesia and have oral endotracheal intubation. Preoperative antibiotics are given to cover oral flora. If teeth are present, they are protected with a rubber dental guard; if edentulous, a moist gauze is used to protect the alveolus. The eyes are protected with Tegaderm to maintain closure and gauze secured over top. A shoulder roll is used as needed to optimize position.
- A bivalve diverticuloscope is then used to expose the ZD. Either the adjustable Weerda diverticuloscope (Karl Storz, Tuttlingen, Germany) or the slightly longer, fixed blade van Overbeek (Medin, Groningen, Holland) is generally used. It is advanced into the postcricoid space and further into the hypopharynx with care not to cause mucosal injury by forcing the scope. The posterior blade is directed into the ZD and the anterior blade into the esophagus. If using the Weerda, adjustments are made to maximize visualization and the diverticuloscope is attached to a laryngeal suspension arm. At this point, the common wall or septum should be centered in the operative field between the two blades of the scope and probing of both the ZD and esophagus can be readily performed (**FIG 3**). Any food debris within the ZD is cleared with suction. The use of a 0- or 30-degree rigid Hopkins rod telescope facilitates excellent visualization of the surgical field. The authors prefer using a 30-degree telescope as the beveled lens affords varying views simply by rotation of the scope.
- It is at this stage in the endoscopic treatment of ZD that many variations and options exist. As stated, the most frequently performed procedure is a staple-assisted repair. This decreases the concern some surgeons have about the risk of mediastinitis in the setting of a sutureless repair as several staple lines are deployed along each side of the incision. Typically, the 35-mm Endo GIA (U.S. Surgical Corp, Norwalk, CT) is used in this technique (**FIG 4**). If this is not long enough, the surgeon may elect to use multiple 35-mm staple loads, a 45-mm staple load, or occasionally, the combination of endoscopic stapler and Harmonic scalpel. In an effort to minimize the amount of residual septum and thus the amount of residual CP muscle remaining after endoscopic staple-assisted repair, modification of the instrument was introduced. By shortening the anvil, the incising blade and the staple lines are allowed to extend closer to the base of the septum, thus leaving a lower residual septum and presumably minimizing the risk of persistent or recurrent symptoms. On the contrary, this modification does potentially increase the risk of perforation as the incising blade is more readily able to pass beyond the confines of the diverticulum. The authors routinely used a modified form of the Endo GIA stapler with excellent results and no increase in complications. Regardless of whether the stapler is modified, the staple cartridge blade is placed in the esophagus and the anvil blade is placed in the diverticulum (**FIG 5**). Once the blades are in position, they are approximated, thus grasping the septum. Again, the use of a telescopic lens allows rapid confirmation of accurate placement of

FIG 4 ● **A,B.** Endo GIA stapler. The area indicated at the tip of the stapler anvil represents the portion that is removed when a modified stapler is used.

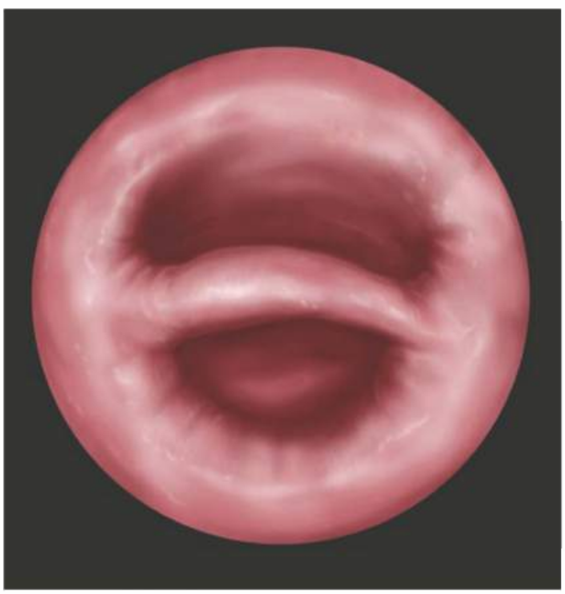

FIG 3 ● Endoscopic view of exposed ZD.

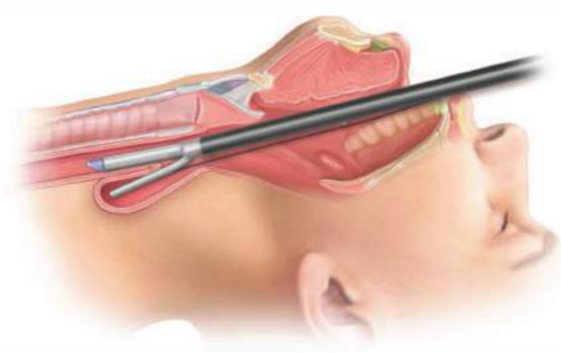

FIG 5 ● Lateral view showing the correct placement of the endoscopic stapler.

A
B
C

FIG 6 ● Endoscopic stapler-assisted repair of ZD. **A.** Endoscopic exposure with Weerda diverticuloscope. Note esophagus at the *top* of the photo and the ZD at the *bottom* of photo. **B.** Placement of the Endo GIA stapler with the staple cartridge blade in the esophagus and the anvil blade in the diverticulum. **C.** Appearance after division of the common wall by deployment of the Endo GIA staple cartridge.

the stapler. Activation of the stapler leads to simultaneous incision of the septum and stapling of both sides. Removal of the stapler allows assessment of the adequacy of the repair (**FIG 6**). If desired, a nasal feeding tube can be placed under direct visualization at this time.

- Additional methods for the endoscopic treatment of ZD include Harmonic scalpel and CO_2 laser. The authors use the Harmonic scalpel for endoscopic treatment of smaller ZD as this instrument is more readily able to grasp the septum (**FIG 7**). Whited et al.[10] reported an increased complication rate when comparing Harmonic to staple-assisted repair (25% vs. 4.88%). On the contrary, Sharp et al.[11] reported a higher complication rate in staple-assisted repair as compared to Harmonic scalpel (17.9% vs. 5%), although this was not significant. It should be noted that both studies reported that all complications occurred in patients with ZD larger than 2 cm. In the study by Sharp et al.,[11] the Harmonic scalpel was preferentially used in cases with smaller diverticulum size, a fact that may account for the lower complication rate in that group. Further, the authors use the CO_2 laser primarily for performing CP myotomy to treat cases such as CP dysfunction without ZD formation. This is primarily due to reports of mediastinitis as well as an increased incidence of subcutaneous emphysema with CO_2 laser division of the common septum,[12,13] indicating a possible increased risk of transmural injury of the pharynx. It is the opinion of the authors that this is most likely due to collateral thermal damage as well as the necessity of incising the mucosa and underlying muscle without grasping the septum, an aspect of both stapler- and Harmonic-assisted repair, which serves in part to limit the incision to tissue present within the lumen.

A
B
C

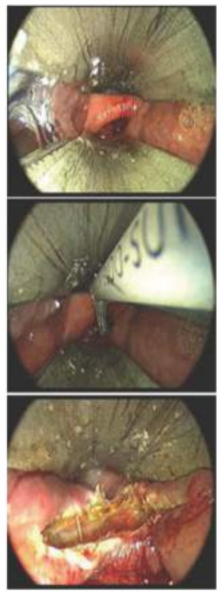

FIG 7 ● Endoscopic Harmonic-assisted repair of ZD. **A.** Endoscopic exposure with Weerda diverticuloscope. Note esophagus at the *top* of the photo and the ZD at the *bottom* of photo. **B.** Placement of the Harmonic scalpel on the common wall between the esophagus and the ZD. **C.** Appearance after division of the common wall with Harmonic scalpel.

PEARLS AND PITFALLS

- Diagnosis is generally suspected via history and confirmed by barium esophagram.
- Patients should be counseled regarding all treatment options including observation, open repair, and endoscopic repair. A surgeon who treats ZD should be comfortable with both endoscopic and open treatment as performing the same procedure for every patient is not likely to provide the best care.
- Regardless of approach, a complete CP myotomy is essential and failure to completely divide the muscle likely results in an increased rate of recurrent ZD.

POSTOPERATIVE CARE

- Following endoscopic ZD repair, patients are kept NPO until the absence of a pharyngeal leak is confirmed with a water-soluble contrast (i.e., Gastrografin) esophagram. The authors most often perform this on the morning of the first postoperative day but can be performed as early as 6 to 8 hours after surgery. If no leak is detected and a nasal feeding tube was placed, it is removed at this time and the diet is advanced. The patient is typically discharged at this time on a restricted liquid diet for the first 3 postoperative days and advanced to a soft diet as tolerated until follow-up appointment 2 weeks after discharge. If doing well, they can advance the diet to normal as tolerated at this time. On the contrary, if a leak is identified, the patient is kept NPO and maintained on enteral nutrition via a nasogastric feeding tube. If no nasal feeding tube was placed at the time of surgery, this is best accomplished under fluoroscopy to ensure the tube is not placed in a false passage. Alternatively, provided the leak was noted to be small, the patient can be kept NPO and maintained on intravenous (IV) fluids for a few days until a repeat esophagram shows resolution of the leak.

OUTCOMES

- Narne et al.[14] reported a 30-year experience comparing 297 patients treated via an open approach (n = 116) and an endoscopic staple-assisted approach (n = 181). Successful resolution of symptoms was reported in 92% and 94% in the endoscopic group and the open group, respectively. Of note, follow-up in the endoscopic group was 2 years compared to 4 years for the open group. Chang et al.[6] reported on 159 patients treated with endoscopic staple-assisted repair noting excellent results but a 12% recurrence rate. Other studies cite recurrence rates as high as 19% to 32%.[15,16] Another report compared patients treated by external approach (n = 101) with patients treated by an endoscopic approach (n = 86) and concluded that significantly more patients have symptomatic relief after open repair.[17] Although open and endoscopic approaches for treatment of ZD have not been compared in prospective clinical trials, most surgeons today prefer the less invasive endoscopic approach when feasible. Despite some variability in the data, treatment of ZD is via either approach.

COMPLICATIONS

- As with any transoral procedure, there is a risk of dental injury during the procedure. This risk can be minimized by use of a dental guard and exercising caution during the exposure. Major complications from endoscopic repair of ZD are predominately related to pharyngeal leak and associated infectious sequelae. Although recurrent laryngeal nerve injury has been reported from endoscopic repair of ZD,[18] the fact that the approach is intraluminal makes this complication exceedingly rare. Gutschow et al.[17] reported an increased rate of fistula in open repair compared to endoscopic repair (8.6% vs. 0%). Interestingly, five of the six cases of salivary fistula occurred after open repair that was performed without CP myotomy, further underscoring the importance of complete myotomy in the treatment of ZD. Three cases of mediastinitis occurred in this series, all in patients treated with CO_2 laser–assisted endoscopic repair.[17]

Several other studies comparing endoscopic staple-assisted and laser-assisted repair noted an increased rate of subcutaneous emphysema in those treated with the CO_2 laser.[12,13,19] Chang et al.[6] reported a 2.0% rate of significant complications without any mortality. Wasserzug et al.[20] reported two complications in his series of 60 patients treated with endoscopic staple-assisted repair. Esophageal perforation occurred in one case while severe esophageal edema occurred in another; both resolved with only conservative management.[20] Overall, the complication rate for endoscopic approach to repair of ZD is comparable if not favorable when compared to an open approach.

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Chapter 14

Epiphrenic Diverticulum Treatment

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James D. Luketich

DEFINITION

- Epiphrenic diverticula are those that occur in the distal 10 cm (lower third) of the esophagus. They constitute approximately 20% of all esophageal diverticula. The underlying pathophysiologic mechanism is a result of increased intraluminal pressure, presumably secondary to an esophageal motility disorder. Most commonly, epiphrenic diverticula occur in the setting of achalasia or diffuse esophageal spasm. A high-pressure environment in the esophageal lumen is potentially created by some form of distal functional or mechanical obstruction, such as a nonrelaxing, hypertensive lower esophageal sphincter (LES); repetitive normal to high amplitude simultaneous contractions; or a distal peptic stricture. A prior fundoplication for the treatment of reflux may also lead to epiphrenic diverticula in the setting of an esophageal motility disorder. Any of these processes may lead to herniation of the mucosa and submucosa through an area of weakness in the muscle layers of the esophagus. Epiphrenic diverticula are thus false, or pulsion, diverticula.

DIFFERENTIAL DIAGNOSIS

- The differential diagnosis of epiphrenic diverticula includes hiatal hernia, esophageal webs and strictures, esophageal duplication cyst, and esophageal carcinoma. Equally relevant is the differential diagnosis of the underlying cause of the epiphrenic diverticulum, which includes achalasia, diffuse esophageal spasm, nonspecific motility disorder, hypertensive LES, end-stage gastroesophageal (GE) reflux disease with a "burnt out" esophagus, peptic stricture, or failed previous fundoplication.

PATIENT HISTORY AND PHYSICAL FINDINGS

- Epiphrenic diverticula are estimated to be symptomatic in only 15% to 20% of cases. Typical symptoms include dysphagia and regurgitation. Reflux and chest pain may also commonly occur. Pulmonary symptoms may include chronic cough, productive or purulent sputum, or chronic dyspnea. Malodorous breath may also be present.
- On history, it is important to elicit whether the patient experiences symptoms of GE reflux disease, regurgitation, chest pain, or dysphagia. Additional medical history such as recurrent pneumonia, lung abscesses, or repeated aspiration episodes is pertinent. A history of weight loss is not uncommon.
- Prior procedures such as esophageal dilations or botulinum toxin injection are also pertinent.

IMAGING AND OTHER DIAGNOSTIC STUDIES

- Epiphrenic diverticula are associated with an underlying esophageal motility disorder in most cases. It is imperative to not only assess the size and location of the diverticulum but also to characterize the motor function of the esophagus.
- A barium esophagram is the initial test performed to define the anatomy of the diverticulum and esophagus. Size, location, and right or left sidedness can be determined from the esophagram. This provides a "road map" for operative planning, as diverticula more than 7 to 10 cm above the diaphragm are not easily accessible through the transhiatal route and may be better approached from the chest. Barium esophagrams may also offer information about motility.
- High-resolution manometry, the current gold standard, is necessary to evaluate for an underlying esophageal motility disorder. In the setting of achalasia, manometry demonstrates aperistalsis with a nonrelaxing LES. Other manometric patterns seen in the setting of epiphrenic diverticula include diffuse esophageal spasm (80% or more simultaneous contractions of normal amplitude), nonspecific motility disorder, nutcracker esophagus, or hypertensive LES. Failure to identify and treat the underlying motility disorder during diverticulum resection has been associated with high rates of recurrence and leak along the suture line in the range of 10% to 20%.[1] Specifically, failure to perform an adequate myotomy in such patients has yielded leak rates exceeding 25% when diverticulectomy alone is performed.
- Preoperative upper endoscopy is necessary to examine the esophagus and stomach for the presence of Barrett's, esophagitis, and to exclude malignancy.[2] In addition, the presence of a pop upon passage of the scope across the LES may further confirm the diagnosis of achalasia. Lastly, it is important to remove debris from the diverticulum on the day of surgery.

SURGICAL MANAGEMENT

- The need for surgical resection of epiphrenic diverticula largely depends on the patient's symptoms. Small, asymptomatic diverticula (less than 3 cm) often do not require intervention. Symptomatic patients with small diverticula may benefit from myotomy (with concomitant partial fundoplication) to correct the underlying motility disorder. Larger diverticula require diverticulectomy in addition to myotomy (with concomitant partial fundoplication).

Preoperative Planning

- A review of the barium esophagram is helpful to confirm the size and location of the diverticulum relative to the diaphragm and GE junction. It also defines the esophageal anatomy in terms of degree of esophageal dilation and presence of megaesophagus or sigmoid appearance in the setting of achalasia.
- The patient's diet should be restricted to clear liquids for 2 days prior to surgery to minimize the accumulation of food debris in the diverticulum prior to operation.
- The anesthesiologist must be informed that rapid sequence induction is needed to minimize risk of aspiration.
- After induction of anesthesia, upper endoscopy should be performed to delineate esophageal anatomy, rule out malignancy, and remove debris from the pouch. Esophagogastroduodenoscopy (EGD) should also evaluate for the presence of a "pop," which is consistent with achalasia.
- Prophylactic antibiotics should be administered prior to skin incision, with consideration given to covering for oral flora, anaerobes, and yeast.
- Standard procedures such as sequential compression devices and Foley catheter are employed.

Positioning

- Positioning of the patient varies with surgical approach. When approaching epiphrenic diverticula from the abdomen, the patient is positioned supine. If a thoracic approach is chosen, the patient is placed in either a right or left lateral decubitus position. The authors prefer a right-sided video-assisted thoracic surgery (VATS) approach, and therefore use the left lateral decubitus position. If a thoracic approach is used, single-lung ventilation is needed with use of a double lumen endotracheal tube or bronchial blocker.

TECHNIQUES

VIDEO-ASSISTED THORACIC SURGERY

- Either a right or left VATS may be used for a minimally invasive thoracic approach to the diverticulum. The location of the diverticulum typically dictates the side of the approach. Classically, distal diverticula have been approached from the left side, whereas more proximal diverticula are more readily approached from the right. However, in the authors' experience, a right-sided VATS approach works equally well for the classic, distally located right- or left-sided epiphrenic diverticula.

Video-Assisted Thoracic Surgery Port Placement

- We commonly employ a five-port approach to VATS resection of epiphrenic diverticula. The port placements are identical to the ports we employ for minimally invasive esophagectomy. Specifically, the surgeon works from the posterior ports, which include an infrascapular tip 5-mm port and a 10-mm port in the 9th interspace along a line parallel to the infrascapular tip port. The remaining three ports are assistant ports and include a 10-mm camera port in the 9th interspace along the posterior axillary line, a 5-mm port for endoscopic suction in the 7th interspace in the midaxillary to posterior axillary line, and a lung retraction 10-mm port in the 5th interspace in the posterior axillary line. See **FIG 1** for ideal placement of ports.[3]

Entering the Chest and Mobilizing the Esophagus

- Upon entering the chest, the inferior pulmonary ligament is divided and the lung is retracted superiorly and anteriorly.
- A diaphragm stitch is placed through the central tendon of the diaphragm with a 48-in 0-Surgidac Endo Stitch. It is brought out the right flank at the level of the inferior diaphragm insertion using an endoscopic Endo Close device. Tension is applied to the retraction stitch to retract the diaphragm caudally, exposing the distal esophagus and esophageal hiatus.
- Using sharp dissection with a heat source such as an ultrasonic scalpel, the mediastinal pleura overlying the esophagus is opened. As much of the pleura as possible is kept intact so that it may be reapproximated over the repair at the end of the procedure. As such, the pleura is gently dissected away from the esophagus. Opening

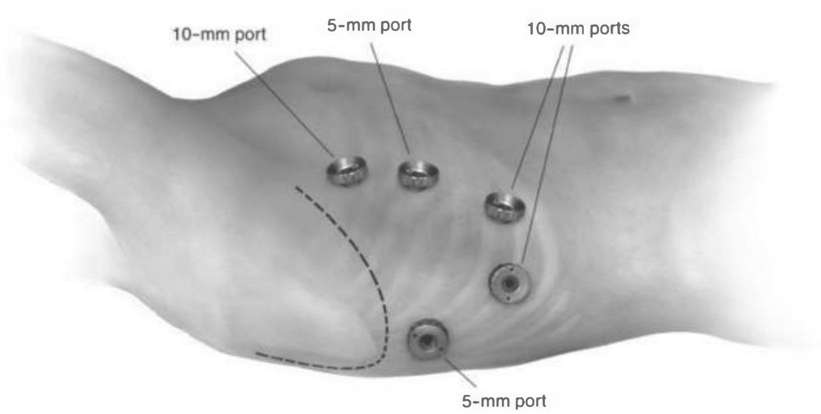

FIG 1 ● Right VATS thoracoscopic port placement.

of the mediastinal pleura from the diaphragm up to the azygous vein is beneficial, as it will be necessary for the performance of a long myotomy. The azygous vein can be divided as needed with an endoscopic stapler.

- Once the pleura has been opened adequately, esophageal mobilization is carried out. If an ipsilateral approach is taken to the diverticulum (right VATS for a right-sided diverticulum), minimal mobilization is needed. However, if the diverticulum protrudes on the contralateral aspect of the esophagus, the esophagus must be mobilized so that it may be rotated to provide adequate exposure for dissection of the diverticulum and its neck.
- A Penrose drain may be used to encircle the esophagus and aid in esophageal mobilization.
- Both vagus nerves should be identified and preserved whenever possible.
- It is necessary to expose the entire diverticulum and its neck. The diverticulum may be grasped with an endoscopic Babcock grasper (Snowden-type endoscopic forceps). Alternatively, a long stitch may be placed in the apex of the diverticulum to aid with retraction during dissection. Subsequently, the diverticulum is circumferentially dissected free from its surrounding attachments. It is not uncommon for there to be significant inflammatory type adhesions from the diverticulum to surrounding structures. It is essential to dissect the surrounding esophageal muscle fibers down to the neck of the diverticulum. This maneuver is critical in order to ensure complete resection of the diverticulum at the time of stapling. A common technical error is failure to expose the true neck of the diverticulum, which subsequently results in improper positioning of the stapling device and therefore leaves a residual diverticulum.

Diverticulectomy

- Once the neck of the diverticulum is clearly visualized, either the endoscope or a 48- to 54-Fr bougie should be inserted into the esophagus beyond the GE junction. This prevents narrowing of the esophageal lumen during stapling of the diverticulum. If difficulty is encountered passing the bougie, intraoperative upper endoscopy should be performed and a wire passed distally through the true lumen of the esophagus into the stomach. The bougie may then be passed over the wire to minimize risk of perforation.
- With minimal tension on the diverticulum, the stapling device is positioned along the base (neck), parallel to the longitudinal axis of the esophagus (**FIG 2**).
- The diverticulum is then transected with a reticulating endoscopic stapler. The authors prefer to use a vascular load for transection of the mucosa and submucosa that comprises the diverticulum.

Esophagomyotomy

- It is preferable to perform the myotomy at least 90 degrees away from the diverticular staple line if possible. The longitudinal esophageal muscle fibers are incised initially with either an ultrasonic scalpel or hook cautery along the direction of the fibers. Alternatively, the myotomy may also be started with a blunt technique by pulling apart the longitudinal muscle fibers. Once the underlying circular muscle fibers are exposed, they are sharply divided. It is critical to lift the circular muscle fibers away from the underlying mucosa to avoid perforation of the mucosa layer (**FIG 3**).

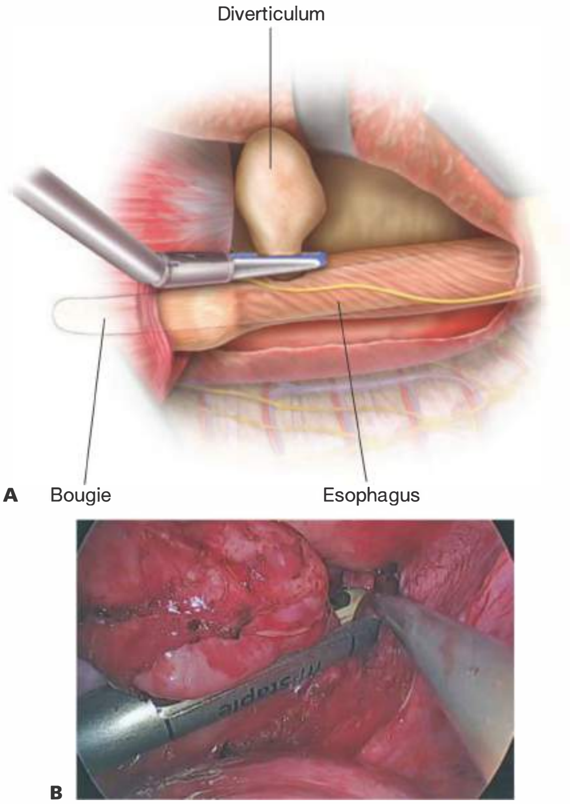

FIG 2 ● **A.** Circumferential dissection of the diverticulum, bougie in the esophagus, and endoscopic stapler excising the diverticulum. **B.** Excision of the diverticulum with the stapler placed at the neck of diverticulum.

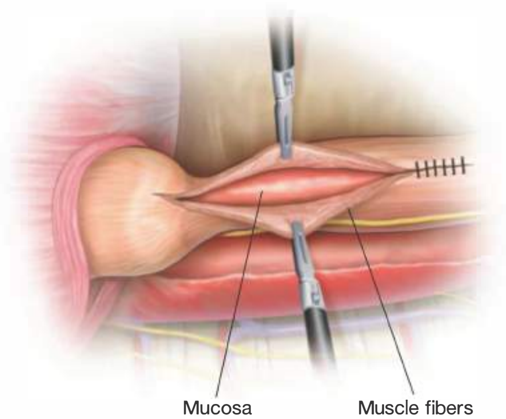

FIG 3 ● Esophageal myotomy with gastric cardia extension.

- Attempt to preserve the main vagal trunks while performing the myotomy.
- The total length of the myotomy should extend several centimeters (3 to 5 cm) above the proximal extent of the diverticulum. Distally, the myotomy should extend to or across the GE junction, depending on the preoperative manometry results and the underlying pathologic diagnosis. For example, an LES that has a normal resting pressure and normal relaxation may not require myotomy across the GE junction, preserving its natural antireflux function. If the patient has achalasia, the myotomy should ideally extend to 3 cm below the GE junction, carrying the myotomy onto the sling muscle fibers of the gastric cardia.
- The muscle layer is dissected laterally off the underlying mucosa for a short distance in the submucosal plane to prevent potential healing of the myotomy site (muscle reconstitution).
- The integrity of the myotomy and diverticulectomy sites are submerged under saline and upper endoscopy with insufflation of air is done to check for leaks. Intraoperative mucosal perforations are repaired with interrupted absorbable suture. The muscle layers are then reapproximated over the diverticulectomy staple line with interrupted 2-0 Surgidac Endo Stitch.
- The mediastinal pleura may also be loosely reapproximated over the esophagus with interrupted 2-0 Surgidac Endo Stitch for additional protection of the staple line.
- The need for an antireflux procedure should also be addressed at this point, depending on the patient's preoperative reflux symptoms and motility studies.[1,4] If the patient carries a diagnosis of achalasia, an antireflux operation should be considered. There are several options at this point. If performing the case from a left VATS, one may attempt a Belsey Mark IV fundoplication. This can be quite challenging and technically demanding from a VATS approach (traditionally performed via left thoracotomy). A second option is to combine VATS with laparoscopy and perform a standard laparoscopic Dor or Toupet (partial) fundoplication. Partial fundoplications are favored in the setting of esophageal motility disorders, as a complete (Nissen) fundoplication may lead to obstruction of the dysmotile esophagus and recurrent diverticula. Lastly, one could forego the antireflux procedure and treat any reflux symptoms with proton pump inhibitors (PPI), opting to perform a fundoplication selectively at a later time depending on patient symptoms and response to medical therapy.

Closure

- Once hemostasis is achieved, a pleural drain (chest tube, Blake drain, or pigtail catheter) is placed.
- A Jackson-Pratt (JP) drain is also placed along the posterior mediastinum near the diverticula staple line to control any leak that can potentially occur postoperatively.
- Intercostal bupivacaine is injected for analgesia.

OPEN THORACIC APPROACH

- The operative steps for an open transthoracic epiphrenic diverticulum resection are similar to those described earlier for the minimally invasive approach. A 7th interspace thoracotomy is used. An open left thoracic approach is ideal when a fundoplication is to be performed from the chest (Belsey Mark IV). Use of a thoracoabdominal (TA) stapler or resection and hand-sewn closure of the mucosa are commonly used techniques for resection of the diverticulum when an open approach is used.

LAPAROSCOPIC TRANSHIATAL APPROACH

Port Placement

- The patient is initially positioned supine, with arms out and a footboard in place (to allow for reverse Trendelenburg positioning, which improves hiatal exposure). The surgeon operates from the right side of the table.
- The abdomen is then mapped. A line is drawn from the xiphoid to the umbilicus and divided into thirds. Five abdominal ports are used (**FIG 4**). The initial port is placed via an open (Hassan) technique in the right paramedian area at the junction of the upper and middle thirds of the previous markings. Pneumoperitoneum is set to 15 mmHg. The left paramedian port serves as the camera port. The assistant then retracts the hepatic flexure to expose the lateral abdominal wall just below the 12th rib. A 5-mm port is placed here and the liver retractor brought in and placed under the left lobe of the liver, retracting it superiorly to expose the esophageal hiatus. Finally, bilateral

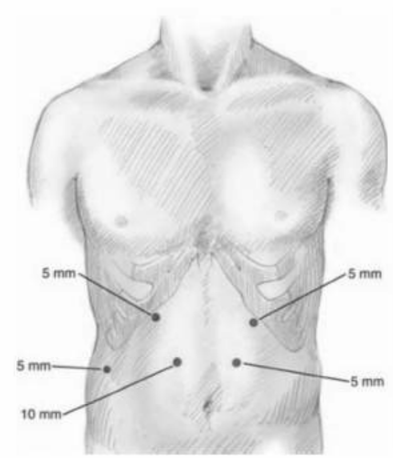

FIG 4 ● Laparoscopic port placement for abdominal approach.

midclavicular subcostal ports are placed. All ports should be a handbreadth apart to avoid unwanted contact between the surgeon's and assistant's instruments. Skin incisions must be made as small as possible to help ports remain in place and minimize accumulation of subcutaneous emphysema. See FIG 4 for ideal placement of ports.[2,5]

Mobilizing the Esophagus

- The gastrohepatic ligament is opened with an ultrasonic scalpel or other energy device to expose the right crus.
- The phrenoesophageal membrane is divided circumferentially around the esophageal hiatus to gain access to the mediastinum and intrathoracic esophagus. The peritoneal lining along the left and right crura should be preserved. Mediastinal mobilization of the esophagus, GE junction, and any associated hiatal hernia is then performed. The anterior and posterior vagal nerves should be identified and preserved during this dissection.
- The short gastric vessels and gastrosplenic attachments are divided so that the upper third of the fundus along the greater curvature is completely mobile for creation of the fundoplication.

Diverticulectomy

- As described earlier, it is necessary to expose the entire diverticulum and its neck. The diverticulum is circumferentially dissected free from its surrounding attachments. Again, it is essential to dissect off the surrounding esophageal muscle fibers down to the neck of the diverticulum. This maneuver is critical in order to ensure complete resection of the diverticulum at the time of stapling.
- Once the neck of the diverticulum is clearly visualized, either the endoscope or a 48- to 54-Fr bougie should be inserted into the esophagus beyond the GE junction as described previously. This prevents narrowing of the esophageal lumen during stapling of the diverticulum.
- With minimal tension on the diverticulum, the stapling device is positioned along the base (neck) parallel to the longitudinal axis of the esophagus.
- Transect the diverticulum with a reticulating endoscopic stapler at its neck.

Esophagomyotomy

- It is preferable to perform the esophagomyotomy 180 degrees from the staple line. However, if this is not possible, then it is preferable to perform the myotomy at least 90 degrees away from the diverticulectomy site.
- The authors prefer to start the myotomy by separating the longitudinal muscle fibers with a blunt technique using Snowden forceps. It is important to pull with equal tension along each side during this maneuver. Once the myotomy is started, we often switch to sharp division of the remaining longitudinal and circular fibers using the ultrasonic scalpel or hook electrocautery. The proximal extent of the myotomy should extend several centimeters above the proximal extent of the diverticulum. If the patient has achalasia, the distal extent of the myotomy should be 3 cm distal to the GE junction so as to include the sling fibers of the proximal most aspect of the gastric cardia.
- Once again, the muscle layer is dissected off the underlying mucosa laterally on each side for a short distance in the submucosal plane to prevent potential healing of the myotomy site (muscle reconstitution).
- Mucosal integrity can be examined by submerging the esophagus in saline and insufflating with the endoscope to look for an air leak. Small leaks can be closed with a simple stitch.
- Along the diverticulectomy site, the muscle layers of the esophagus are reapproximated over the staple line with 2-0 Surgidac Endo Stitch.
- As mentioned previously, at the end of the esophagomyotomy, an antireflux procedure is often performed, which is most commonly a partial fundoplication (Dor, Toupet, or Belsey Mark IV). The authors prefer an anterior 180-degree fundoplication (Dor) for most cases of achalasia and epiphrenic diverticula (FIG 5).

Closure

- A JP drain is placed through the hiatus along the diverticulum staple line to control any potential leak that may occur postoperatively.

FIG 5 ● Laparoscopic Dor anterior fundoplication.

PEARLS AND PITFALLS

Diverticulectomy	■ Staple over a bougie or endoscope to prevent esophageal luminal narrowing. ■ Incomplete dissection of the diverticular neck can lead to stapling too high, leaving a residual diverticulum.
Esophagomyotomy	■ Failure to perform an adequate esophagomyotomy is associated with up to a 20% rate of recurrence and/or leak. Be sure to extend the myotomy beyond the borders of the staple line longitudinally and to address the original motility disorder. ■ Reapproximate the esophageal wall muscle loosely over the diverticulum resection site. This can help minimize the development of pseudodiverticulum at the site. ■ Attempt to preserve the mediastinal pleura that overlies the esophagus. It is helpful to have this layer to close at the end of the case.
Fundoplication	■ Choice of antireflux procedure should be based on patient's reflux symptoms, anatomy, and esophageal motility.

POSTOPERATIVE CARE

- Postoperatively, patients are maintained NPO overnight. Standard use of deep venous thrombosis (DVT) and gastrointestinal (GI) prophylaxis is employed.
- Due to the presence of a fresh myotomy, the authors typically avoid usage of a nasogastric tube. Hang a sign over the patient's bed that states, "Do Not Place a Nasogastric Tube Under Any Circumstance." Blind passage of a nasogastric tube without endoscopic guidance could result in perforation of the mucosa.
- Barium esophagram is performed 24 to 48 hours after surgery to rule out leak or perforation.
- After esophagram, patients can be started on a clear liquid diet (Nissen clear liquid diet).
- The diet is then advanced to Nissen full liquids in the following days, followed by a soft diet. The diet may then be advanced further when the patient is seen in the clinic 2 weeks later.

OUTCOMES

- Interpretation of the literature regarding surgical management of epiphrenic diverticula is difficult owing to the variability in the following:
  - Approach (thoracotomy, VATS, laparoscopic, or combination of approaches)
  - Direction from which the esophagus is approached (right transthoracic, left transthoracic, or transabdominal)
  - Procedures performed (diverticulectomy alone, myotomy alone, diverticulectomy + myotomy, diverticulectomy + myotomy + fundoplication)
  - Choice of fundoplication (Dor, Toupet, Nissen, Belsey Mark IV)
  - Only small case series being reported
- Controversy exists regarding whether or not all epiphrenic diverticula should be treated surgically. Some surgeons have advocated for a more selective approach,[6] whereas others have supported surgical treatment of all patients with epiphrenic diverticula.[1] The current trend is to only operate on patients with severe symptoms (e.g., dysphagia, regurgitation, aspiration) owing to the low rate in progression of symptoms noted in asymptomatic/mildly symptomatic diverticula, which was noted to be 2.8% in a review by Zaninotto and colleagues.[7]
- There are currently no reports in the literature directly comparing open to minimally invasive approaches; however, recent reviews have concluded that better outcomes are obtained with a minimally invasive approach in regard to morbidity, mortality, and length of stay (greater than 1 week in open series and less than 1 week in most minimally invasive series).[8,9]
- Reported morbidity rates in open series range from 5% to 38%[1–3,10–13] with leaks rates ranging from 0%[1,10] to as high as 21%.[2] Thirty-day mortality rates ranging from 0% to 15% demonstrates that surgical treatment of epiphrenic diverticula is not without risk.
- Although minimally invasive approaches (VATS, laparoscopic, or a combination of the two) appear to have similar morbidity rates, ranging from 7% to 45% in series with greater than 10 patients,[4,5,14–18] mortality appears to be significantly lower with only one reported 30-day death[5] and one additional in-hospital death.[4] Leaks rates again are similar in these series, ranging from 0% to 23%.
- There are currently two published small series[19,20] reporting the results of VATS treatment of epiphrenic diverticula. Six of eight patients operated on were completed thoracoscopically in the series reported by Perrachia,[19] whereas one of five patients required laparoscopy to complete the procedure in van der Peet's series.[20] The few other series reporting use of a VATS approach include a mix of other approaches as well,[4,13,15,21,22] making it impossible to make comparisons between minimally invasive approaches (e.g., laparoscopic vs. VATS). The authors favor a right VATS approach for diverticula 7 cm or more above the hiatus, diverticula with anticipated dense adhesions, and redo operations for treatment of recurrent diverticula previously treated with a transabdominal approach.
- The literature reporting use of a laparoscopic approach is more robust,[4,5,15,16,18,22,23] with some authors proposing that the laparoscopic approach be considered the standard initial approach for surgical treatment of epiphrenic diverticula.[22]
- There also remains controversy about what procedures need be performed for adequate surgical treatment of epiphrenic diverticula. Those in favor of both diverticulectomy and myotomy note that recurrence and suture line leaks appear to be more common in patients who have not had a myotomy.[2,3] There are also proponents who favor a more selective approach for myotomy, particularly in patients with

hypotonic esophageal body motor function and/or LES as well as normal esophageal motility.[11,24]

- The length/extent of myotomy required also remains to be clarified. Some authors prefer not to carry the myotomy across the GE junction in case where there is normal LES function. Although others favor a long myotomy that is carried across the GE junction and onto the gastric cardia in all cases.[25,26] The reason for this being that some esophageal motility disorders may occur intermittently and therefore may not be revealed on preoperative manometry testing.[12] The authors favor a long myotomy in all cases, except for those in which there is a distal mechanical obstruction (peptic stricture, stenotic previous fundoplication) with normal esophageal motility. In cases such as this, removal of the distal obstruction (dilation, revision to a partial fundoplication) and diverticulectomy may be all that is needed.
- Inclusion of an antireflux procedure and which type of fundoplication should be employed are additional areas of debate. Some believe that an antireflux procedure should be included in all cases in which the myotomy is carried across the LES and onto the stomach, as these patients are more prone to reflux given the loss of the barrier function of the LES. Most surgeons favor a partial fundoplication (Dor, Toupet, or Belsey Mark IV) due to the high prevalence of ineffective esophageal motility. It should be noted that performing a fundoplication via a VATS approach is technically challenging. The authors favor a laparoscopic Dor fundoplication, either from an initial laparoscopic approach or in combination with a right VATS approach, for patients with significant GE reflux preoperatively, achalasia, hiatal hernia, or when significant dissection in the area of the GE junction performed.

COMPLICATIONS

- Leak
- Perforation
- Pleural effusion
- Pneumothorax
- Empyema
- Bleeding
- Recurrence
- Death

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Chapter 15

Long Myotomy for Diffuse Esophageal Spasm

David D. Odell   James D. Luketich

DEFINITION

- Diffuse esophageal spasm (DES) is a nonspecific motility disorder of the esophagus characterized by intermittent and disorganized smooth muscle contractions, often resulting in debilitating dysphagia and/or severe substernal chest pain.

DIFFERENTIAL DIAGNOSIS

- DES is part of a spectrum of motility disorders affecting the esophagus. Consequently, a careful assessment of the clinical presentation and objective diagnostic testing is imperative in order to avoid misdiagnosis and inappropriate treatment. Several conditions may mimic the symptomatic presentation of DES.
  - Achalasia: Characterized by incomplete relaxation of the lower esophageal sphincter coupled with aperistalsis of the esophageal body. Focal distal (Heller) myotomy extending onto the gastric cardia is the treatment of choice for this condition.
  - Nutcracker esophagus: Primary motility disorder of the esophagus characterized by high-amplitude, peristaltic contractions of the distal esophagus. Patients present with pain but do not have dysphagia. Treatment is predominantly medical with the use of calcium channel blockers.
  - Connective tissue disorders: Connective tissue diseases such as scleroderma frequently impact esophageal motility. Patients presenting with primary symptoms of dysphagia should be evaluated for other systemic manifestations of these conditions.
  - Gastroesophageal reflux disease (GERD): Patients with untreated or poorly treated long-standing reflux may develop esophageal dysmotility from chronic inflammation caused by the refluxate. In these patients, control of the reflux (medically or surgically) will typically resolve the motility issues.
  - Pseudoachalasia: Mechanical obstruction of the esophagus from tumor, hiatal hernia, prior antireflux surgery, or foreign body may cause symptoms of dysphagia, esophageal dilation, and dysmotility. Correction of the underlying pathology is the appropriate treatment in these patients and esophageal motility often returns to normal once this is accomplished.

PATIENT HISTORY AND PHYSICAL FINDINGS

- A careful history focused on symptoms of dysphagia is helpful in evaluating patients for DES. Patients should be asked to characterize the frequency (every meal, daily, weekly, etc.) and severity (solids, liquids, salivary secretions, etc.) of their dysphagia.
- Patients should be asked about pain. The quality and duration of symptoms are important details to elicit as well as the relationship of symptoms to swallowing.
- Typical and atypical reflux symptoms should be directly questioned.
  - Typical: heartburn, history of stricture/dysphagia, water brash, globus sensation
  - Atypical: cough, hoarseness of voice, aspiration, recurrent pulmonary infection
- Cardiac history (prior myocardial infarction, history of exertional chest pain, review of any prior cardiac procedures or evaluations [i.e., catheterizations or stress testing])
- Connective tissue disease history: Evaluation of cutaneous lesions, healing difficulty, and concomitant visual problems

IMAGING AND OTHER DIAGNOSTIC STUDIES

- Barium swallow—will show a classic corkscrew appearance of the esophagus characteristic of the disease and corresponding to the simultaneous contractions.
- Esophageal manometry—primary tool for establishing the diagnosis. The disease is typically characterized by simultaneous contractions (30 to 100 mmHg) with intermittent normal peristalsis. DES is typically defined as the presence of symptoms in concert with simultaneous contractions after greater than 10% to 30% of wet swallows. Amplitude of these simultaneous contractions should exceed 30 mmHg to support the diagnosis. The diagnosis of DES is more certain with a higher percentage of simultaneous contractions.
- Esophagogastroduodenoscopy (EGD)—required to assess the anatomy prior to intervention and to rule out alternative pathology. EGD will allow causes of pseudoachalasia (tumor, stricture, obstruction/compression) to be fully assessed with biopsies taken as necessary. This also allows the surgeon the ability to assess for the presence of reflux-related changes, such as Barrett's esophagus, which may require further surveillance. In advanced stages of DES, the endoscopic appearance of the esophagus may be somewhat corrugated as hypertonic muscular bands tend to form in fixed positions.
- Endoscopic ultrasound (EUS)—a useful adjunctive test in surgical planning, as the extent of the spasmodic muscular segment may sometimes be identified by the presence of thickening of the muscular layer on EUS.
- pH studies—may confirm the presence of acid reflux and may help guide the decision to include a fundoplication at the time of surgical correction.

SURGICAL MANAGEMENT

- The bulk of surgical treatment is discussed in the "Techniques" section. Here, consider indications and other more general concerns.

Preoperative Planning

- Patients should be thoroughly counseled regarding the risks of the operation including esophageal perforation, persistent dysphagia, and exacerbation of reflux symptoms. Alternative treatment options including pharmacotherapy with calcium channel blockers should be discussed.

- A liquid diet should be administered for 2 days prior to surgery (longer if significant delay in esophageal clearance is expected).

Patient Positioning

- The patient is turned to the left lateral decubitus position. A beanbag is placed underneath the patient to afford additional support and to fix the patient in position. An axillary roll is positioned at the base of the axilla to minimize nerve compression. Position of the double lumen endotracheal tube, placed prior to turning the patient lateral, is reconfirmed using a pediatric endoscope. The operating surgeon stands on the right side of the table (facing the patient's back) while the assistant stands on the left side of the table.

Airway Management

- The patient is intubated with a double lumen endotracheal tube. This allows for lung isolation on the operative side to provide adequate exposure.

THORACOSCOPIC APPROACH

Port Placement

- A total of five thoracoscopic ports are used (**FIG 1**). A 10-mm camera port is placed in the 8th or 9th intercostal space, just anterior to the midaxillary line. The working port is a 10-mm port placed in the 8th or 9th intercostal space, posterior to the posterior axillary line. Another 10-mm port is placed in the anterior axillary line at the 4th intercostal space, through which a fan-shaped retractor aids in retracting the lung to expose the esophagus. A 5-mm port is placed just inferior to the tip of the scapula for the surgeon's left hand. A final 5-mm port is placed at the 6th rib, at the anterior axillary line for suction by the assistant.

Diaphragm Retraction

- Adequate retraction of the diaphragm is essential to achieve visualization of the lower thoracic esophagus and to aid in the dissection. A retracting suture is used to facilitate this retraction (**FIG 2**). We place a 48-in, 0-Surgidac suture through the central tendon of the diaphragm using the Endo Stitch device. The suture is brought out through the lateral chest wall at the level of the insertion of the diaphragm through a small stab incision, retracting the diaphragm inferiorly in order to expose the distal esophagus.

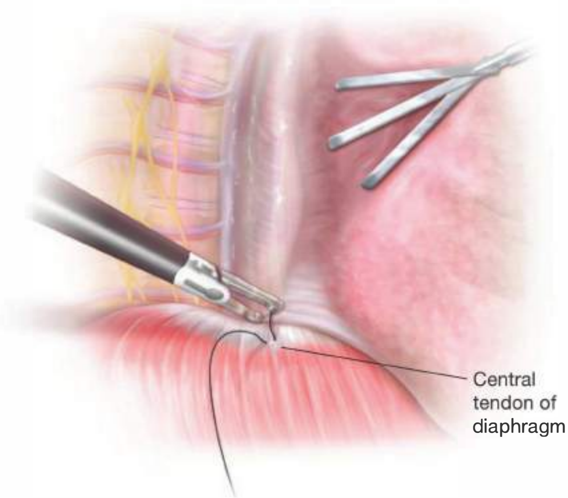


FIG 2 ● Diaphragm retraction suture. Placement of a suture in the central tendon of the diaphragm facilitates retraction and improves visualization of the esophagus.

Pleural Dissection and Esophageal Mobilization

- The inferior pulmonary ligament is divided to the level of the inferior pulmonary vein to allow for maximal anterior lung retraction (**FIG 3A**).

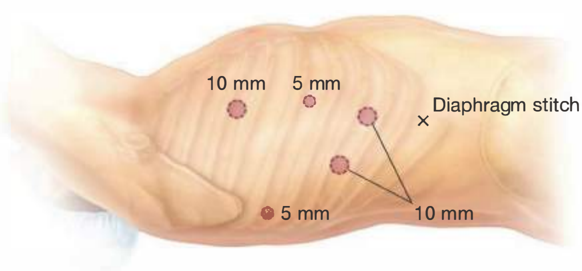


FIG 1 ● Port placement: positioning of the thoracoscopic ports used for esophageal myotomy.

- The dissection is carried onto the avascular pleural plane along the surface of the pericardium, overlying the esophagus (**FIG 3B**). The pleura is incised to expose the esophagus. This dissection is carried superiorly to the level of the subcarinal space. As the goal is to adequately mobilize the esophagus, the nodes may be left in situ rather than mobilizing them with the esophagus, as would be done in a cancer operation.

Airway Dissection

- Care must be taken to identify the membranous wall of the right mainstem bronchus (**FIG 3C**), as it is easily injured during this phase of the dissection. Removing any suction from the right lung during this dissection will prevent the membranous wall from collapsing and can aid in visualization.

Superior Dissection

- The lung is next retracted anteriorly and the pleura incised along the anterior border of the esophagus to the

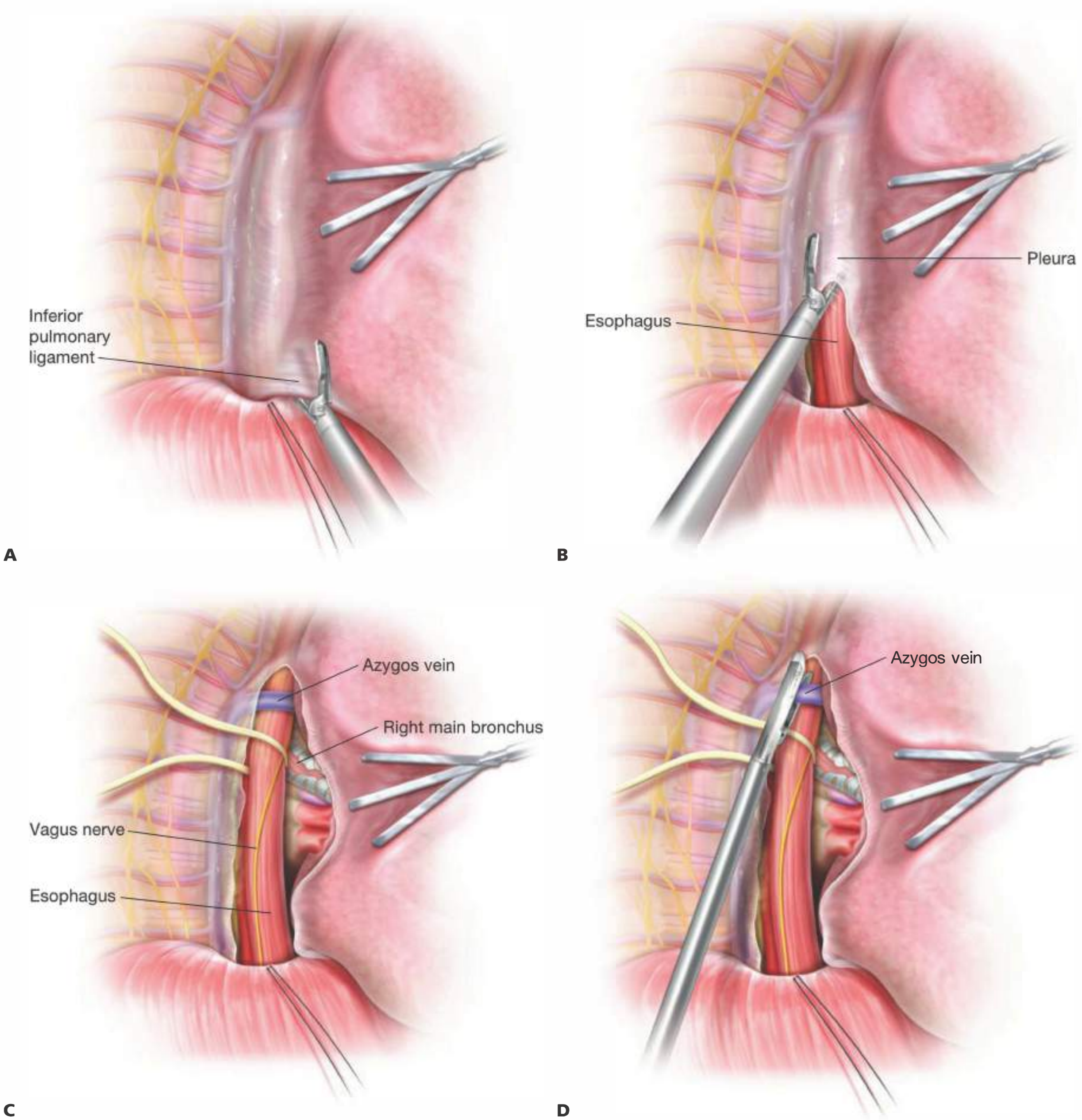
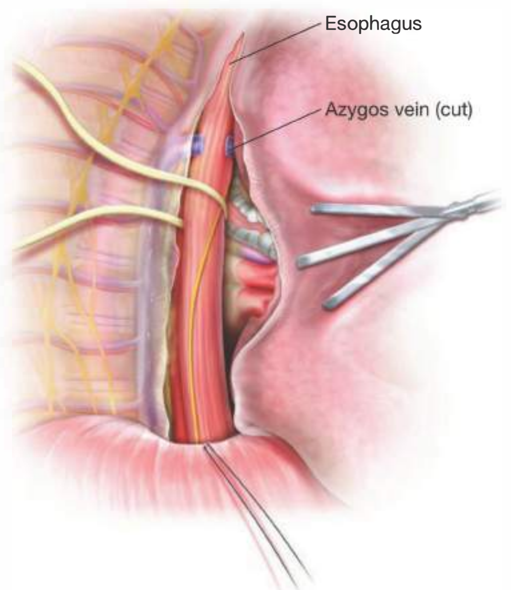


FIG 3 ● Pleural dissection. **A.** Mobilization of the inferior pulmonary ligament. **B.** Beginning of the dissection along the pericardium. **C.** Pleura is incised overlying the esophagus and a Penrose drain used to encircle the esophagus for retraction. The anterior boundary of dissection along the bronchus intermedius. **D.** Division of the azygous vein using an endoscopic stapler. *(continued)*



E

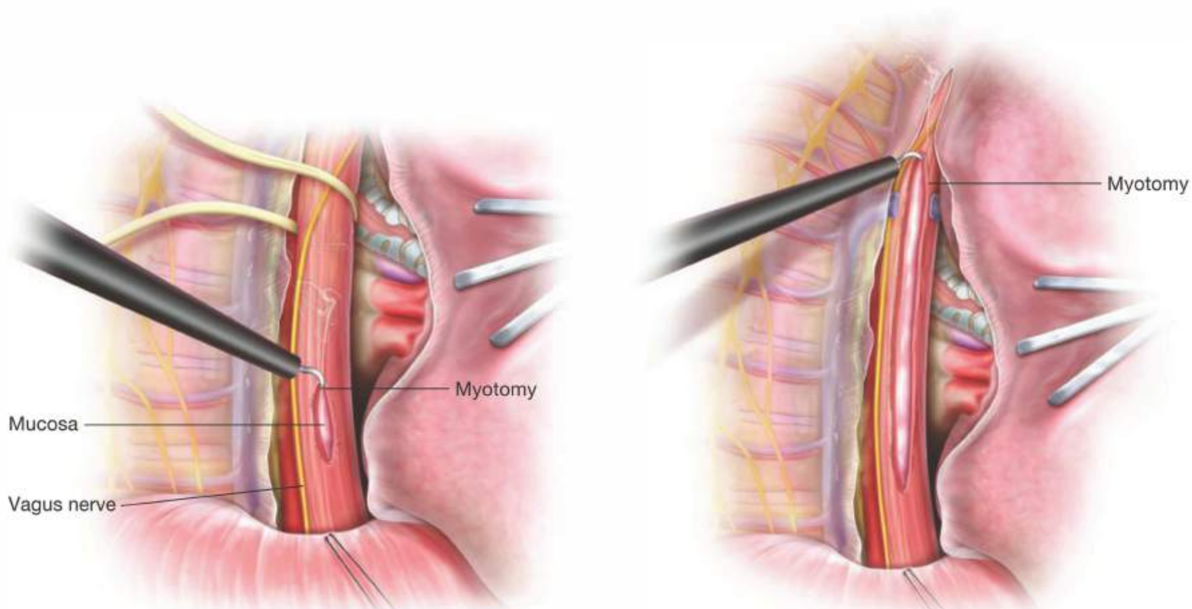
FIG 3 ● *(continued)* **E.** Dissection above the azygous directly on the esophagus to avoid recurrent nerve injury.

level of the azygous vein. The azygous may be divided if the spasmodic segment of esophagus extends above this level (**FIG 3D**). The vagus nerve should be identified and preserved to retain normal gastric emptying and pyloric function.

- Above the level of the azygous vein, dissection is kept close to the esophagus to avoid injury to the recurrent laryngeal nerves (**FIG 3E**). The extent of superior dissection and mobilization depends on the location of the spasmodic portion of the esophagus. Careful review of the preoperative barium swallow examination and manometry studies is necessary to make this determination.

Esophagomyotomy

- The myotomy is begun 6 to 7 cm above the diaphragm. The longitudinal muscle layer of the esophagus is visualized and incised using either hook electrocautery or an energy dissection device (**FIG 4**). The myotomy is carried through the underlying circular muscle layer to expose the esophageal mucosa. The cut ends of the muscle layer should be gently separated from one another to prevent early reapproximation as the myotomy heals. Careful examination of the mucosa should be performed to ensure it is intact.
- The myotomy may be carried onto the stomach if the preoperative manometry indicates dysfunction of the lower esophageal sphincter as a contributing factor in the pathology. The esophagogastric junction and beginning of the gastric cardia may be elevated into the thorax by applying traction to the muscular wall of the esophagus. The esophagogastric junction is marked by the phrenoesophageal ligament through which the left gastric vein travels and is a reasonable landmark for the dissection. Extra care should be taken in the dissection at this level, as the mucosa becomes appreciably thinner at the esophagogastric junction (EGJ).



A B

FIG 4 ● **A,B.** Esophagomyotomy is performed using an energy device.

Evaluation for Leak

- A careful endoscopy is performed to examine the mucosa for any evidence of injury incurred during the creation of the myotomy. Water or saline may be instilled into the chest to submerge the myotomized esophagus in order to elucidate small mucosal tears or full-thickness injury identified with air insufflation via the endoscope.

Closure

- A single chest tube is left in place at the completion of the operation and the lung is aerated under direct vision to ensure complete parenchymal reexpansion. Skin incisions are then closed in layers with absorbable suture.

LEFT THORACOTOMY APPROACH

Thoracotomy Incision

- A left posterolateral thoracotomy incision is made through the 6th or 7th intercostal space (**FIG 5**). A 1-cm section of the 7th rib is resected posteriorly to facilitate wide exposure of the left hemothorax. A nasogastric tube is left in position to facilitate easy identification of the esophagus. The inferior pulmonary ligament is divided so that the lung can be retracted superiorly away from the hiatus (**FIG 6**).

Pleural Incision and Esophageal Exposure

- The mediastinal pleura is incised overlying the esophagus just above the level of the hiatus (**FIG 7**). Dissection is carried circumferentially and a Penrose drain is looped around the esophagus to facilitate retraction without trauma during the course of the dissection. A complete mobilization of the esophagus may not be needed if a fundoplication is not required, although this step will be necessary if a concomitant antireflux procedure (such as a Nissen or Belsey Mark IV fundoplication) is planned.

Esophageal Myotomy

- Using a Metzenbaum scissors or an energy device, the longitudinal layer of muscle is incised to expose the circular muscle fibers (**FIG 8**). These circular fibers are then incised and the cut edges retracted laterally to reapproximation with healing.
- The myotomy length is determined by the extent of abnormal esophagus as assessed on the preoperative imaging evaluation as well as the intraoperative endoscopy (**FIG 9**). In many cases, the spastic segment does not involve the lower esophageal sphincter (LES) and this structure can be spared, preserving the native antireflux mechanism. For those patients in whom the myotomy is carried across the LES, an antireflux procedure may be performed either from the left chest via thoracotomy or by repositioning for a transabdominal approach. Once the myotomy has been performed, attention is given to closure of the crura so as to prevent herniation.
- An air leak test can be performed as described in the video-assisted thoracic surgery (VATS) approach.

Chest Closure

- Standard principles of thoracotomy closure are applied to this case. A single chest tube is left in place in the pleural space to assist with lung expansion.

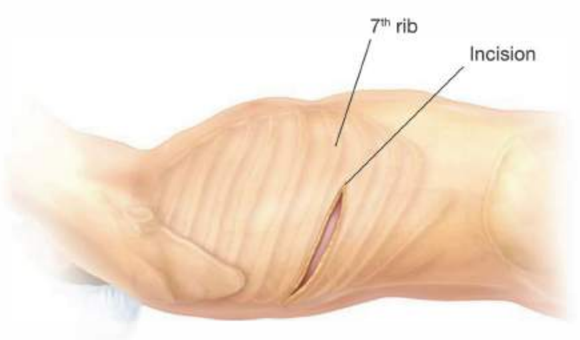


FIG 5 ● Thoracotomy performed through the 7th intercostal space.

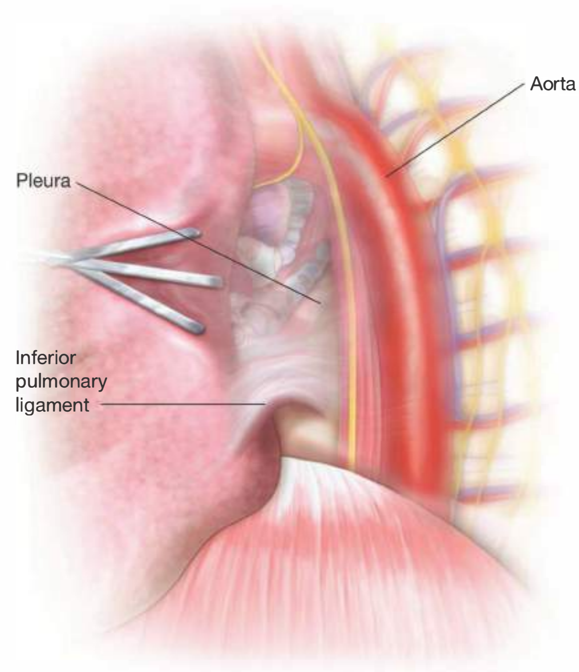


FIG 6 ● Division of the inferior pulmonary ligament and posterior retraction of the lung.

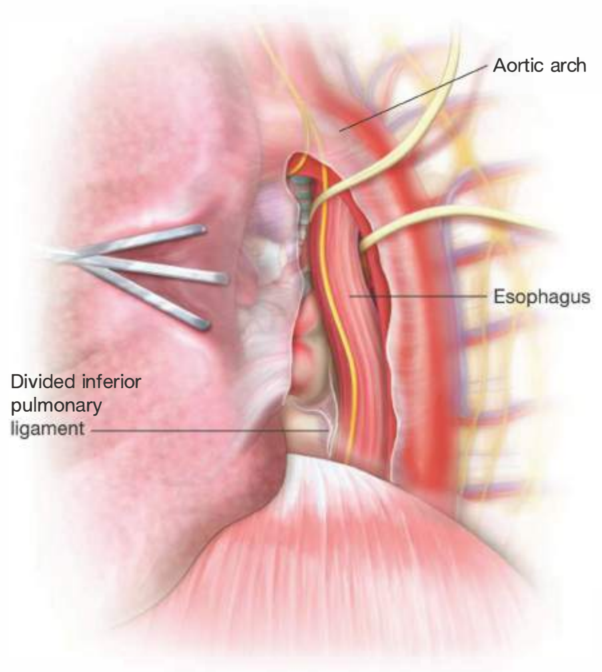


FIG 7 ● Opening of the pleura overlying the esophagus. The esophagus can be encircled with a Penrose drain to facilitate retraction.

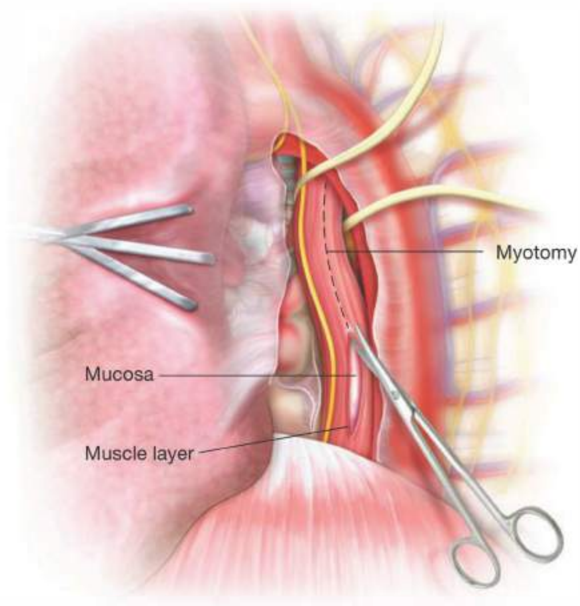


FIG 8 ● The myotomy is begun with a Metzenbaum scissors or an energy device.

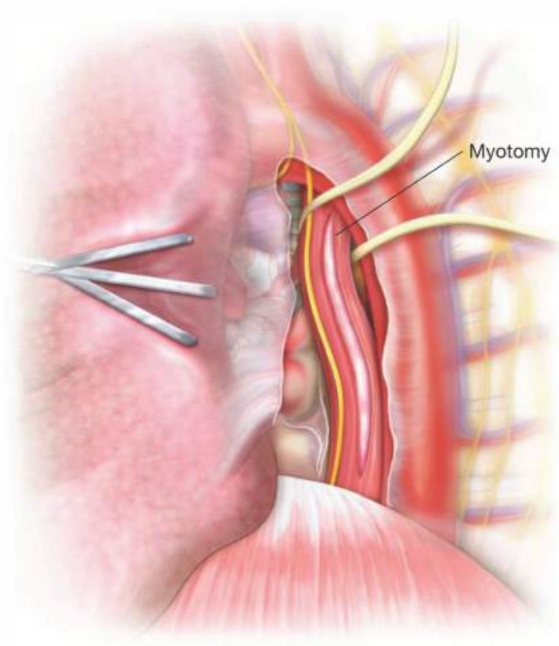


FIG 9 ● Extent of the myotomy should be determined by a combination of intraoperative endoscopy and analysis of the preoperative manometry studies.

PEARLS AND PITFALLS

Reflux	■ An antireflux procedure should be performed in addition to the myotomy if reflux is documented on preoperative pH studies. ■ Many surgeons advocate an antireflux procedure when the myotomy is carried across the EGJ, although this is not uniformly agreed upon. ■ A Belsey fundoplication may be performed from the left chest in the left thoracotomy approach. Otherwise, a laparoscopy may be performed following the thoracic portion of the operation to create the fundoplication. The authors prefer a laparoscopic Dor anterior fundoplication in this setting.
Chylothorax	■ A careful thoracic duct ligation should be considered if there is concern for trauma to the duct.
Extent of myotomy	■ Myotomy should be taken above the level of the aortic arch and ideally, to the thoracic inlet, as smooth muscle fibers may comprise as much as one-third of the upper thoracic esophageal muscle.
Esophageal leak	■ Intraoperative air test can be performed. Unexplained postoperative tachycardia, fever, or chest pain should prompt an urgent water-soluble contrast esophagram.

POSTOPERATIVE CARE

- Postoperative hospital stay is usually limited to 1 to 2 days.
- Barium or Gastrografin swallow may be performed prior to initiation of oral intake to ensure that no mucosal injury or perforation is present as well as to confirm free passage of contrast through the distal esophagus and into the stomach. This may also be useful to establish a postoperative baseline for reference, should delayed issues with reflux or dysphagia arise.
- A liquid diet may be initiated on the first postoperative day following confirmation of esophageal integrity with esophagram. A liquid diet is initially begun, with the patient being advanced to a mechanical soft diet over the course of the first week.

OUTCOMES

- Include functional and prosthetic survivorship data, as applicable.

COMPLICATIONS

- Reflux: Reflux symptoms are common following myotomy and are noted in up to 50% of patients if an antireflux operation is not performed at the time of myotomy. The decision to perform an antireflux operation at the time of the index operation must be individualized to the patient. The extent of demonstrable preoperative acid reflux as well as the degree of esophageal dysmotility must be carefully weighed. Mild to moderate postoperative symptoms may be well controlled with the addition of a proton pump inhibitor to the patient's medications. Lifestyle modifications including the avoidance of late evening meals and head of bed elevation while sleeping can also be quite effective in symptom management. In rare cases, a laparoscopic antireflux operation may be necessary at a later date for patients whose symptoms fail to respond to medical management.
- Dysphagia: Persistent dysphagia following surgical intervention is frequently related to an incomplete myotomy. Additionally, the possibility of an inaccurate diagnosis must also be considered if symptoms persist following myotomy. Edema at the myotomy site, scar formation, and an overly tight antireflux repair should also be considered and may respond to endoscopic dilation.
- Perforation/leak: Unrecognized mucosal injury will often present within 24 to 72 hours with peritonitis, dyspnea and pleuritic pain from pleural effusion, fever, leukocytosis, or overt sepsis. A high index of suspicion is necessary for early diagnosis and aggressive surgical intervention is warranted to facilitate adequate drainage and, when possible, repair of the injury. A feeding jejunostomy should be considered if a prolonged healing time is anticipated. The specific approach is dictated by the location of injury and presentation of the patient. However, a careful endoscopic examination should always play a role in the evaluation of a postmyotomy leak.

Chapter 16

Laparoscopic Heller Myotomy and Anterior Fundoplication for Esophageal Achalasia

Marco E. Allaix Marco G. Patti

DEFINITION

- Esophageal achalasia is a primary motility disorder characterized by lack of esophageal peristalsis and failure of the lower esophageal sphincter (LES) to relax properly in response to swallowing.

DIFFERENTIAL DIAGNOSIS

- Benign strictures secondary to gastroesophageal reflux disease (GERD) and esophageal neoplasms may mimic the clinical presentation of achalasia.
- An infiltrating tumor of the gastroesophageal junction can mimic not only the clinical and radiologic findings of achalasia but also the manometric profile. This condition, defined as "secondary achalasia" or "pseudoachalasia," should be suspected and ruled out in patients older than 60 years of age, with recent onset of dysphagia (less than 6 months), and with excessive weight loss.[1]

PATIENT HISTORY AND PHYSICAL FINDINGS

- Dysphagia is the main complaint, being reported by about 95% of patients. It is often for both solids and liquids. Most patients are able to maintain a stable weight due to changes made in their diet.
- About 60% of patients experience regurgitation of undigested food. It occurs more frequently in the supine position and may lead to aspiration that in turn can cause respiratory symptoms, such as cough, hoarseness, wheezing, and episodes of pneumonia.[2]
- Heartburn is present in about 40% of patients: It is due to stasis and fermentation of undigested food in the distal esophagus rather than due to gastroesophageal reflux (GER).
- Esophageal distention can cause chest pain in up to 40% of patients, and it is usually experienced at the time of a meal.

IMAGING AND OTHER DIAGNOSTIC STUDIES

- A thorough evaluation to establish the diagnosis should be performed in all patients with symptoms suggestive for achalasia.[3] It consists of the following studies:
  - *Upper endoscopy* is usually the first test that is performed to rule out the presence of a mechanical obstruction secondary to a peptic stricture or cancer.
  - *Barium swallow* shows a narrowing at the level of the gastroesophageal junction (the so-called *bird's beak*), slow esophageal emptying with an air–fluid level, and either absence of or tertiary contractions of the esophageal wall (**FIG 1**). It also defines the diameter and the axis of the esophagus (dilated and sigmoid in long-standing achalasia) and associated pathologic findings, including an epiphrenic diverticulum. The gastric air bubble is usually absent.

FIG 1 ● Barium swallow: dilatation of the esophageal body, retained barium, and distal esophageal narrowing (bird's beak).

  - *Esophageal manometry* is the gold standard for the diagnosis of achalasia. Lack of peristalsis and absent or incomplete LES relaxation in response to swallowing are the key criteria for the diagnosis. The LES is hypertensive in only about 50% of patients.[3] Recently, a new classification of esophageal achalasia has been proposed based on high-resolution manometry (HRM): type I, classic, with minimal esophageal pressurization; type II, achalasia with panesophageal pressurization; and type III, achalasia with spasm (**FIG 2**).[4]

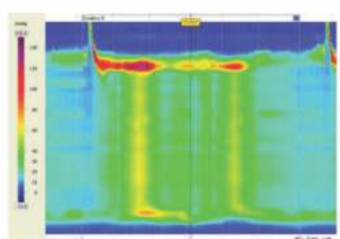


FIG 2 ● High-resolution esophageal manometry: type II achalasia according to the Chicago classification.

- *Ambulatory pH monitoring* is important in untreated patients when the diagnosis is uncertain in order to distinguish between GERD and achalasia. Postoperatively, ambulatory pH monitoring can be performed to rule out GER that is present in about 30% to 40% of cases after Heller myotomy and is often asymptomatic.[5]

SURGICAL MANAGEMENT

Preoperative Planning

- A careful systematic evaluation and the tests described before should be performed in every patient before treatment.

Positioning

- After induction of general endotracheal anesthesia, the patient is positioned supine in low lithotomy position with the lower extremities extended on stirrups, with knees flexed 20 to 30 degrees or straight if using a split-leg table.
- To avoid sliding as a consequence of the steep reverse Trendelenburg position used during the procedure, a beanbag is inflated to create a "saddle" under the perineum.
- Because increased abdominal pressure from pneumoperitoneum and the steep reverse Trendelenburg position decrease venous return, pneumatic compression stockings are always used as prophylaxis against deep venous thrombosis.
- An orogastric tube is placed to keep the stomach decompressed during the procedure and it is removed before starting the myotomy.
- A Foley catheter is inserted at the beginning of the operation and removed at the end.
- The surgeon stands between the patient's legs. The first and second assistants stand on the right and left side of the operating table (**FIG 3**).

FIG 3 ● Position of the patient and surgical team in the operating room.

TECHNIQUES

PLACEMENT OF PORTS

- Five 10-mm trocars are used for the procedure (**FIG 4**).
  - The first incision is made in the midline 14 cm distal to the xiphoid process and a Veress needle is introduced into the peritoneal cavity. The peritoneal cavity is insufflated to a pressure of 15 mmHg. Subsequently, under direct vision, an optical port with a 0-degree scope (**port 1**) is placed. Once this port is placed, the 0-degree scope is replaced with a 30-degree scope and the other trocars are inserted under laparoscopic vision.
- **Port 2** is placed in the left midclavicular line at the same level of port 1. It is used by the assistant for traction on the gastroesophageal junction and as an instrument to take down the short gastric vessels.

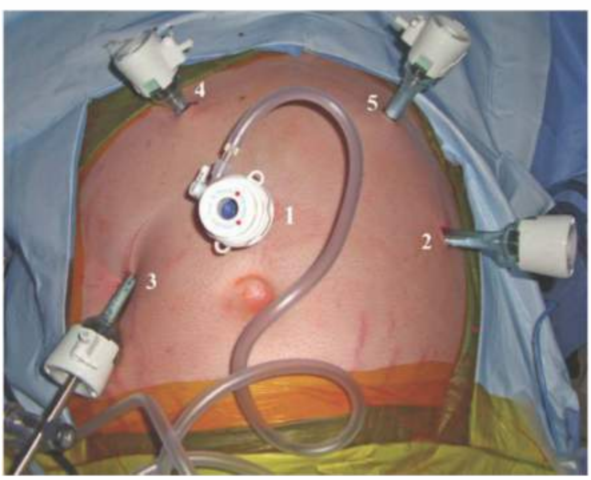


FIG 4 ● Placement of the ports.

- **Port 3** is placed in the right midclavicular line at the same level of the other two ports. A retractor is used through this port to lift the left lateral segment of the liver to expose the gastroesophageal junction. The retractor is held in place by a self-retaining system fixed to the operating table.
- **Ports 4** and **5** are placed under the right and left costal margins so that their axes and the camera form an angle of about 120 degrees. These ports are used by the operating surgeon.
- The instrumentation necessary for the laparoscopic myotomy is reported in Table 1.

Table 1: Instrumentation for Laparoscopic Heller Myotomy and Partial Fundoplication

Five 10-mm ports
0- and 30-degree scope
Graspers and needle holder
Babcock clamp
L-shaped hook cautery with suction–irrigation capacity
Scissors
Laparoscopic clip applier
Electrothermal bipolar vessel-sealing system
Liver retractor
Suturing device
2-0 silk sutures

DISSECTION

- The gastrohepatic ligament is divided, beginning the dissection above the caudate lobe of the liver, where the ligament is thinner, and continuing toward the diaphragm until the right pillar of the crus is identified and separated from the esophagus by blunt dissection.
- Subsequently, the peritoneum and the phrenoesophageal membrane overlying the esophagus are divided and the anterior vagus nerve is identified (**FIG 5A**).
- The left pillar of the crus is then separated from the esophagus (**FIG 5B**).
- Blunt dissection is finally performed in the posterior mediastinum, laterally and anteriorly to the esophagus in order to have about 4 to 5 cm of esophagus without any tension below the diaphragm. Posterior dissection is necessary only if a partial posterior fundoplication is planned.

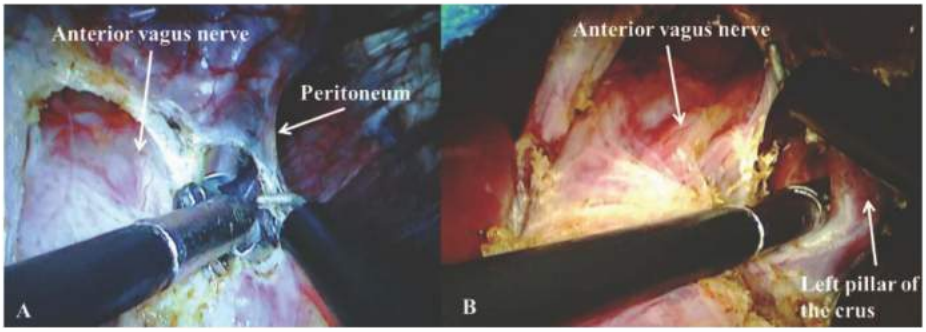


FIG 5 ● **A.** Division of the peritoneum and the phrenoesophageal membrane overlying the esophagus with anterior vagus nerve identification. **B.** Separation of the left pillar of the crus from the esophagus.

DIVISION OF THE SHORT GASTRIC VESSELS

- The short gastric vessels are taken down all the way to the left pillar of the crus, starting from a point midway along the greater curvature of the stomach (**FIG 6**).[6]

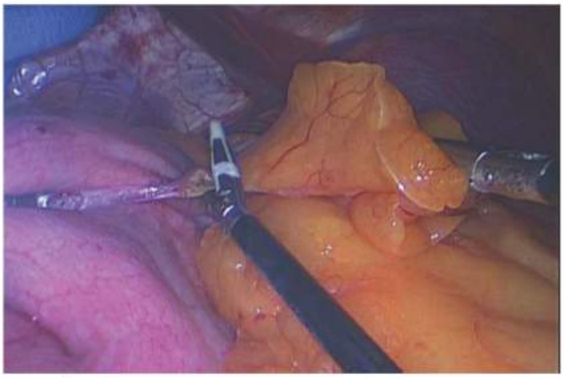


FIG 6 ● Division of the short gastric vessels.

MYOTOMY

- The fat pad should be removed to expose the gastroesophageal junction after identification of the anterior vagus nerve.
- Traction is then applied with a Babcock clamp, grasping below the gastroesophageal junction and pulling downward and to the left in order to expose the right side of the esophagus.
- A myotomy is performed on the right side of the esophagus in the 11 o'clock position using a hook cautery. The proper submucosal plane is found using the cautery, about 3 cm above the gastroesophageal junction.
- Once the mucosa is exposed, the myotomy is extended proximally for about 6 cm above the gastroesophageal junction and distally for 2.5 to 3 cm onto the gastric wall (FIG 7).[7]
- The edges of the muscles are then separated with a dissector in order to have 30% to 40% of the mucosa not covered by muscles.
- Intraoperative endoscopy is rarely necessary, particularly when enough experience is present and a long myotomy onto the gastric wall is performed.

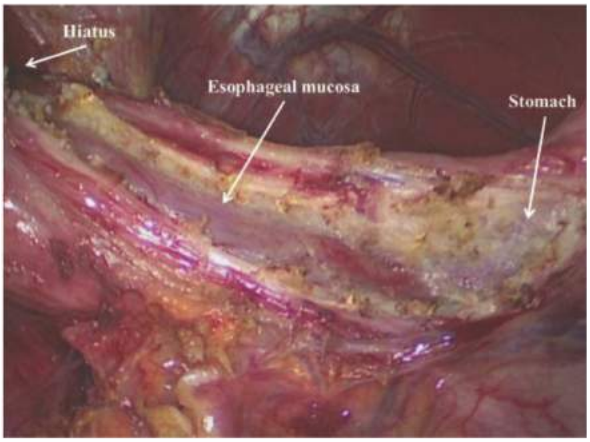


FIG 7 ● Esophageal myotomy.

PARTIAL FUNDOPLICATION

- The main goal of the surgical treatment is relief of dysphagia while preventing GER.[8]
- A laparoscopic Heller myotomy (LHM) alone is associated with postoperative GER in about 50% to 60% of patients.[9]
- Better functional results are achieved with a partial fundoplication added to the myotomy compared to a total fundoplication that is associated with higher rates of postoperative dysphagia.[10]
- Regarding the type of partial fundoplication, no significant differences are evident in terms of control of GER after the partial anterior and partial posterior fundoplication.[5]
- We prefer the partial anterior fundoplication because it is simpler to perform, as posterior dissection is not necessary, and because it covers the exposed esophageal mucosa.

Partial Anterior Fundoplication (Dor)

- The Dor fundoplication is a 180-degree anterior fundoplication.
- Two rows of sutures (2-0 silk) are used. The first row is on the left side of the esophagus and has three stitches. The top stitch incorporates the fundus of the stomach, the muscular layer of the left side of the esophagus, and the left pillar of the crus (FIG 8).

FIG 8 ● Dor fundoplication: top stitch of the left row of sutures.

FIG 9 ● Dor fundoplication: second and third stitches of the left row of sutures.

- The second and third stitches incorporate the gastric fundus and the muscular layer of the left side of the esophagus (**FIG 9**).
- The fundus is then folded over the exposed mucosa so that the greater curvature of the stomach is next to the right pillar of the crus.

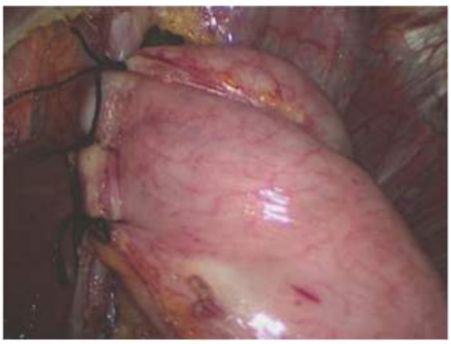


FIG 10 ● Dor fundoplication: right row of sutures.

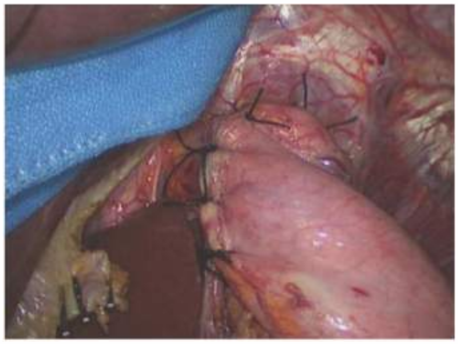


FIG 11 ● Completed Dor fundoplication.

- The second row of sutures on the right side of the esophagus consists of three stitches between the fundus and the right pillar of the crus (**FIG 10**).
- Finally, two additional stitches are placed between the fundus and the rim of the esophageal hiatus to eliminate any tension from the fundoplication (**FIG 11**).

Partial Posterior Fundoplication

- Some authors argue that the posterior partial fundoplication should be used as it might be more effective in preventing GER and because it keeps the distal edges of the myotomy separated.[11]
- The posterior fundoplication requires the creation of a posterior window between the left pillar of the crus, the stomach, and the esophagus followed by the passage of the gastric fundus under the esophagus.
- The hiatus is loosely closed posterior to the esophagus.
- Subsequently, each side of the wrap is attached to the esophageal wall lateral to the myotomy with three stitches. The resulting wrap measures about 220 to 240 degrees.

PEARLS AND PITFALLS

Indications	■ A careful evaluation including manometry, 24-hour pH monitoring, upper endoscopy, and barium swallow must be done.
Placement of ports	■ Extreme care must be taken when positioning port 1, because the site of insertion is just above the aorta. ■ We recommend using an optical trocar with a 0-degree scope to obtain access. ■ If port 3 is too low, the left lateral segment of the liver will not be properly retracted and exposure of the esophagogastric junction may be inadequate. ■ If port 2 is too low, the esophagogastric junction or the upper short gastric vessels may be difficult to access. ■ If ports 4 and 5 are too low, the dissection at the beginning of the procedure and the suturing at the end will be challenging. ■ If port 3 is too medial, the liver retractor may interfere with the instrument used through port 4.
Dissection	■ An accessory left hepatic artery originating from the left gastric artery is frequently present in the gastrohepatic ligament. If this vessel limits the exposure, it may be safely divided. ■ The electrocautery should be used with extreme caution. Because of the lateral spread of the monopolar current, vagus nerves may be damaged even without direct contact. A bipolar instrument represents a safer alternative.

Short gastric vessels division	■ Bleeding, either from the short gastric vessels or from the spleen, and damage to the gastric wall are possible complications. ■ Excessive traction and division of a vessel not completely coagulated are the main causes of bleeding. ■ A burn caused during dissection of the short gastric vessels or traction applied with the graspers or the Babcock clamp are the most common mechanisms of damage to the gastric wall.
Myotomy	■ In patients who have had previous treatment with botulinum toxin injection, the myotomy is technically more challenging due to the fibrosis that alters the normal anatomic planes and may increase the risk of perforation.[12] ■ If a mucosal perforation occurs, it can be repaired with 5-0 absorbable material. ■ In case of bleeding from the cut muscular fibers, gentle compression with a sponge is recommended rather than the electrocautery, which can cause thermal damage to the esophageal wall.

Partial anterior fundoplication	■ To reduce the risk of postoperative dysphagia due to the fundoplication
	  ■ The short gastric vessels should be divided.
	  ■ The wrap should be performed using the fundus rather than the body of the stomach.

POSTOPERATIVE CARE

- Patients spend an average of 1 to 2 days in the hospital and return to work in 2 to 3 weeks.
- Patients are fed the morning of the first postoperative day with clear liquids and then a soft diet.
- They are instructed to avoid meat, bread, and carbonated beverages for the following 2 weeks.
- Most patients resume their regular activity within 2 to 3 weeks.

OUTCOMES

- Long-term follow-up shows that symptoms are improved in 90% to 95% of patients at 5 years and in 80% to 90% at 10 years.
- Most LHM failures present within the first 2 to 3 years of follow-up and may reflect fibrosis of the distal edge of the myotomy that can be successfully treated in most cases with pneumatic dilatation.
- Postoperative GER occurs in about 30% to 40% of patients, and it is usually controlled by acid-reducing medications.

COMPLICATIONS

- Esophageal leak may occur during the first 24 to 36 hours postoperatively, and it is usually the result of a thermal injury of the esophageal mucosa.
  - Typical signs and symptoms include pain, fever, and dyspnea. A chest x-ray may show a pleural effusion.
  - An esophagogram confirms the location and the extension of the leak.
  - Treatment options vary based on the time of diagnosis and on the location and extension of the leak. In case of early diagnosis, small leaks can be repaired directly. If the damage is too extensive or the inflammatory reaction in case of late diagnosis does not allow a direct repair, an esophagectomy may be indicated. In selected cases, wide drainage and placement of a feeding jejunostomy tube with or without the use of an esophageal stent may allow the leak to heal without esophagectomy.
- Pneumothorax occurs in case of intraoperative violation of the parietal pleura. Usually, it resolves spontaneously and does not require tube thoracostomy as the CO_2 is rapidly absorbed.
- Persistent dysphagia is usually due to technical errors, such as a too short of a myotomy or a too constricting fundoplication.
- Recurrent dysphagia after a symptom-free period may be caused by scar tissue in the distal edge of the myotomy, postoperative GER, technical errors cited earlier, or esophageal cancer. In either case, a thorough evaluation is mandatory to rule out malignancies and make a correct diagnosis. Subsequent treatment is tailored to the results of this workup and includes pneumatic dilatation and/or a reoperation.

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Chapter 17

Repair of Congenital Defects: Morgagni Diaphragmatic Hernia

Scott A. Anderson Mike K. Chen

DEFINITION

- A Morgagni congenital diaphragmatic hernia (CDH) refers to a defect in the anteromedial diaphragm through the foramen of Morgagni. The most common contents of the hernia include omentum and transverse colon but can also include stomach, liver, spleen, and other segments of bowel. Morgagni hernias more commonly include a hernia sac.
- They account for approximately 3% of surgically repaired diaphragmatic hernias. They are more frequently seen in females and the majority of them are right-sided. Bilateral Morgagni hernias can be seen but are not common.
- Unlike Bochdalek CDHs, Morgagni hernias are generally not associated with pulmonary hypoplasia. They are typically smaller and more frequently an isolated congenital anomaly.

DIFFERENTIAL DIAGNOSIS

- Morgagni CDH can be mistaken for a number of other thoracic anomalies, both congenital and acquired. In infancy, these can include congenital cystic lung disease, esophageal hiatal hernia, and mediastinal mass.
- Later in life, Morgagni hernia can be confused with a mediastinal mass, pericardial fat pad, atelectasis, pneumonia, or a pleural abscess.
- The various imaging and diagnostic studies used to distinguish among these are mentioned in a subsequent section.

PATIENT HISTORY AND PHYSICAL FINDINGS

- The diagnosis of a Morgagni diaphragmatic hernia can sometimes be a long and winding road. Neonates do not frequently arrive with the diagnosis already made by prenatal imaging, as is often the case with Bochdalek CDH. The signs and symptoms of Morgagni hernias are also usually nonspecific. Likewise, routine radiologic imaging can also overlook the more subtle defects. Because of this, Morgagni hernias are sometimes not diagnosed until later in life.
- The most common presentation in neonates and infants is an increased work of breathing or respiratory distress. Many, however, are relatively asymptomatic. Children may present with a history of recurrent chest infections. Teenagers and adults can present with any variety of symptoms including dyspnea, chest pain, abdominal pain, nausea and vomiting, and constipation or they may be completely asymptomatic. Predisposing conditions, such as chronic cough, trauma, pregnancy, and obesity, can contribute to the likelihood of symptomatic presentation.
- The physical examination is most commonly normal. However, distant heart tones and unequal breath sounds may be present. In cases of strangulation or volvulus, the patient may demonstrate significant abdominal tenderness and signs of shock. A detailed physical examination is always indicated in newborns to assess for congenital abnormalities.
- Although most commonly isolated, Morgagni hernias can be associated with congenital heart disease, malrotation, and Down's syndrome.[1] The workup should include an echocardiogram when the diagnosis is made in infancy.

IMAGING AND OTHER DIAGNOSTIC STUDIES

- Morgagni hernias are not frequently detected on prenatal imaging.
- A posteroanterior (PA) and lateral chest radiograph is the initial diagnostic study of choice. This can have different appearances depending on the contents within the hernia. It may show air-filled loops of bowel projecting over the anterior mediastinum (**FIG 1A,B**) or a well-defined opacity in the right cardiophrenic angle (**FIG 2**). The latter, however, is not very specific.
- The diagnosis can be more readily made on computed tomography or magnetic resonance imaging (MRI) (**FIG 3**).

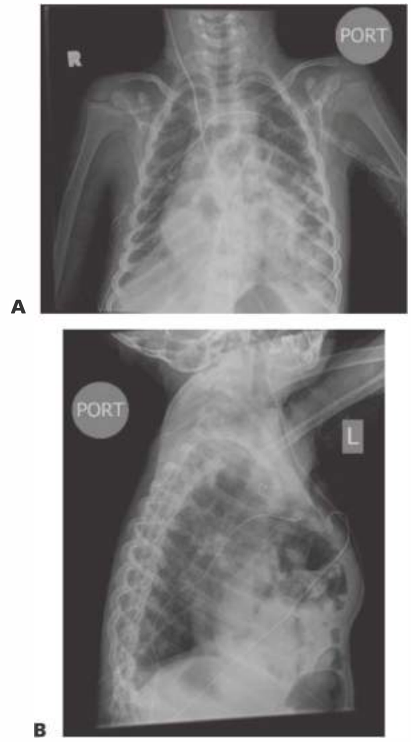

FIG 1 ● PA **(A)** and lateral **(B)** chest x-ray demonstrating air-filled loops of bowel in the anterior mediastinum consistent with a Morgagni diaphragmatic hernia.

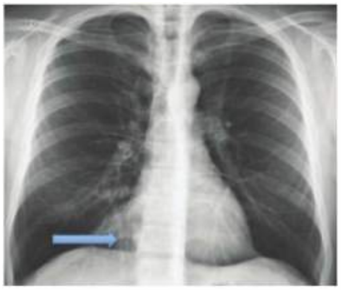

FIG 2 ● PA chest x-ray demonstrates a Morgagni hernia indicated by the opacity *(arrow)* at the right cardiophrenic angle. This hernia most commonly contains omentum.

- Ultrasound, barium enema, and upper gastrointestinal (GI) series also can be a useful part of the diagnostic workup.
- Diagnostic thoracoscopy or laparoscopy is recommended if the diagnosis remains unclear after appropriate imaging studies.

SURGICAL MANAGEMENT

Preoperative Planning

- In general, elective repair of Morgagni hernias is recommended to prevent future complications such as incarceration, strangulation, or volvulus.
- Morgagni diaphragmatic hernias can be successfully repaired through either transabdominal or transthoracic approach using open or minimally invasive techniques. We tend to favor the transabdominal approach when feasible because it allows for better visualization of the central diaphragm and for detection of bilateral hernias that may not be clearly seen on preoperative imaging. Laparoscopy is generally well tolerated in infants, even those with congenital heart disease.[2]

FIG 3 ● Computed tomography of the chest in a patient with a Morgagni hernia. Note the contrast-opacified intestinal contents within the anterior mediastinum, shifting the heart posteriorly and to the right.

- In infants, who can present with respiratory distress, lung protective strategies are initiated. When a ventilator is required, spontaneous respiration and permissive hypercapnia are used. Surgery is then performed on an elective basis, once medically stable, prior to discharge.
- For the patients with Morgagni hernias that present with acute incarceration, strangulation, or volvulus, immediate surgical management is indicated. Appropriate resuscitative measures should be initiated prior to surgery.
- Prior to taking the patient to the operating room, all diagnostic studies should be thoroughly reviewed and the patient appropriately marked on the affected side.
- Ensure that the airway is secure and the endotracheal tube is in a stable position. Pre- and postductal oxygen saturation monitoring is maintained in neonates to assess for signs of right-to-left shunting.

TECHNIQUES

OPEN MORGAGNI HERNIA REPAIR

Positioning

- The patient is placed in the supine position on the operating room table (**FIG 4**).
- Sterile plastic drapes are used as a barrier over the patient outside of the operative field. A warming blanket is also used to maintain temperature stability.

Incision

- A transverse, subcostal incision is made one to two fingerbreadths below the costal margin. An incision made too close to the costal margin can make for a more difficult repair and subsequent fascial closure. An upper midline incision may also be used.
- The abdominal wall muscle and fascia are divided and the peritoneum entered.

Exposure of the Defect and Hernia Reduction

- The falciform ligament of the liver is taken down off the abdominal wall and the left lateral segment mobilized if needed.

FIG 4 ● The patient is positioned in a standard fashion in the operating room.

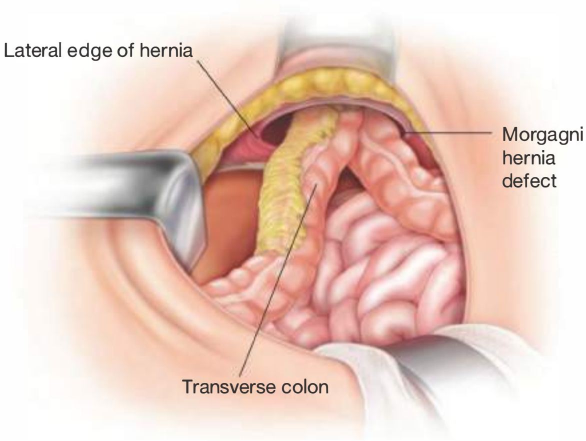

FIG 5 ● The Morgagni hernia defect is exposed and the hernia contents (transverse colon, omentum) are identified and manually reduced.

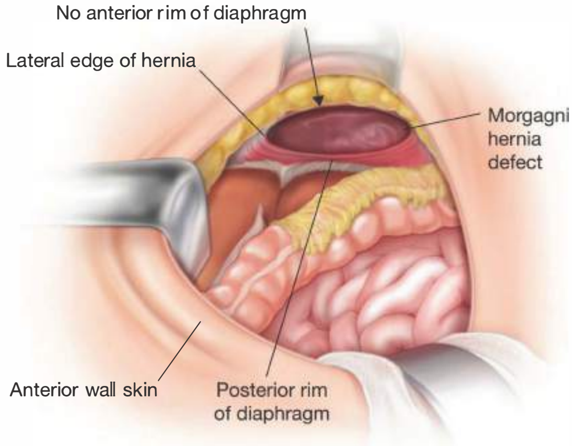

FIG 6 ● The Morgagni hernia contents have been reduced, providing full exposure of the defect. Note that there is essentially no anterior rim of diaphragm present *(arrow)*, and hernia defect is contiguous with the anterior abdominal wall.

- The liver is carefully retracted away from the diaphragm to expose the posterior and lateral boundary of the diaphragmatic hernia defect (**FIG 5**).
- The abdominal contents within the hernia are carefully reduced and returned to the abdomen.
- A hernia sac, when present, is excised with electrocautery.

Repair of the Diaphragm

- An assessment is made to determine the amount of native diaphragm. There is typically no anterior rim of diaphragm and the defect is contiguous with the anterior abdominal wall (**FIG 6**).
- If the Morgagni hernia is small enough for primary closure without significant tension, this is preferred. The defect is repaired with interrupted, simple sutures using nonabsorbable, braided suture material (**FIG 7**). Pledgeted mattress sutures may also be used. However, the diaphragmatic muscle is often attenuated, particularly for those well into adulthood. Therefore, an overlay patch to reinforce the repair may be beneficial.
- For those defects that are too large to close primarily, a prosthetic patch is used. Nonbiologic materials, such as polytetrafluoroethylene (PTFE)/expanded polytetrafluoroethylene (ePTFE), or biologic materials are effective. The patch is carefully fashioned so as to maintain the shape of the diaphragm and to have 2 to 3 cm of overlap. The posterior wall of the diaphragm is sewn first to the patch with interrupted sutures using a braided nonabsorbable material. The sutures are left untied initially. Once the posterior wall sutures are all in place, the patch is then parachuted down and the sutures are individually tied secure. Then, before closure of the anterior diaphragmatic defect is initiated, care is taken to ensure hemostasis on the thoracic side of the patch.
- The anterior portion of the patch is then secured to the anterior abdominal wall and posterior rectus sheath with interrupted suture to complete the repair.

Closure

- Once hemostasis and satisfactory repair is assured, the abdominal wall musculature and skin are then closed in layers. A drain is not needed.

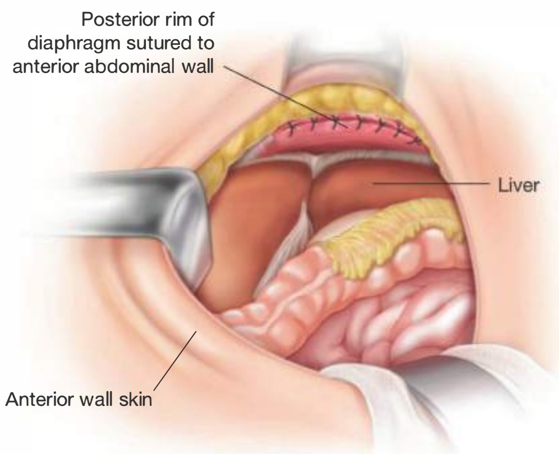

FIG 7 ● The posterior rim of diaphragm is sutured to the anterior abdominal wall with interrupted nonabsorbable suture for a relatively tension-free primary repair.

MINIMALLY INVASIVE MORGAGNI HERNIA REPAIR

- Both thoracoscopic and laparoscopic approaches have been used for Morgagni hernia repair. They each have their benefits and drawbacks, and the technical aspects of the two approaches are not dissimilar.
- We tend to favor the laparoscopic approach in that it provides excellent visualization of both hemidiaphragms. This minimizes the risk of underestimating or missing a more central or bilateral Morgagni hernia defect.

Positioning

- The patient is positioned in a similar manner as a patient undergoing a laparoscopic fundoplication so that the surgeon may stand at his or her feet. Infants and young children are supine and frog-legged at the end of the operating room table (**FIG 8**). Older children and adults are placed in dorsal lithotomy with their lower extremities in stirrups. The operating surgeon stands between the patient's legs.
- Care is taken to properly pad all pressure points.
- The monitors are positioned over the patient's head.

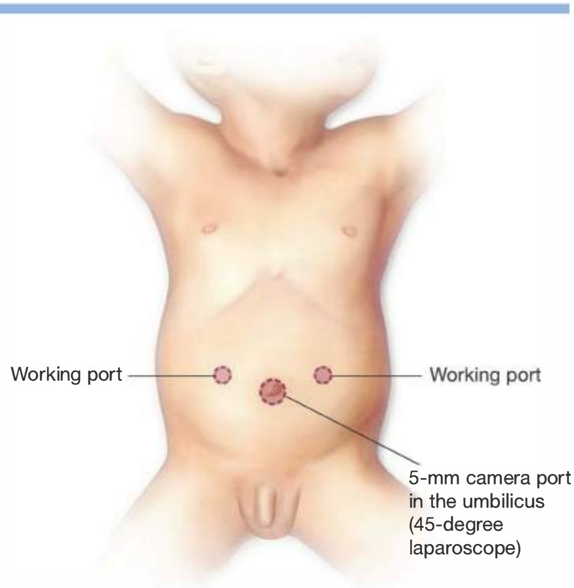

FIG 9 ● A 5-mm port is placed through the umbilicus. Two additional working ports are typically all that is needed and are positioned to appropriately triangulate the hernia defect.

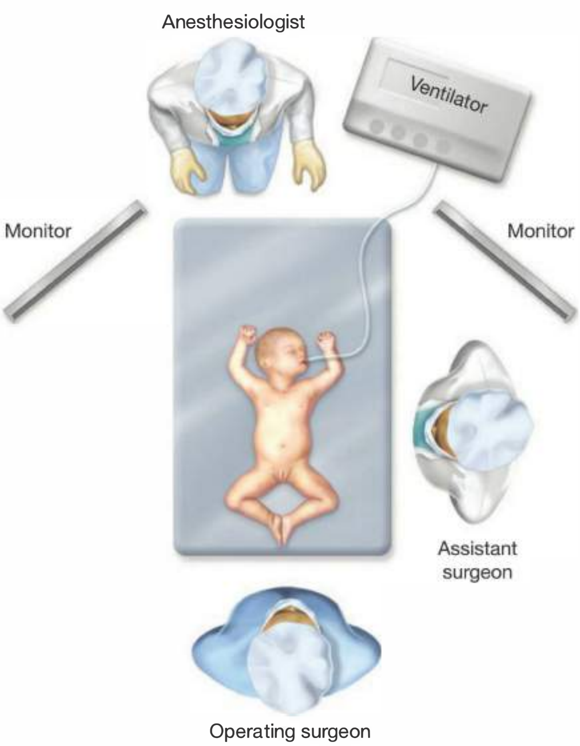

FIG 8 ● The child is positioned at the end of the operating room table in a "frog-leg" position. The operating surgeon stands at the patient's feet with the monitors placed over the patient's head.

Laparoscopic Morgagni Hernia Repair

Trocar placement

- A 5-mm trocar is placed in the umbilicus.
- Pneumoperitoneum is initially set between 8 and 15 mmHg depending on the patient's age and size.
- A 5-mm, 30-degree scope is used for visualization.
- Two additional trocars are placed under direct laparoscopic vision, in the right and left upper quadrants. These will be the primary working ports (**FIG 9**).
- An additional trocar occasionally is needed for retraction.
- A single-incision endosurgical approach is also feasible.

Reduction of the Morgagni hernia

- The hernia contents, typically the omentum and abdominal viscera, are carefully reduced with atraumatic graspers (**FIG 10**). Cotton-tipped Endo Kittners are used to help reduce the liver or spleen when present within the hernia.
- To fully expose the native diaphragm, the falciform ligament may be taken down from the abdominal wall (**FIG 11**). This will often lead the surgeon directly to the lateral extent of the Morgagni hernia and allow for adequate overlap with patch placement.
- The hernia sac, if one is present, is carefully excised circumferentially off the diaphragmatic defect using hook cautery or other endoscopic sealing device. However, this may also be left intact when dissection into the mediastinum proves too arduous to avoid the risk of pneumothorax and pneumopericardium.[3] The peritoneum is then taken off the edge of the hernia defect with cautery.

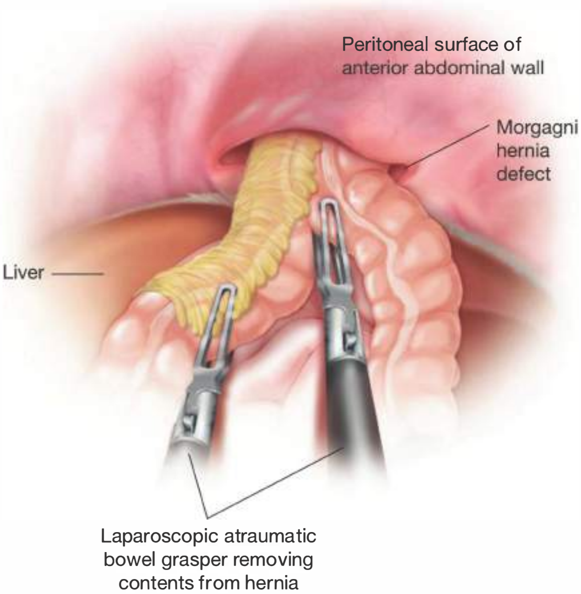

FIG 10 ● The Morgagni hernia is identified and the hernia contents are reduced back into the abdomen with atraumatic graspers.

Repair of the Morgagni hernia

- The hernia defect is measured and an assessment is made as to whether the repair is feasible via a relatively tension-free primary repair or that it will require a patch repair.

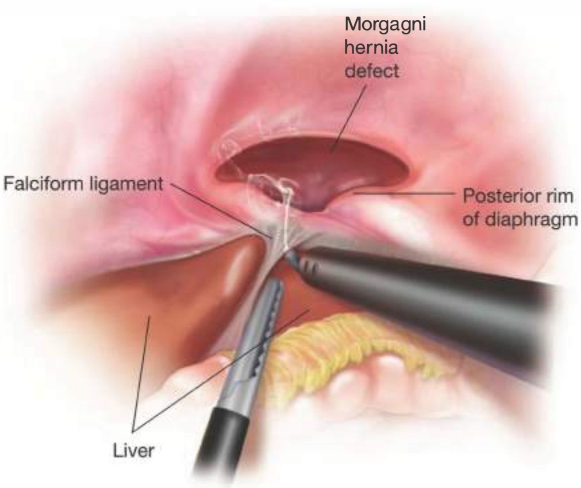

FIG 11 ● The falciform ligament abuts the posterior rim of the Morgagni hernia defect. It is taken down with hook cautery or a bipolar endosurgical device. This provides full exposure of the defect and frees up tension on the hernia repair.

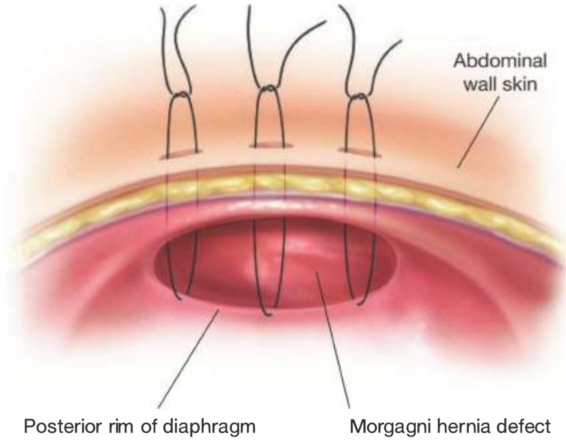

FIG 12 ● A suture is introduced through the anterior abdominal wall and endoscopically passed through the posterior margin of the diaphragmatic hernia defect. The suture is then passed back out through the anterior abdominal wall and the knots may be tied in the subcutaneous tissue.

- For a primary repair, the diaphragm is reapproximated using interrupted nonabsorbable sutures. The closure is begun at the most posterior aspect of the hernia and carried up to the anterior abdominal wall.
- The closure of the defect along the anterior portion of the hernia defect can be challenging but is feasible with intracorporeal suturing techniques. However, we favor a percutaneous technique using an endoscopic suture passer. Small stab incisions are made in the abdominal wall over the central margin of the hernia defect. The suture is percutaneously introduced into the abdomen with an external needle driver through the anterior abdominal wall stab incision. The suture needle is then grasped with the laparoscopic needle driver and passed through the posterior rim of diaphragm intended to be reapproximated. The endoscopic suture passer is then introduced into the abdomen through the same external stab incision but now directed through the anterior abdominal wall fascia about 1 cm away from which the suture was first passed. The suture is retrieved and the knots can be tied extracorporeally within the subcutaneous plane (**FIGS 12** and **13A,B**).
- A prosthetic patch may be needed to achieve a relatively tension-free closure. Similar to open repair, a biologic or nonbiologic prosthetic patch is selected and fashioned to provide 2 to 3 cm of overlap. The patch is rolled tightly and passed through a trocar, or directly through one of the trocar site incisions. It is then unrolled, oriented, and secured to the diaphragm using interrupted nonabsorbable suture or an endoscopic tacking device. Care is taken to avoid injuring the pericardium at the central aspect of the hernia defect. Along the anterior portion, the patch is fixed to the posterior rectus fascia, just below the costal margin (**FIG 14**). This is accomplished using intracorporeal

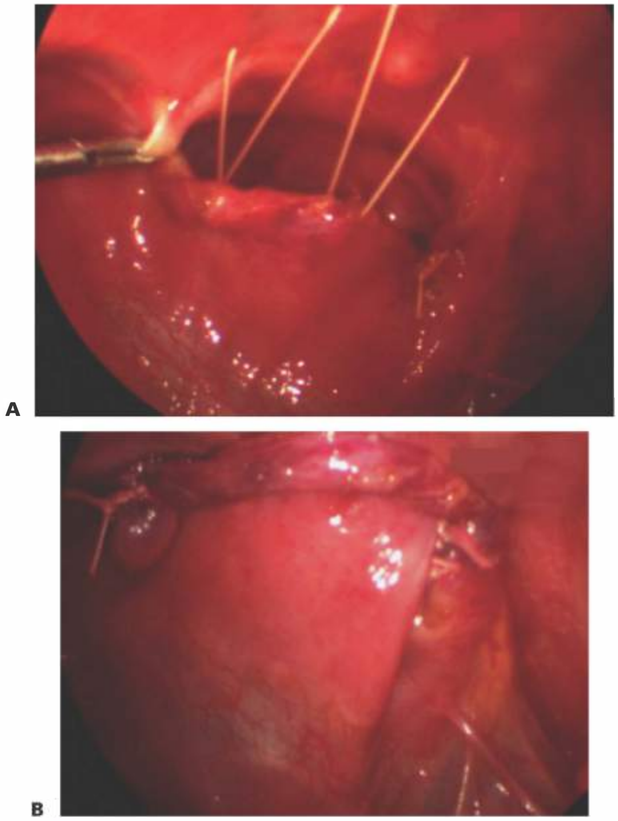

FIG 13 ● **A.** Percutaneous sutures have been passed through the posterior rim of diaphragm and brought back out through the anterior abdominal wall. **B.** The knots have been tied extracorporeally in the subcutaneous tissue, closing the defect.

suturing techniques or an endoscopic tacking device or may be secured externally using a suture passer technique as described earlier.

Closure

- No drains are needed.
- The pneumoperitoneum is released and the liver is allowed to abut the hernia repair.
- The ports are removed in a stepwise fashion.
- The incisions are reapproximated with absorbable suture and skin glue is applied as a dressing.

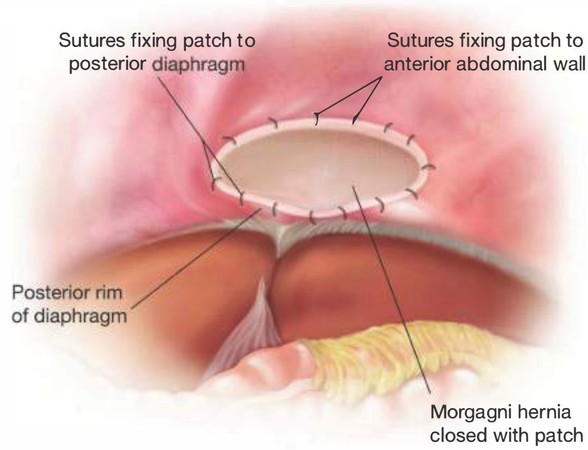

FIG 14 ● A prosthetic or biologic patch is secured to the diaphragm and anterior abdominal wall with 2 to 3 cm of overlap.

PEARLS AND PITFALLS

Preoperative planning	■ A missed bilateral hernia or more extensive central hernia can be avoided with a transabdominal approach.
Incision	■ A transverse subcostal incision should be well away from the costal margin so that there is adequate space to close the anterior portion of the diaphragmatic defect.
Hernia reduction	■ The hernia sac may be left alone to avoid risk of disrupting the pleura or pericardium.
Hernia repair	■ Multiple stitches may be placed through a single abdominal wall stab incision by dissecting a bit subcutaneously. ■ Maintain a low threshold for using a prosthetic patch to achieve a tension-free repair.
Laparoscopy	■ External manual compression of the lower chest and upper abdominal wall can help with suture placement anteriorly.

POSTOPERATIVE CARE

- The majority of patients will be successfully extubated at the completion of the repair.
- They are admitted postoperatively for observation and, barring other issues, are ready for discharge in 24 to 48 hours.
- Follow-up PA and lateral chest radiographs are taken at 1, 6, 12, and 24 months postoperatively to assess for recurrence.

OUTCOMES

- Survival is quite good in all age groups and will primarily depend on other comorbidities.

- Small series in children have demonstrated no difference between laparoscopic and open repair with regard to recurrence rate or intraoperative complications.[4] However, a recent series demonstrated a fairly high recurrence rate—42%—following laparoscopic repair when a patch was not used.[5]
- The complication rate in adults for laparoscopic repair, by comparison, is fairly low at 5%.[6]

COMPLICATIONS

- Recurrent hernia
- Patch infection
- Fluid collection in foramen of Morgagni
- Pneumothorax
- Pericardial effusion or pneumopericardium

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Chapter 18

Repair of Congenital Defects: Bochdalek Congenital Diaphragmatic Hernia

Scott A. Anderson   Mike K. Chen

DEFINITION

- A Bochdalek congenital diaphragmatic hernia (CDH) refers to a defect in the posterolateral diaphragm. The abdominal viscera partially translocates through the defect in the thorax in the developing fetus. This affects the growth and maturation of both lungs. The size of the defect can range from fairly small to complete diaphragmatic agenesis. Affected infants are born with pulmonary hypoplasia, lung immaturity, and pulmonary hypertension, to varying degrees. Successful management of these issues is most critical to a favorable outcome.
- The incidence of CDH is 1 in 2,000 to 1 in 5,000 births overall. Approximately 80% will occur on the left side; bilateral defects are rare. It continues to be one of the more challenging congenital anomalies in pediatric surgical patients.

DIFFERENTIAL DIAGNOSIS

- Prenatally and postnatally, Bochdalek CDH can be mistaken for a number of other congenital thoracic anomalies. These can include Morgagni CDH, diaphragmatic eventration, congenital cystic lung disease, esophageal hiatal hernia, and primary lung agenesis.
- The various imaging and diagnostic studies used to distinguish among these are discussed in a subsequent section.

PATIENT HISTORY AND PHYSICAL FINDINGS

- Many, but certainly not all, CDH patients are born with the diagnosis already made on prenatal ultrasound. A team of neonatologists, high-risk obstetricians, and pediatric surgeons are involved in their perinatal care to ensure a safe delivery and expeditious treatment. These patients are immediately resuscitated after delivery with endotracheal intubation and nasogastric decompression. Ventilation with Ambu bag and mask is avoided to minimize gastrointestinal (GI) distention, which can worsen the compression in the thoracic cavity. A strategy of spontaneous respiration and permissive hypercapnia is employed to minimize ventilator-induced lung injury.
- For those without prenatal diagnosis, patients will present shortly after birth with typical signs of respiratory distress, including tachypnea, grunting, and cyanosis. They also will commonly have a scaphoid abdomen, barrel-shaped chest, and diminished or absent breath sounds on the affected side. The heart tones are also shifted toward the contralateral side.
- Ten percent to 50% of CDH patients will have other congenital anomalies, so a thorough physical examination and assessment is indicated. See Table 1.
- Also, a number of syndromes have been associated with CDH including Frey; Beckwith-Wiedemann; Goldenhar; Fryns; and trisomy 21, 18, and 13. A genetics consult is warranted if any of these are suspected.

Table 1: Associated Congenital Anomalies

Cardiac
VSD
Aortic coarctation
Heart hypoplasia
Outflow tract abnormalities
Musculoskeletal
Tracheobronchial
Genitourinary
Neural tube defects
Chromosomal

VSD, ventricular septal defect.

IMAGING AND OTHER DIAGNOSTIC STUDIES

- Prenatal workup includes ultrasound and/or fetal magnetic resonance imaging (MRI). Evaluation of fetal karyotype via amniocentesis or other methods can provide additional information that aids in properly informing and preparing the parents.
- After birth, a chest radiograph is the primary diagnostic study of choice. For a left-sided CDH, this will classically show multiple gas-filled bowel loops within the left hemithorax and contralateral shift of the mediastinum (**FIG 1**). The presence

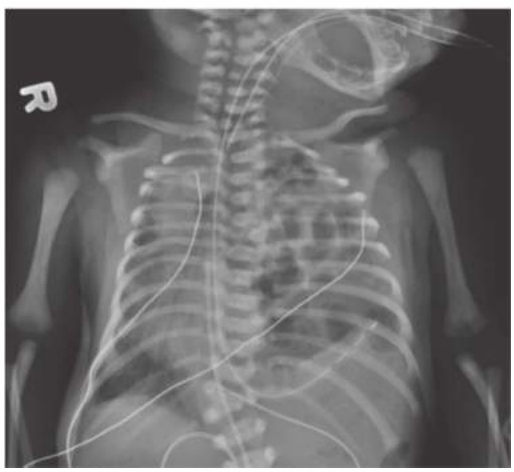

FIG 1 • Chest x-ray in neonate demonstrating a left CDH. Note that the stomach and liver are both transposed into the left chest and the mediastinum is shifted to the right.

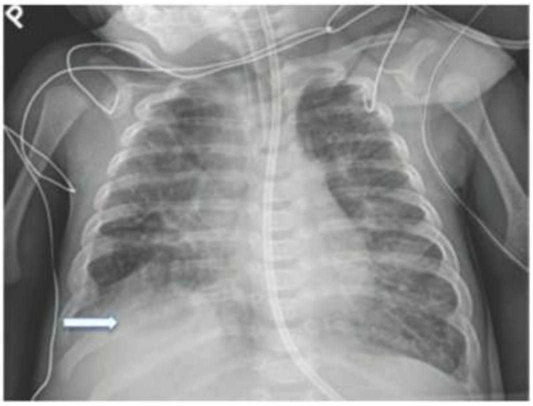

FIG 2 ● Chest x-ray demonstrating a right CDH. The *arrow* denotes the elevated liver at the site of the hernia defect.

of the liver and/or stomach in the chest on plain film can help estimate the size of the hernia defect. A right-sided CDH may demonstrate only an elevated liver shadow if no other visceral contents have traversed the hernia defect (**FIG 2**).

- Computed tomography, MRI, ultrasound, fluoroscopy, and upper GI series with small bowel follow-through may be used as well when the diagnosis is not certain. Diagnostic thoracoscopy or laparoscopy is recommended if the diagnosis remains unclear after appropriate imaging studies.
- An echocardiogram should be obtained as part of the workup for associated congenital anomalies. It can also be useful in quantifying the degree of pulmonary hypertension and then following its treatment. Additionally, intracranial imaging with a head ultrasound is useful, particularly when perioperative extracorporeal membrane oxygenation (ECMO) is considered as part of the infant's management.

SURGICAL MANAGEMENT

Preoperative Planning

- CDH is a physiologic emergency and not usually a surgical emergency. The careful management of the neonate's pulmonary hypoplasia, lung immaturity, and pulmonary hypertension is most critical to his or her successful outcome.
- The optimal timing for surgical repair is unclear, although most current strategies include a period of medical stabilization followed by delayed operative repair.
- Both open and minimally invasive techniques can be used for repair. We favor a thoracoscopic repair for a small defect in the stable patient and an open repair in the less stable patient with a larger hernia defect.
- Prior to taking the patient to the operating room, all diagnostic studies should be thoroughly reviewed and the patient should be appropriately marked on the affected side.
- Ensure that the airway is secure and the endotracheal tube in a stable position. Pre- and postductal oxygen saturation monitoring should be maintained.
- Arterial access is ideal for perioperative and intraoperative blood gas monitoring.
- The infant's own ventilator is preferred over the typical anesthesia circuit.
- If the patient is on ECMO, appropriate perioperative bleeding protocols should be initiated.
- For less stable infants, it may be more appropriate for the surgical repair to take place in their neonatal intensive care unit (NICU) bed space.

TECHNIQUES

OPEN LEFT CONGENITAL DIAPHRAGMATIC HERNIA REPAIR

Positioning

- In the operating room, the infant is placed in the supine position on a shortened bed (**FIG 3**).
- Sterile plastic drapes are used as a barrier over the infant outside of the operative field. A warming blanket is also used to maintain temperature stability.
- For operative repairs in the NICU, the infant is brought to the end of his or her bed at an angle, with his or her feet directed toward one corner (**FIG 4**).
- Both the abdomen and chest are prepared as the operative fields. The umbilical catheters are secured to the patient's lower quadrant, contralateral to the operative side.

FIG 3 ● The infant is positioned in the center of a shortened operating room table. The operating surgeon stands on the side of the CDH with the surgical assistant on the opposite side.

FIG 4 ● The infant is positioned in his or her NICU bed at a 45-degree angle with his or her feet directed toward one corner. The operating surgeon then stands on the side of the CDH and the surgical assistant on the opposite side. The ventilator and other equipment are kept at the head of the bed.

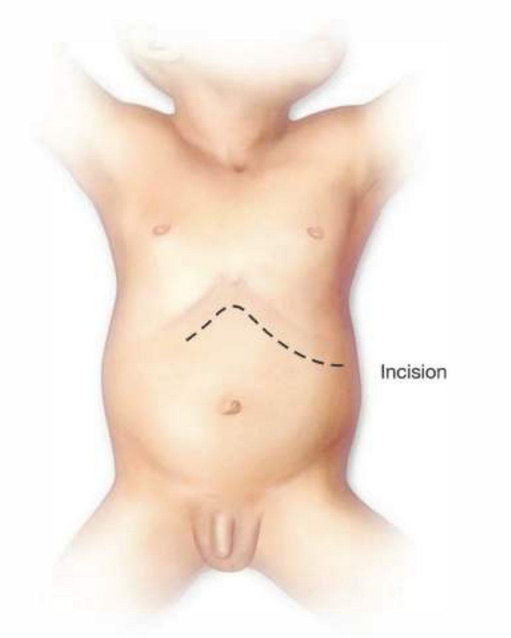

FIG 5 ● A subcostal incision is made one to two fingerbreadths below the costal margin. It may need to be extended across midline to provide adequate exposure for larger diaphragmatic defects.

Incision

- For a left CDH, an ipsilateral subcostal incision is made. Do not make the incision too close to the costal margin as it may leave little room to work with on the lateral chest wall and it may make closure more difficult. The subcostal incision will need to be extended across midline for larger diaphragmatic hernia defects (**FIG 5**).
- The abdominal wall muscle and fascia are divided and the peritoneum entered. The infant's abdominal wall may be gently stretched to help increase domain for the hernia reduction.

Hernia Reduction

- First, the liver needs to be mobilized. The triangular ligament is taken down and the left lateral segment completely freed up. The falciform ligament can usually be left intact.
- The liver is carefully retracted away from the diaphragmatic defect to expose the medial boundary of the diaphragmatic hernia defect (**FIG 6**).
- The reduction of the hernia is typically done in a stepwise fashion.
- The anterior aspect of the incision is retracted cranially. Next, the liver is very carefully reduced from the hernia (if up) and retracted medially with moist lap pads and soft malleable retractors. Then, the small and large bowels are gently reduced from the hernia. Care is taken to keep the mesentery properly oriented and to avoid trauma to the splenic capsule when reducing the colon. Finally, the stomach and spleen are reduced together. This is best done with the index finger. Special attention is paid to avoid traction on the short gastric vessels. All the abdominal viscera can usually be packed within the abdominal cavity using moistened mini-lap pads and malleable retractors. This helps with temperature control and allows some time for the abdominal cavity to begin to accommodate prior to fascial closure. For prolonged procedures, the tightly packed bowel may need to be intermittently unpacked and inspected for ischemia.
- If a hernia sac is present, this is excised.

Repair of the Diaphragm

- An assessment is made to determine the amount of native diaphragm. The posterior aspect of native diaphragm may need to be mobilized and unfolded from the retroperitoneum to fully use it in closure. The anterior diaphragm is then traced medially and the left crus is identified.

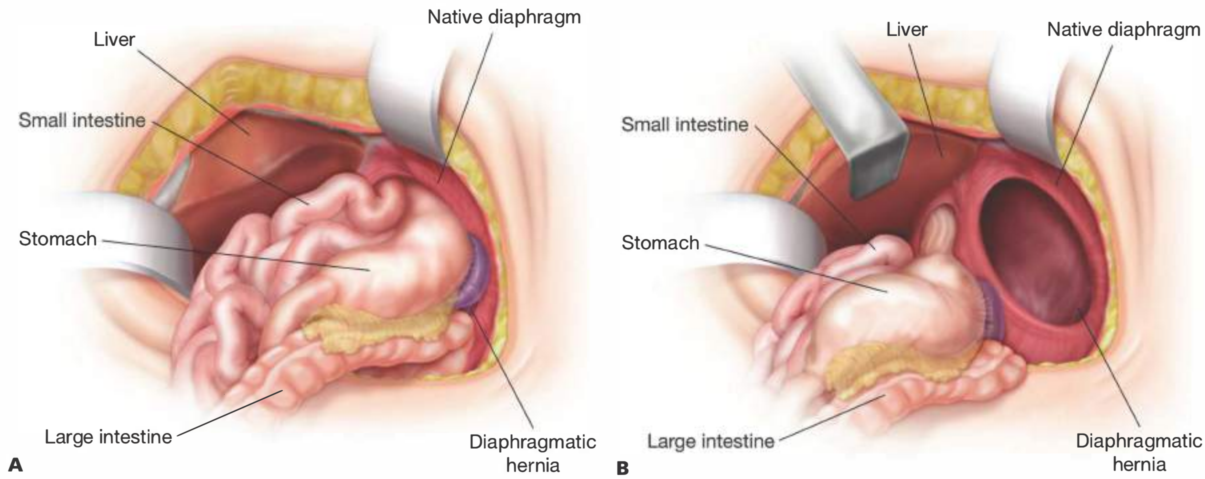

FIG 6 ● **A.** The diaphragmatic hernia defect is exposed. **B.** The abdominal contents have been reduced from the diaphragmatic hernia and the native diaphragm is assessed.

- If the diaphragmatic hernia is small enough for primary closure without significant tension, this is preferred. The defect is repaired with interrupted simple sutures using nonabsorbable braided suture material. For those defects that are too large to close primarily, a 1-mm Gore-Tex soft tissue patch is used. This is carefully fashioned so as to maintain the rounded, dome shape of a normal diaphragm. The posterior wall is sewn first to the patch with interrupted sutures using a braided nonabsorbable material. The sutures are left untied initially (**FIG 7**). Once all in place, the patch is then parachuted down, and the sutures are individually tied secured (**FIG 8**). Then, before closure of the anterior diaphragmatic defect is initiated, care is taken to ensure hemostasis on the thoracic side of the patch.
- For portions of the diaphragmatic defect with no native diaphragm present, the soft tissue patch is sewn directly to rib. A thick taper needle is brought in through the superior aspect of rib and out through the center of the rib to avoid the neurovascular bundle. Once adequate hemostasis is achieved, the anterior wall of the diaphragm is closed (**FIG 9**). A chest tube is not placed unless the patient is anticoagulated on ECMO.

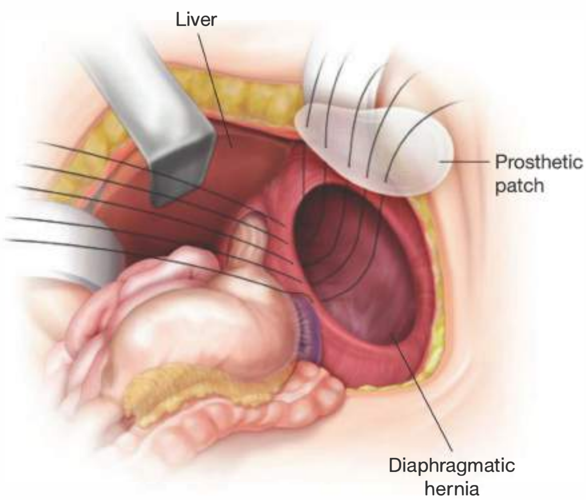

FIG 7 ● The diaphragmatic patch is first sewn to the posterior diaphragmatic defect or chest wall. The sutures are initially left untied to facilitate adequate placement. Once the posterior row is in place, the patch is parachuted down in place and the sutures are tied. Prior to closing the anterior rim of diaphragm, the thorax is inspected for hemostasis.

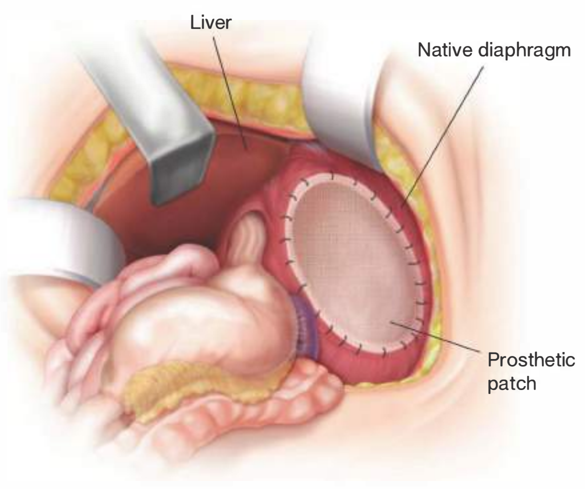

FIG 8 ● The diaphragmatic hernia repair is completed with the patch sewn in place in a tension-free manner.

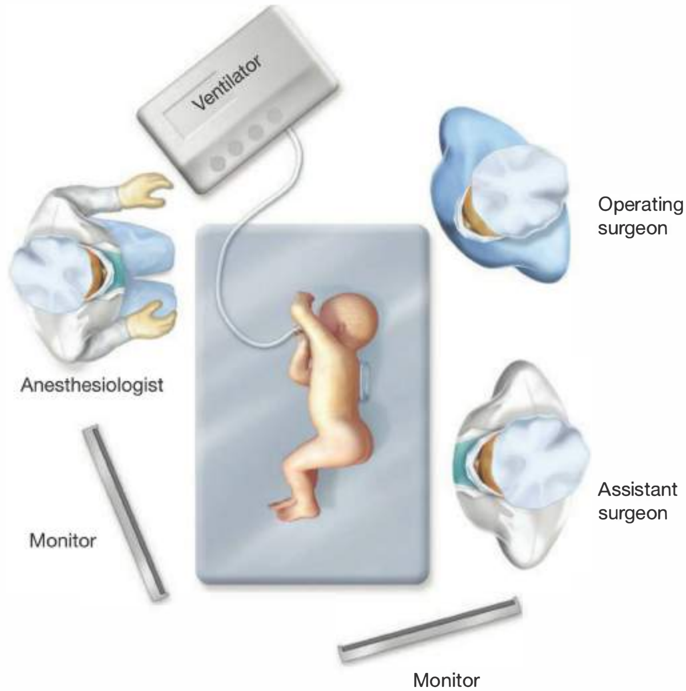

FIG 9 ● The infant is positioned in lateral decubitus position with the affected side up. The infant is placed at one end of the operating table so that the operating surgeon is able to be positioned at the infant's head and the surgical assistant to his or her side.

- At this time, the retractors are released and the bowel is inspected.

Closure

- Position the abdominal viscera in anatomic position. The spleen is placed in the left upper quadrant abutting the repaired diaphragm. The bowel is positioned to keep the mesentery flat and untwisted. Only if there is little chance for the patient to be anticoagulated, such as for ECMO, are Ladd bands divided. An appendectomy is not routinely performed and should be avoided when a prosthetic patch is used. Lastly, the left lateral segment of liver is placed back over the anterior gastric wall.
- The abdominal wall musculature and skin are then closed in layers.
- For some patients, there will be loss of abdominal domain after hernia reduction and primary abdominal closure may not be feasible. If this is the case, a silo or patch may be easily used to avoid potential issues with postoperative abdominal compartment syndrome.

THORACOSCOPIC LEFT CONGENITAL DIAPHRAGMATIC HERNIA REPAIR

Positioning

- The infant is placed in the lateral decubitus position with the affected side up. An axillary roll is placed and care is taken to ensure all pressure points are properly padded.
- The ipsilateral arm is extended anteriorly and superiorly to open the axilla.
- The patient is oriented on the operating room table so that the operating surgeon may stand at the patient's head. The monitor is accordingly positioned over the infant's feet (**FIG 9**).

Trocar Placement

- A Veress needle is first introduced followed by a 5-mm radially expanding trocar placed just caudal to the angle of the scapula.
- Pneumothorax is initially set at 4 mmHg and ventilator changes along with carbon dioxide (CO_2) are closely monitored. Mainstem intubation is typically not needed.
- A 4-mm, 30-degree scope is used for visualization.
- Two additional 4-mm trocars are placed under direct thoracoscopic vision, anterior and posterior to the first trocar, and one to two rib spaces caudally. These will be the primary working ports (**FIG 10**).
- An additional trocar may be needed to retract the lung out of the operative field.

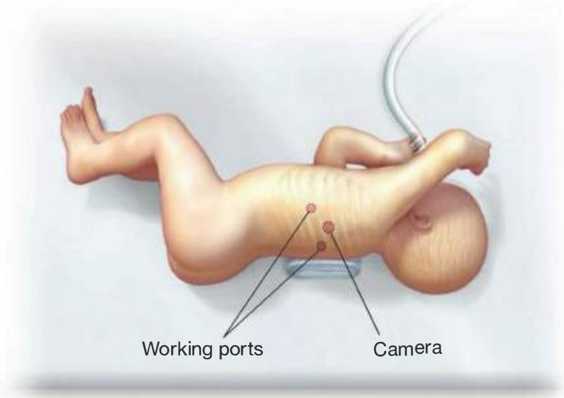

FIG 10 ● The initial 5-mm port is placed at the angle of the scapula following introduction of pneumothorax via the Veress needle. Two additional 4-mm ports are inserted to the right and left, one to two rib spaces inferiorly. This allows the 4-mm camera to be repositioned when necessary. An additional posterior port may be added if needed.

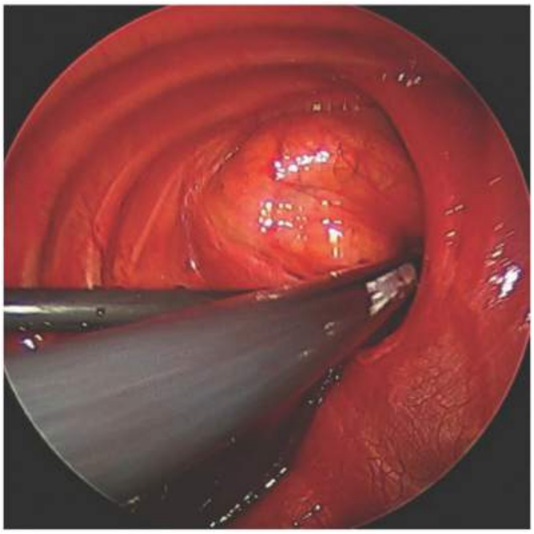

FIG 12 ● A cotton-tipped Endo Kittner can be particularly helpful with reduction of the spleen.

Reduction of the Diaphragmatic Hernia

- The abdominal viscera are carefully reduced with blunt graspers and a cotton-tipped Endo Kittner. The pneumothorax will aid in this process (**FIGS 11** and **12**).
- If the spleen is included in the herniated viscera, this is reduced last, and it may provide an initial "plug" to the defect.
- The hernia sac, if one is present, is carefully excised circumferentially off the diaphragmatic defect using hook cautery. It may be otherwise left attached to any abdominal viscera.

Repair of the Congenital Diaphragmatic Hernia

- When a relatively tension-free primary repair is feasible, the defect is reapproximated using braided nonabsorbable sutures placed in an interrupted fashion. The hernia defect is best repaired beginning from medial, where it is the most narrow, to lateral, where it is at its widest (**FIGS 13** and **14**).
- The most lateral aspects of the diaphragmatic hernia repair typically require pericostal stitches because the costal insertions of the diaphragm are too wide for primary reapproximation. These pericostal stitches close the defect by securing the native diaphragm to the lateral chest wall. A small stab incision is made directly over the rib that the suture is to be secured around. The suture is introduced into the chest inferior to the rib under thoracoscopic vision using a standard needle driver. Once thoracoscopically sutured to the diaphragm, it is retrieved using an endosnare and brought back out the superior

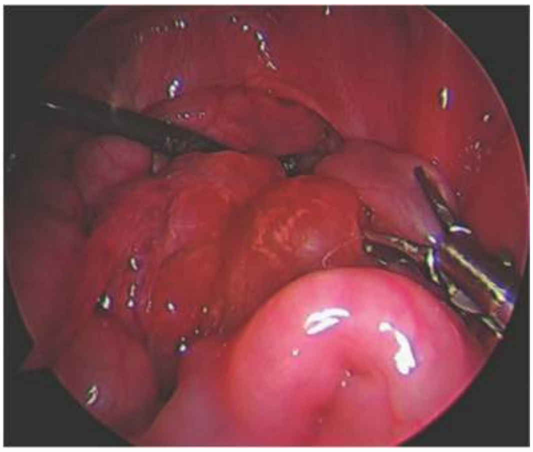

FIG 11 ● The abdominal viscera are carefully reduced through the diaphragmatic hernia defect with blunt graspers. The CO_2 pneumothorax can aid in this as well.

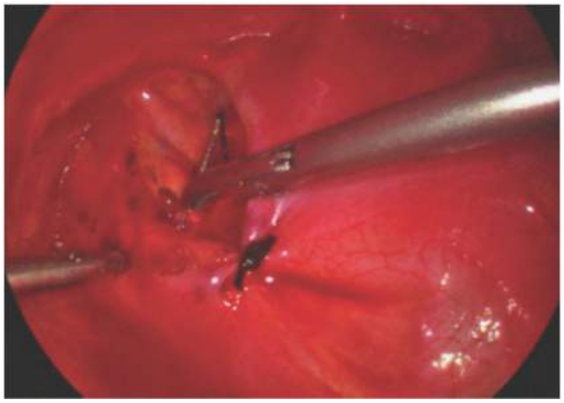

FIG 13 ● The thoracoscopic hernia repair is begun in a medial to lateral fashion using intracorporeal suturing techniques. The diaphragm is reapproximated using interrupted sutures in a tension-free manner.

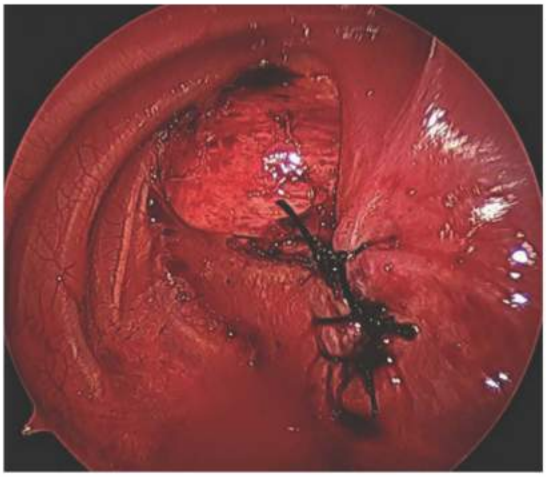

FIG 14 ● As the repair approaches the lateral chest wall, the defect becomes wider due to the fixed nature of the diaphragm on the chest wall. This will not primarily reapproximate without significant tension.

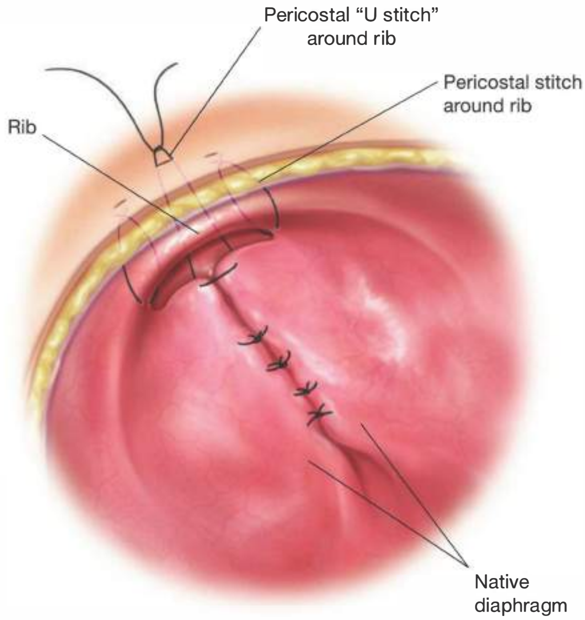

FIG 16 ● A pericostal U stitch is used to close the remaining diaphragmatic hernia defect while securing it to the chest wall.

side of the rib (**FIG 15**). The suture is then tied extracorporeally. The central portion of the diaphragmatic defect usually requires a pericostal "U stitch" that brings the posterior and lateral rim of the diaphragm together, fixing them to the lateral chest wall (**FIG 16**). This allows complete closure of the hernia defect (**FIG 17**).

- If a patch is needed, this may be secured to the diaphragm in a fashion similar to open repair and to the chest wall using the earlier described pericostal U-stitch technique. Additionally, a synthetic patch may also be used as an onlay for weaker areas of the diaphragmatic repair. Using a thin composite mesh may provide for easier introduction and intracorporeal manipulation.

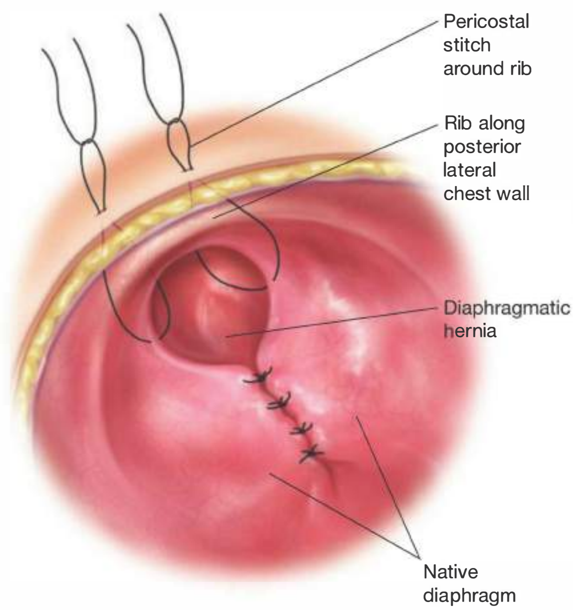

FIG 15 ● Pericostal stitches are placed through small stab incisions in the patient's lateral chest wall. These both secure the diaphragm repair to the rib and reduce the size of the remaining hernia defect without significant tension.

Closure

- The pneumothorax is released and the lung reexpanded. A chest tube may be placed through the anterior trocar site if deemed necessary.
- The incisions are reapproximated with absorbable suture and skin glue is applied as a dressing.

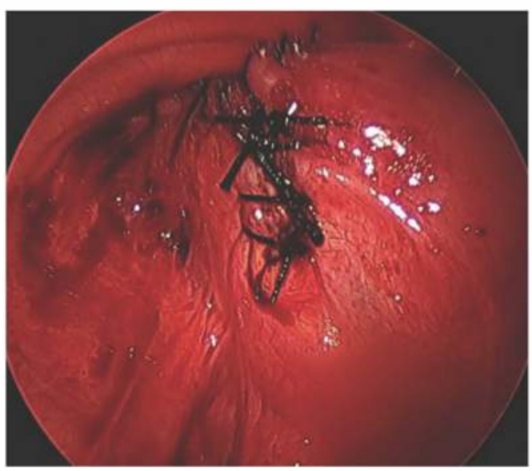

FIG 17 ● The completed CDH repair.

PEARLS AND PITFALLS

Incision	■ If perioperative ECMO is likely, use electrocautery as much as safely possible during repair and avoid mobilization of retroperitoneal area.
Hernia reduction	■ Be on the lookout for abnormally draining hepatic veins when mobilizing and reducing the liver. ■ Avoid trauma to the short gastric vessels and splenic capsule.
Hernia repair	■ The patch may need to be secured to esophagus, pericardium, or aortic adventitia if no medial diaphragm is present. ■ Incorporate enough redundancy in the patch construction so as to allow the repaired diaphragm to have a normal, rounded shape instead of a flattened one.
Thoracoscopy	■ Mark the rib(s) for the pericostal stitches prior to insufflating the thorax to prevent overflattening the diaphragm. ■ External compression by the assistant on the lateral chest wall may aid in the placement of the more difficult lateral sutures.
Closure	■ If in question, use a silo or patch to aid abdominal wall closure.

POSTOPERATIVE CARE

- The principles of postoperative care are similar to the preoperative care of CDHs and close monitoring of pulmonary hypertension is critical. Close attention to fluid status is also required as the fluid demands in the immediate postoperative period will typically rise. The ventilator, once stabilized, is slowly and deliberately weaned as tolerated.

OUTCOMES

- The overall survival of infants with CDH varies between 60% and 90%. For the subset of infants that require ECMO, the survival remains at around 50%.[1]
- The recurrence of CDH is bimodal, with early recurrences typically seen within 2 months of surgery and late recurrences at approximately 2 years of age. Data from the CDH registry suggest that the early, in-hospital recurrence rate is significantly higher for thoracoscopic (7.9%) versus open (2.7%) repair.[2]
- Multiple different patch materials have been used. These include nonabsorbable prosthetic, biologic, and muscle flaps. At this time, there is no clear advantage with regard to survival, recurrence, or bowel obstruction among any of these patch materials.[3–5]
- CDH patient survivors are at risk for chronic pulmonary, cardiovascular, neurodevelopmental, GI, and musculoskeletal problems and should be closely followed for these well into the school ages.

COMPLICATIONS

- Recurrence
- Patch infection
- Postoperative pulmonary hypertension
- Abdominal compartment syndrome
- Postoperative hemorrhage
- Bowel obstruction

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Chapter 19

Paraesophageal Hernia Repair: Laparoscopic Technique

John G. Hunter   Mark J. Eichler

DEFINITION

- For millennia, the existence of hiatal hernias was well known. First described by Henry Bowditch in 1853, and later in 1951 officially by Philip Allison, the paraesophageal hernia (PEH) presents a physiologic link to reflux esophagitis, ulceration, stricture, and other esophageal pathology.[1,2]
- Of the four types of hiatal hernias known today, 95% of incidence resides with the type I or sliding hiatal hernia, which typically can be managed medically with gastric acid suppression. The remaining three types are lumped as "paraesophageal hernias." These include the true PEH (type II), combined sliding and paraesophageal (type III), and extragastric (type IV) (**FIG 1**). With the advent of modern antireflux surgery, failed fundoplication overlaps with this classification (**FIG 2**). Furthermore, disruption of the esophageal hiatus for other disease processes, such as esophagectomy, potentiates the PEH, especially type IV.
- This chapter, in concert with other procedures such as fundoplication and esophageal lengthening (Collis gastroplasty), will deal with the surgical management of PEH types II to IV, which anatomically may also encompass redo fundoplication. Principles of repair include definition of anatomy and symptoms, safe reduction of abdominal organs back to the peritoneal cavity, excision of the hernia sac, closure of crura (with or without mesh repair), evaluation of intraabdominal esophageal length, and an antireflux procedure.[3,4]

PATIENT HISTORY AND PHYSICAL FINDINGS

- Necessity for PEH repair lies with the patient symptomatology, medical status, and chance of obstruction or strangulation. PEHs can encompass symptoms of gastroesophageal reflux disease (GERD), which includes typical symptoms of heartburn, acid reflux, and dyspepsia. In contrast, atypical GERD symptoms manifest as laryngeal and pulmonary complaints of noncardiac chest pain, dyspnea, poor dentition, sinusitis, asthma, chronic cough, pneumonia, and halitosis. PEH-specific complications include gastric volvulus, incarceration, gastric outlet obstruction, and higher mortality when performed emergently. Early studies on mortality in the 1960s demonstrated mortality rates over 50% for PEHs with associated gastric volvulus, although more recent analysis suggests that number to be overestimated and is actually more likely to be under 20% for such patients in duress from PEH.[5,6] For all PEH patients, overall mortality is under 1% and can safely be performed with a laparoscopic approach even in the face of obstruction, gangrene, and so forth.[7]
- Indications for PEH repair therefore should be tailored to patients who are symptomatic and medically likely to survive an operation. Ultimately, most patients who have a PEH will become symptomatic.[3,5,6]

IMAGING AND OTHER DIAGNOSTIC STUDIES

- Preoperative diagnostic studies help dictate the range of elective, urgent, and emergent nature of a symptomatic patient with a PEH. In those patients who are in extremis, the minimum workup needed for urgent or emergent PEH repair is radiographic evidence of incarceration, perforation, obstruction, or failed antireflux surgery. However, the majority of patients present in an elective manner, and we therefore advocate for a complete workup to assist preoperative planning of the symptomatic patient with PEH by the addition of manometry, pH testing, and endoscopy to rule out pseudoobstruction or esophageal motility disorders.
- Chest x-ray: At presentation, whether to an emergency department or a primary care physician's office, the chest x-ray gives quick and cost-effective information to the severity of the PEH. Mediastinal gas bubble can be seen on plain film radiography as well as the presence of pneumoperitoneum or pneumomediastinum.
- Esophagram: The supine and upright plain film esophagram demonstrates static anatomy and can often locate the gastroesophageal junction (GEJ) in relation to the diaphragm as well as deduce the presence of reflux on delayed films. Mucosal abnormalities can be seen with this modality as well (**FIG 3A,B**).
- Computed tomography (CT): Indications for obtaining CT scans include the emergent presentation, inconclusive but worrisome findings on two-dimensional radiography, and PEH type IV (**FIG 4**). CT aids the preoperative planning by alerting the surgeon to the extent of skin preparation and positioning for operative repair but is not necessary.
- Upper endoscopy: All preoperative patients should undergo upper endoscopy if possible. By visualization of the esophageal and gastric lumen, neoplasm, Barrett's esophagus, and esophagitis can be biopsied, and, in case esophagectomy is warranted, provide histologic diagnosis. Furthermore, anatomic landmarks can be seen such as the distance between the hiatus and the GEJ as well as the size of the hiatal hernia.
- Manometry: Several studies of benign esophageal disorders confirm the use of preoperative manometry.[3,8] Distal esophageal pressures greater than 30 mmHg indicate favorable outcome of response to fundoplication, which, according to some surgeons, is a threshold for performing a complete versus partial wrap for the antireflux component of the PEH repair. Manometry also rules out primary esophageal dysmotility including achalasia, diffuse esophageal spasm, nutcracker esophagus, hypertensive lower esophageal sphincter (LES), and ineffective esophageal motility. We do not advocate performing a complete fundoplication for patients with esophageal dysmotility or low distal esophageal pressures.
- pH study: Although the previous modalities of the PEH workup provide a robust description of the PEH patient, pH studies provide data for the decision in failed antireflux

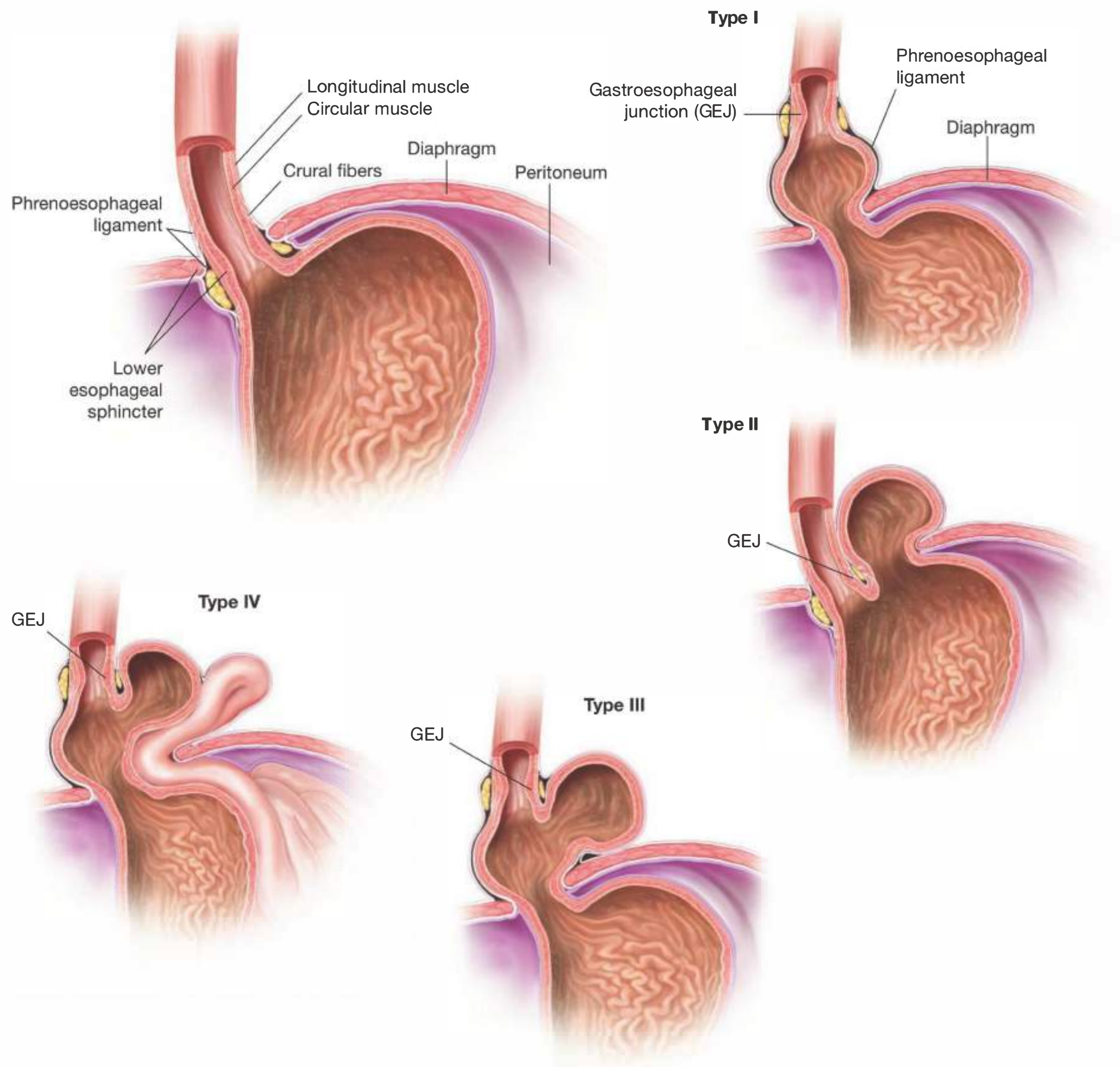


FIG 1 ● The four types of hiatal hernia: type I (sliding): GEJ translates linearly along esophageal axis cephalad into the mediastinum; type II (paraesophageal): GEJ resides intraabdominally with (usually) the gastric fundus or body translating cephalad past the GEJ; type III (combined): GEJ and gastric segments both translate above diaphragm; type IV (extragastric): small bowel, colon, spleen, and even pancreas may translate into the mediastinum and chest.

surgery to dissect and redo a previous fundoplication. In the setting of a negative pH study (by way of DeMeester score <15),[9] a "herniated" fundoplication may indeed be intact, thus saving the risk of tedious and unnecessary redo fundoplication as a component of the PEH repair.

SURGICAL MANAGEMENT

Preoperative Planning

- All studies, including esophagram, esophagogastroduodenoscopy (EGD), manometry, and pH testing should be readily available and reviewed prior to and at the time of surgery. The esophagram should be displayed on a spare or dedicated monitor in the operating theater and EGD images be loaded as well for intraoperative reference.
- Attention to fine detail of the manometric report may avoid an unnecessary and detrimental 360-degree fundoplication, as a complete wrap may worsen symptoms in the light of the following findings[8]:
  - Severe esophageal dysmotility
  - Very low residual postrelaxation LES pressures less than 30 mmHg during wet swallow

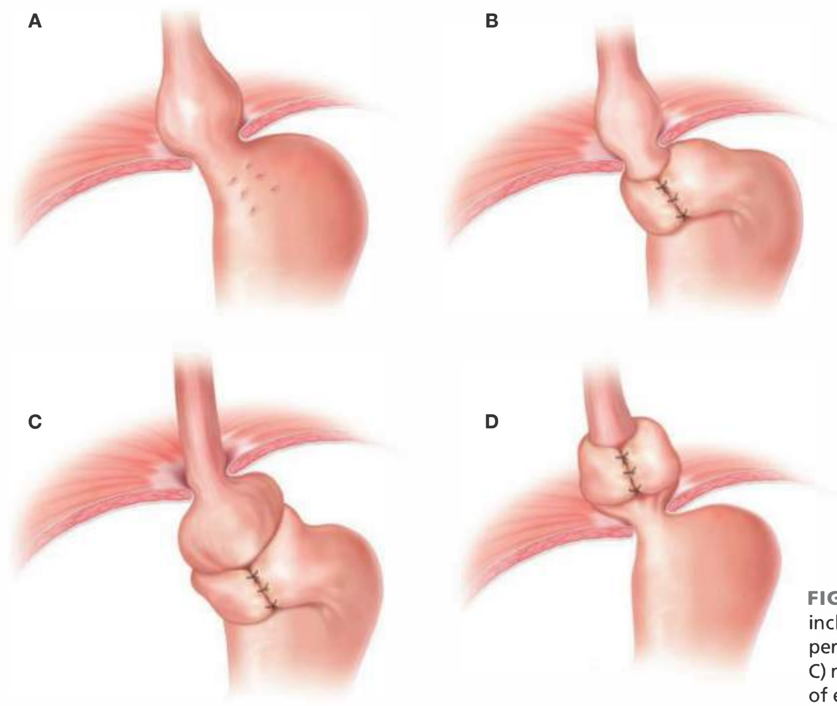


FIG 2 • Anatomy of fundoplication failure, including A) wrap dehiscence B) recurrent or persistent hiatal hernia with wrap slippage C) misplaced or slipped wrap, and D) herniation of entire wrap above the diaphragm.

Positioning

- An operating table capable of steep reverse Trendelenburg position is required. Arms are tucked at the patient's sides but can be out 90 degrees and secured. Footboards on a split-leg table are mandatory, and a preprocedural reverse Trendelenburg test is used for safety confirmation of positioning (**FIG 5A**).
- Assume extensive mediastinal dissection will be warranted, and therefore, pleural compromise is a frequent occurrence. The sterile skin preparation must be wide enough on either flank in case tube thoracostomies are necessary from resultant pneumothorax. However, a red rubber catheter between 10 and 14 Fr may be placed in a witnessed pleural defect intraabdominally, spanning the diaphragm to the hemithorax in question. This reduces the resultant pneumothorax and peak ventilatory pressures with the aid of lowering insufflation pressures as well as anesthesia-assisted ventilatory Valsalva.
- After Veress needle insufflation in either the supraumbilical or the left upper quadrant, trocar placement ensues. Five trocars are used for the laparoscopic PEH repair (**FIG 5B**). After the liver retractor and ports are placed, the patient is positioned into steep reverse Trendelenburg and the dissection begins.

Instrumentation

- As aforementioned, there can be up to a 20% enterotomy rate during PEH repair, especially during redo operations. Therefore, extraordinary care is tantamount to establishing safe dissection planes, especially near the esophagus. Ultrasonic shears are the mainstay of dissection (Harmonic Ace curved shears, Ethicon, Somerville, NJ), whereas when operating extremely close to organs, we advocate switching to laparoscopic scissors as well as blunt dissection to avoid thermal injury.

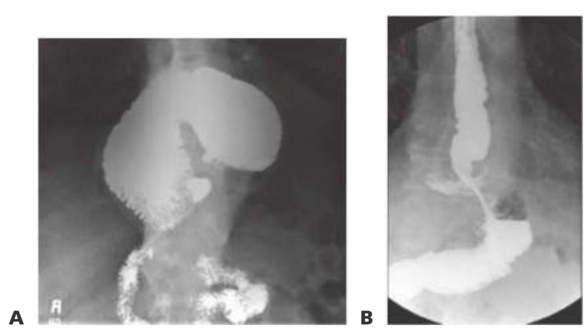


FIG 3 • **A,B.** Esophagram. **A.** Radiography demonstrating a large PEH with herniation of nearly the entire gastric lumen into the posterior mediastinum with mesoaxial volvulus. **B.** Slipped Nissen fundoplication with an intact wrap proximal to the diaphragm.

FIG 4 • CT of massive PEH type IV in which the entire transverse colon has herniated into the left hemithorax.

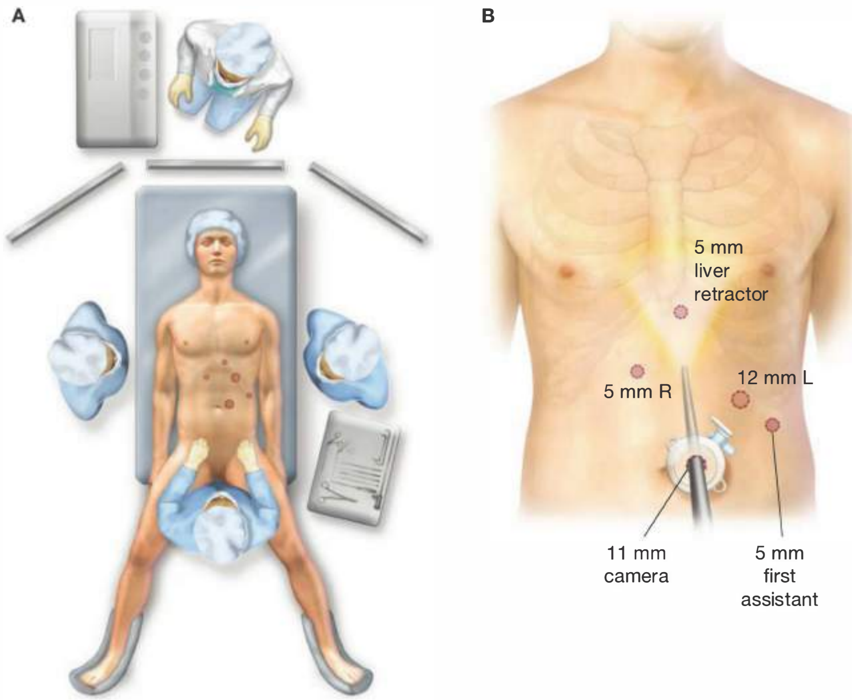


FIG 5 ● Patient positioning **(A)** and trocar placement **(B)**. After pneumoperitoneum is established, lines are drawn at the inferior edge of the costal margin diagonally up to an imaginary point above the xiphoid as a zero point for trocar placement. Five trocars are used for the laparoscopic PEH repair. (1) An 11-mm supraumbilical camera port, offset just to the left of the midline and 15 cm inferiorly. (2) A 12-mm left upper quadrant port, measured 12 cm along the parallel line to the left costal margin, for the surgeon's right hand. This port is placed 1 to 2 cm inferiorly to the 12-cm mark. (3) A 5-mm right upper quadrant trocar, measured 7 to 10 cm from the supraxiphoid point and 1 to 2 cm inferiorly, for the surgeon's left hand. This can be placed to the right of the falciform and then through the falciform. (4) An assistant's 5-mm left flank trocar is placed about a palm's width inferiorly and laterally from the 12-mm trocar. (5) Finally, a 5-mm port is placed and removed in the subxiphoid region for the Nathanson liver retractor. Similarly, a port can be placed at the right flank, symmetrically opposite from the assistant's port for a linear liver retractor, as supplies may vary per operating theater.

REDUCTION OF THE HERNIA

- To whatever extent possible, reduce the contents of the mediastinum previously back into the abdominal cavity by use of both the primary surgeon's hands as well as the assistant's with atraumatic graspers (**FIG 6**). Note that there may be various layers to the hiatal hernia sac (**FIG 7**).

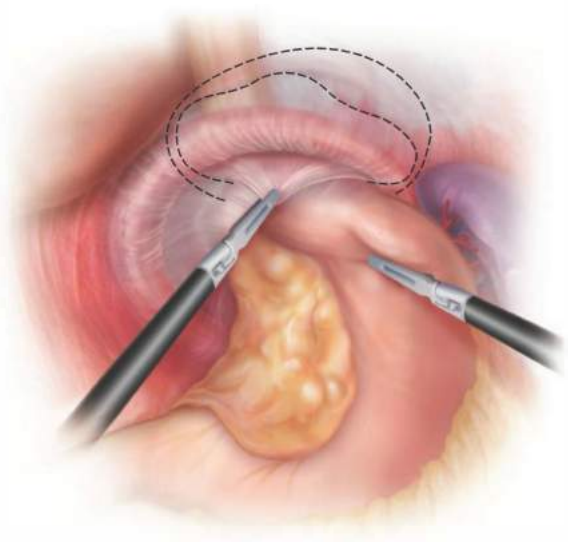


FIG 6 ● Reduction of major viscera with blunt retraction back into the abdomen. The *dotted lines* indicate the plane of dissection about the hernia sac.

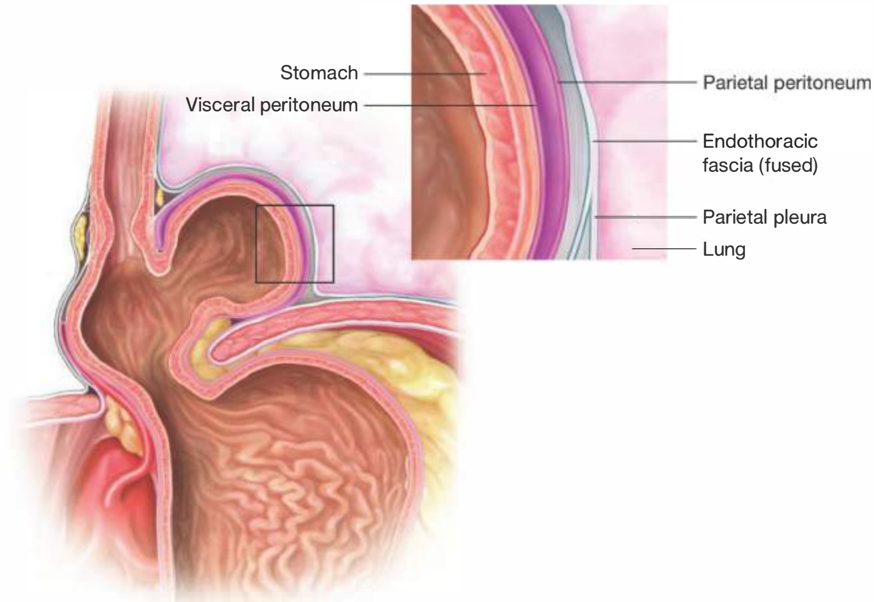


FIG 7 ● Layers of the PEH sac. Note the interface between the visceral peritoneum and endothoracic fascia (sometimes fused to parietal pleura) should be the plane to establish during dissection.

INITIAL HIATAL DISSECTION

- It is usually safe, once countertraction is well established and reduction of the entire PEH is attained, to initiate dissection on the right crus directly to the right of the esophagus, providing a starting point for anterior and posterior dissection. Anterior dissection occurs in a 180-degree fashion anteriorly and then to the left of the hiatus, just in a plane immediately deep to the peritoneum/hernia sac; any deeper and thermal injury or perforation might happen to the esophagus. If the hernia cannot be completely reduced intraabdominally, then we advocate an approach from the left crus, anteriorly 180 degrees to the right crus (**FIG 8A,B**),

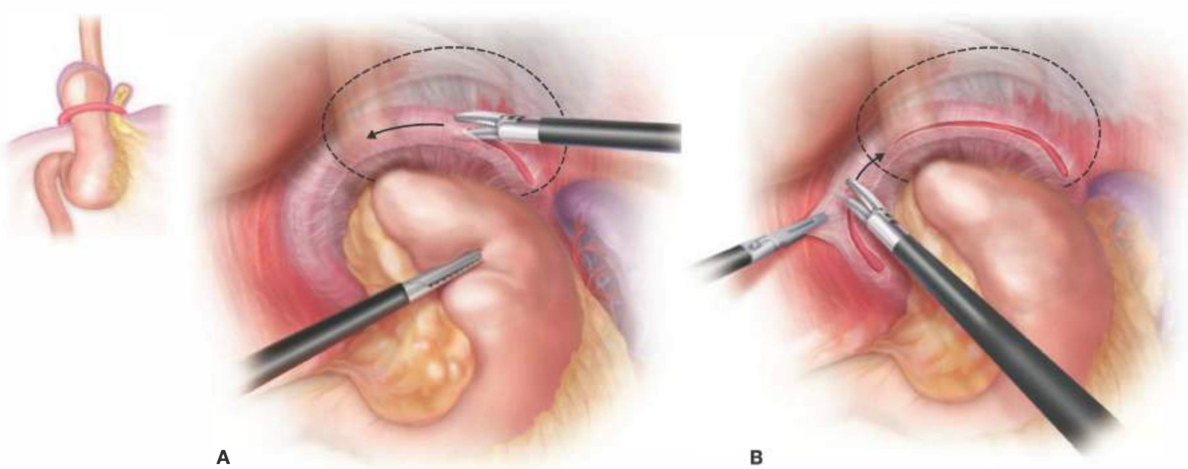


FIG 8 ● **A,B.** Dissection from left to right, anteriorly, starting on the left crus. Ultrasonic dissection takes place directly on the edge of the diaphragm at all times. Countertraction must be kept to prevent retraction of the hernia sac into the mediastinum.

reasoning that the position of the unreduced PEH and true dissection plane on the left can be more readily ascertained. The resultant anterior dissection can be seen in **FIG 9**.

- Posterior dissection ensues from the original starting point to the right of the esophagus to free the right crus posteriorly and deep, then as much as possible, to the left of the GEJ.

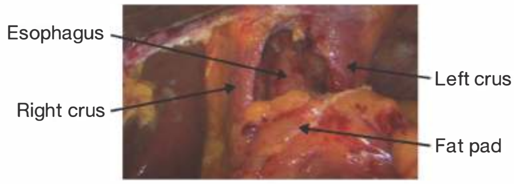


FIG 9 ● Resultant anterior 180-degree dissection.

SHORT GASTRIC VESSEL LIGATION

- Before complete 360-degree dissection can take place, the short gastric vessels must be completely dissected, even if a previous procedure supposedly took place, as some surgeons selectively or incompletely perform short gastric takedown (**FIG 10A–C**). This should be performed on the slow setting of the ultrasonic shears, as premature ligation might allow incompletely ligated vessels to retract into the gastrosplenic ligament uncontrollably. Although endoscopic surgical clips may help, it is more efficacious to regrasp the bleeding ligament and vessels for ultrasonic ligation. Occasionally, depending on the surgeon's skill, an open procedure is necessitated.

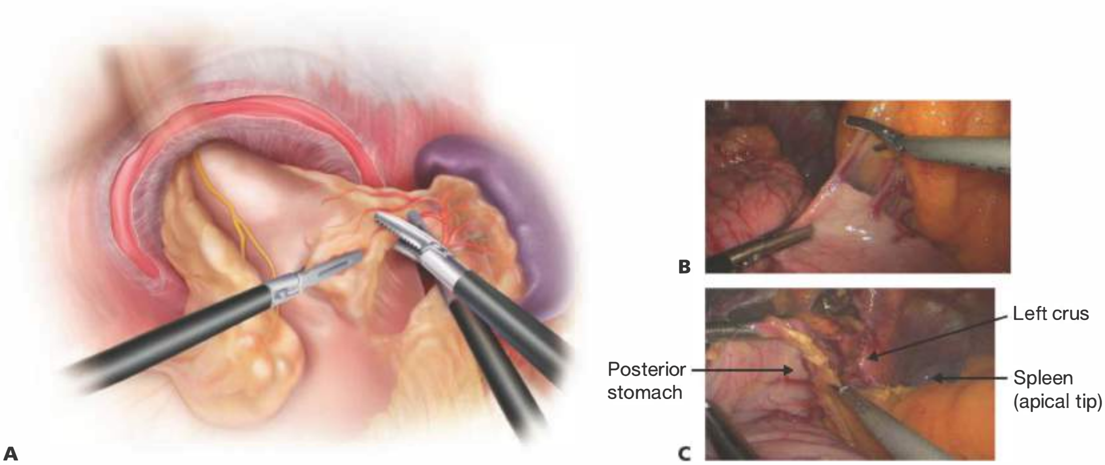


FIG 10 ● **A–C.** Short gastric vessel ligation. **A,B.** Initial dissection begins at a level parallel to the distal splenic tip. **C.** Completion of the short gastric ligation. Note the exposure of the posterior stomach to complete this step.

POSTERIOR GASTRIC ATTACHMENTS

- To complete the circular dissection, the surgeon's left hand and assistant splay the stomach to the anteromedial direction and omentum to the left. This reveals attachments posteriorly from the splenic vessels to the left gastroepiploic vessels. These can be taken also with ultrasonic dissection. After reduction of the posterior sac (**FIG 11**), this completes the 360-degree mobilization (**FIG 12**). A Penrose drain can encircle the GEJ for atraumatic retraction.

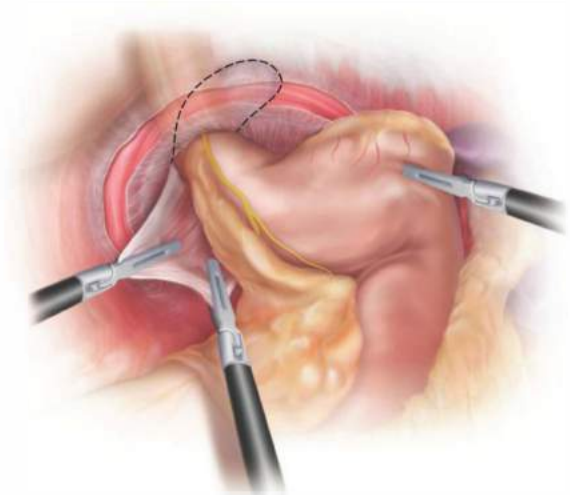


FIG 11 ● Reduction of the posterior sac.

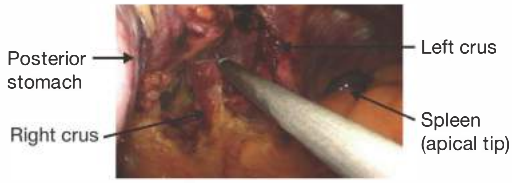


FIG 12 ● Completion of 360-degree dissection.

HERNIA SAC EXCISION

- If properly performed, the hernia sac can be removed en bloc by evidence of the mediastinal component of the hernia sac being contiguous with that of the anterior esophagus and fat pad (**FIG 13A,B**), which may also need excision in order to properly perform the antireflux portion of the operation.
- If the hernia sac is large and will obstruct mediastinal dissection, excision of the sac is warranted. Start on the left crus with traction on the hernia sac and use combinations of blunt dissection when near the esophageal body and ultrasonic dissection to remove the hernia sac when at a safer distance. Manipulation of tissues too far away from the esophagus may compromise the pleural cavity and manipulation too close to the esophagus may incur thermal injury, often unrecognized at time of operation. **FIG 14** demonstrates a close, but safe, distance of dissection to the esophagus.

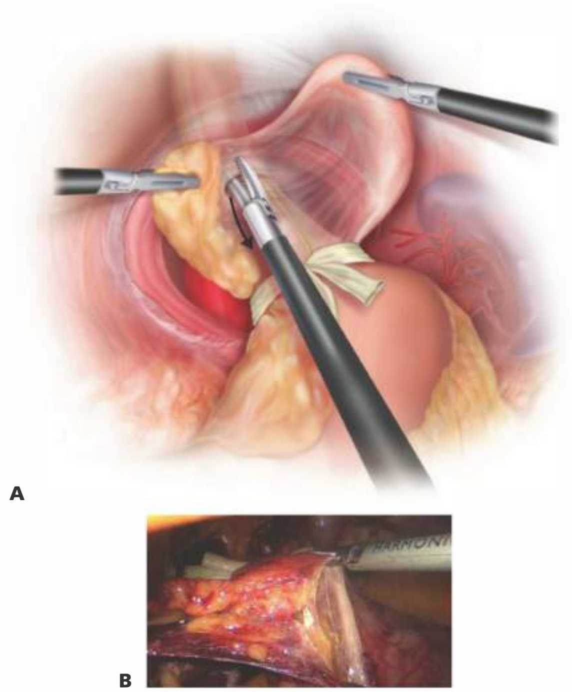


FIG 13 ● **A,B.** Excision of the hernia sac off the anterior esophagus. The sac is placed under countertraction and bivalved just to the left of the vagus nerve.

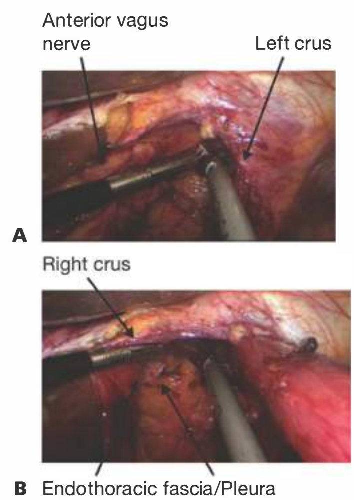


FIG 14 ● **A,B.** Demonstration of proper range of proximity to the esophagus during ultrasonic dissection. **A.** View from left, near esophagus. **B.** View from right, approaching endothoracic fascia and pleura.

FUNDOPLICATION TAKEDOWN

- If there exists a previous fundoplication and preoperative testing demonstrates incompetence of the antireflux procedure, the wrap is mandated to be taken down and redone.
- Extreme care should be implemented as this is the step that carries the most risk of enterotomy either at the stomach or at the esophagus. Once completely dissected, inspection and reinspection of the taken down wrap should take place. Often, the gastric lumen may resemble the shiny planes between the fundus and esophageal body.

MEDIASTINAL DISSECTION

- Adequate mediastinal dissection for esophageal length is encountered when the endothoracic fascia/pleura is placed laterally, and the mediastinal esophagus is visualized in a 360-degree fashion up to the level of the carina or right atrium (FIG 15).

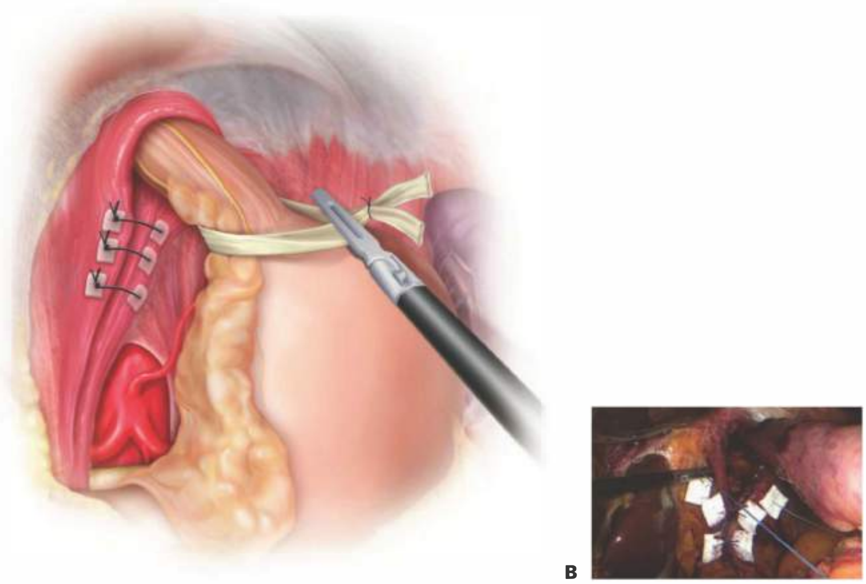
FIG 15 ● Adequate mediastinal dissection as evidenced by 360-degree encirclement of the esophagus up to the level of the carina superiorly, endothoracic fascia/pleura bilaterally, and aorta posteriorly.

ASSESSMENT OF INTRAABDOMINAL ESOPHAGEAL LENGTH

- The left crus is now pulled from left to right, and without any bougie or orogastric tube in place, the intraabdominal esophageal length can be assessed in a relaxed position. If the length is shorter than 2.5 to 3 cm, perform a Collis gastroplasty (see Part 1, Chapter 20).

CRURAL CLOSURE

- Over a 42-Fr bougie, the hiatus is sutured with the appropriate number of coated, braided nonabsorbable suture (0 Ti-Cron, Covidien, Mansfield, MA). Spacing of sutures is approximately 1 cm apart from each other and is placed 1 cm back from the crural edges (FIG 16A,B).
- Pledgets are used on the sutures with the exception of the last sutures needed to avoid pledget ingrowth into the esophagus.
- The quantity of sutures usually numbers two to four, until there is a gap left between the esophagus and crura to easily interpose laparoscopic graspers between the closure.
- If the esophageal hiatus is gigantic, then anterior, in addition to posterior, crural closure can be safely performed to prevent severe angulation of the esophagus at the newly reconstructed hiatus.



A B

FIG 16 ● **A,B.** Crural closure with 0 Ti-Cron pledgeted sutures with 1-cm spacing, both from each suture and from the left and right crural edges. Depending on proximity to the esophagus, the last suture may be unpledgeted to avoid erosion.

TECHNIQUES

MESH PLACEMENT

- If mesh is to be used, two main strategies exist, and both may be affixed by Ti-Cron suture (see "Pearls and Pitfalls"):
  - Keyhole (three-sided) mesh can be sutured or glued to the diaphragm (**FIG 17A**).
- Rectangular mesh is secured along the diaphragm posteriorly (**FIG 17B**).

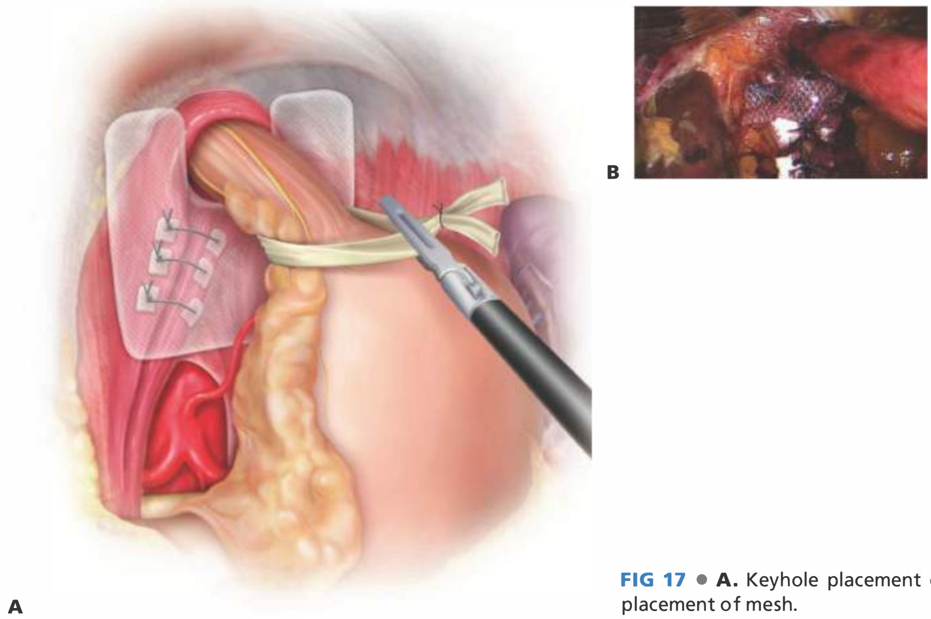


FIG 17 ● **A.** Keyhole placement of mesh. **B.** Rectangular placement of mesh.

ANTIREFLUX PROCEDURE

- The principles of fundoplication apply here, whether a complete (Nissen) (**FIG 18A,B**) or partial (Toupet) wrap is indicated. This completes the goal of reconstructing the angle of His and valvular mechanism of the LES. Refer to the corresponding chapters accordingly.

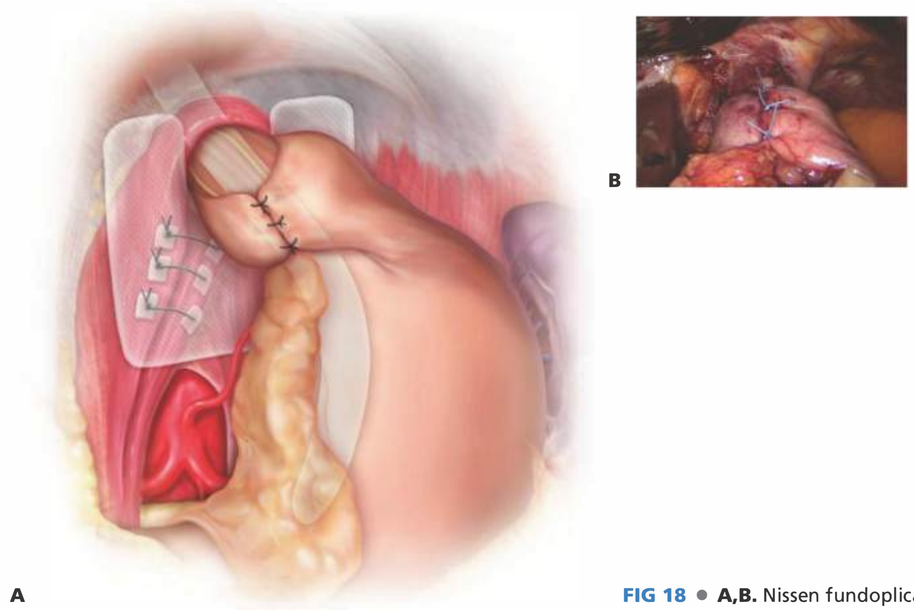


FIG 18 ● **A,B.** Nissen fundoplication.

LEAK TEST

- Two leak tests can be performed.
  - Methylene blue: With dilute methylene blue dripped liberally into a nasogastric tube with the tip above the GEJ, intracorporeal placement of two radiopaque white sponges can detect subtle leaks. Inspect the removed sponges against a white background and back-table light. Any positive test is mandated to be investigated thoroughly with the tear or enterotomy repaired.
  - Bubble leak test (alternative to methylene blue): With the placement of an endoscope and Trendelenburg positioning, irrigate sterile saline intracorporeally and distend the stomach and lower esophagus with insufflation. Any bubbles emanating mandates investigation.

UPPER ENDOSCOPY

- The last portion of the procedure entails direct visualization with an upper endoscope to see the position of the Z line, GEJ, and integrity of the wrap. With retroflexion, the endoscope should move back and forth freely without buckling of the mucosa of the newly reconstructed LES.

PEARLS AND PITFALLS

Enterotomy	■ It is well established that the PEH repair carries up to a 20% risk of enterotomy along the esophagus or stomach, especially in redo operations. If an enterotomy is noticed, for example, during dissection of a slipped Nissen fundoplication, a linear staple firing is warranted across the enterotomy.
Deep hernia sac dissection	■ There is a fine line between removing the hernia sac and perforating or causing thermal injury to the esophagus and/or vagal nerves. With proper superficial dissection at the outset of hiatal dissection allows the surgeon to stay above the esophagus and allows the hernia sac to be excised en bloc.
Pneumothorax	■ Prepare into the field the bilateral lower chest cavities that would access each hemithorax in case a percutaneous tube thoracostomy is needed. Our first recommendation, however, if peak ventilatory pressures are high from a pneumothorax, is to decompress the affected side with the placement of a red rubber catheter through a working 12-mm port and lay it from the hemithorax in question with the opposite end intraabdominally. The lower chest wall should be prepped into the field in case chest tube placement is needed. However, when a pneumothorax is identified, a 14 French red rubber catheter can be placed through the hole with the tip in the chest and the butt in the abdomen. At the completion of the procedure the butt is pulled out a trocar site and is placed in a tub of water (water seal) while the anesthesiologist reinflates the lung with positive pressure ventilations. When the bubbling stops the tube is pulled out the trocar site. A chest x ray in the recovery room confirms re-expansion of the lung.
Inadequate antireflux procedure	■ If redo fundoplication is being performed, it is imperative to obtain preoperative manometry to test the integrity of a "slipped" Nissen versus a simple herniation. If manometry indicates reflux above the wrap, the previous fundoplication should be completely dissected and redone.
Short gastric vessel ligation	■ Do not assume during a redo operation that the previous surgeon has performed adequate short gastric dissection. This tethers the fundoplication, therefore placing improper physiologic vectors on the wrap. Dissect completely the short gastric vessels to avoid tethering.
Intraabdominal esophageal length	■ Inadequate mediastinal dissection results in incomplete abdominal length of the esophagus. Complete and high 360-degree mediastinal dissection allows the true determination if an esophageal lengthening procedure (Collis) is required when performing the antireflux portion of the operation.
Mesh use and material	■ Several studies have investigated the controversy to use or not to use mesh, but no standardization in practice exists due to the many types of mesh material available, shapes into which it is fashioned, and length of study investigated.[10–13] The efficacy of mesh to reinforce the closed crura tapers over time, although the degree of this degeneration is a moving target in the literature. The material choice is widely subject to debate with longer term studies showing no effect on recurrence with small intestine submucosa (Surgisis, Cook Medical, Bloomington, IN), while shorter term studies with human acellular dermal matrix (AlloDerm, LifeCell Corporation, Bridgewater, NJ). Studies ongoing currently involve bioabsorbable woven suture (BIO-A, W. L. Gore & Associates, Inc, Flagstaff, AZ) and porcine acellular dermal matrix (AlloDerm, LifeCell Corporation, Bridgewater, NJ). We currently espouse the use of a rectangular, lightweight, polypropylene, synthetic mesh with four fixation points along the crura (Parietex, Covidien, Inc, Mansfield, MA).
Mesh erosion	■ To avoid mesh erosion, do not place a circular piece of mesh around the closed crura. Keyhole or U-shaped mesh is acceptable with the open end facing anteriorly. Also, a rectangular mesh can be used instead of the U shape with placement from left to right along the closed crura. Care with suture fixation to not place the mesh in contact with the esophagus can alleviate mesh ingrowth and perforation of that organ.

POSTOPERATIVE CARE

- There are two main strata of postoperative care given to patients who undergo PEH repair: with significant adhesiolysis and without significant adhesiolysis.
- Without significant adhesiolysis: For those undergoing their first repair, the dissection can be as simple as an "easy" type I or sliding hiatal hernia. Therefore, if adhesiolysis is simple and straightforward, we elect to give the patients sips of clear liquids immediately postoperatively and advance to full liquids by postoperative day (POD) 1, with discharge for 4 weeks on a proton pump inhibitor. We do not advocate for same day discharge. Home medications should be in liquid or crushable form, and patients are prescribed antinausea, analgesia, and bowel regimen medications. Diet consists of full liquids for 2 weeks then soft mechanical for another 2 weeks.
- With significant adhesiolysis: Redo antireflux disease and technically challenging PEH repairs are usually the mainstay of such operations. The risk of perforation, missed or noticed at the time of surgery, is increased, and therefore, these patients follow a different postoperative pathway. They are kept *nihil per os* (NPO) overnight and studied with a formal esophagram in fluoroscopy, regardless of the ultimate outcome of our intraoperative leak test. If the radiologic exam is negative on the morning of POD 1, the patient's diet is advanced per earlier mentioned protocol with discharge anticipated for POD 2 and the earlier mentioned medication routine. Although it is acceptable to discharge a healthy, good candidate on POD 1, the majority of our patients leave on POD 2 and so forth, depending on medical comorbidities.

OUTCOMES

- Results depend on the nature of the disease process for which an operation is indicated and the number of components of the operation used.
- PEH repair: Mori et al.[6] refer to eight studies that had a mean or median follow-up of 6 to 40 months with a range of 2% to 43% recurrence. Andujar et al.[14] describe laparoscopic PEH repairs being associated with a low incidence of recurrence and reoperation in a series of 166 patients. Improvement was seen in heartburn, regurgitation, dysphagia, and chest pain with an overall 6% reoperation rate for symptomatic PEH (1.2%), reflux (2.4%), and dysphagia (2.4%). With the exception of fundoplication wrap failure in which all required reoperation, one-third of recurrences required surgery, whereas one-tenth of sliding hiatal hernias required surgery; so overall, the reoperation rate is quite low.
- Redo antireflux procedures: In a series of 124 patients, four major failure mechanisms were noticed by Ohnmacht et al.[15]: recurrent hiatal hernia (65%), disrupted fundoplication (32%), perigastric fundoplication (14.5%), and tight fundoplication and hiatal closure (10%).
- Use of mesh: A sentinel series by Oelschlager et al. of patients undergoing crural repair with small intestine submucosa (Surgisis, Cook Medical, Bloomington, IN) mesh initially showed promising data for decreased PEH recurrence rate at 6 months (9% Surgisis, 24% primary repair),[10] but the same group demonstrated that long-term follow-up at a median of 58 months showed no statistical difference (54% Surgisis, 59% primary repair).[11] Notwithstanding shape and material (bioprosthetic vs. synthetic) of mesh used, these studies may be updated in years to come with the use of bioabsorbable mesh, acellular dermal matrix, and various types of synthetic mesh. Ringley et al.[12] reported the use of acellular dermal matrix (AlloDerm, LifeCell Corporation, Bridgewater, NJ) with an initial 6-month follow-up without recurrence versus primary closure involving 9% recurrence. We do not advocate, therefore, prohibiting the use of mesh in PEH repair at this time.
- Choice of antireflux operation: A prospective, randomized trial by Koch et al.[16] of 50 patients in each arm of Nissen versus Toupet fundoplication demonstrated that Nissen procedures favored improvement in hoarseness and showed significant improvement in outcomes manometrically and via multichannel impedance imaging, whereas the Toupet fundoplication was favored by lower dysphagia, inability to belch, and bowel symptoms. Nonetheless, both procedures improved gastrointestinal quality of life indices, GERD symptoms, reconstructed LES pressures, cough and asthma symptoms.

COMPLICATIONS

- PEH recurrence
- Mesh erosion
- Dysphagia
- Esophageal stricture
- Gas bloat syndrome
- Recurrent GERD
- Slipped antireflux procedure

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Chapter 20

Collis Gastroplasty

John G. Hunter Mark J. Eichler

DEFINITION

- Encountering a foreshortened esophagus during surgery at the hiatus, a lengthening procedure is necessary for adequate distal abdominal esophageal length for an antireflux procedure. First described in *Thorax* by John Leigh Collis in 1957 for patients with a short esophagus and hiatal hernia, with or without reflux, a gastroplasty is performed via a thoracotomy on the left aspect of the herniated proximal stomach.[1] This technique has subsequently evolved through thoracoscopic and laparoscopic means for hiatal hernia repairs as well as reflux disease in order to lengthen the abdominal portion of the esophagus for an adequate axial distance around which to perform gastric fundoplication. The Collis gastroplasty commonly involves a laparoscopic stapling technique about the gastroesophageal junction (GEJ) by removing a wedge of stomach at the angle of His, thereby lengthening the effective distal esophageal dimension intraabdominally, about which a fundoplication can be wrapped.[2]

PATIENT HISTORY AND PHYSICAL FINDINGS

- Secondary to chronic acid inflammation and subsequent fibrotic remodeling of the distal esophagus, approximately 10% to 25% of patients with reflux have a shortened esophagus.[3,4] The majority of these patients, however, do not need an esophageal lengthening procedure for a tension-free fundoplication if adequate mediastinal dissection gains return of abdominal esophageal length.[5] Sufficient intraabdominal length can be evidenced by the GEJ lying intraabdominally with a distance between the diaphragmatic hiatus and the GEJ of *at least 2.5 cm*. It is at this threshold of 2.5 cm (approximately the length of a fully opened atraumatic laparoscopic grasper) after adequate mediastinal and crural dissection should the decision to perform a Collis gastroplasty take place,[3] with an overall incidence of implementation of 3% to 4% of reflux operations.

IMAGING AND OTHER DIAGNOSTIC STUDIES

- The preoperative workup for reflux disease spans endoscopy (esophagogastroduodenoscopy [EGD]), esophagography (upper gastrointestinal contrast swallow or esophagram), manometry, and pH probe testing. However, there is no gold-standard radiologic imaging study for preoperative preparation in reflux disease, as the surgical decision making to perform a Collis gastroplasty is done ultimately intraoperatively. Yet, esophagography and endoscopy may be the optimal studies to demonstrate a foreshortened esophagus by the following signs[6]:
  - Hiatal hernia of 5 cm or more
  - Giant type III paraesophageal hernia (**FIG 1**)
  - Esophagitis, Barrett's changes, and/or stricture

SURGICAL MANAGEMENT

Preoperative Planning

- Because the Collis gastroplasty is an adjunctive procedure during gastric fundoplication, the principles of a proper antireflux procedure (wrap) or gastropexy apply, including left and right crural exposure, adequate mediastinal dissection, atraumatic esophageal retraction, and division of the short gastric vessels. Please refer to Part 1, Chapters 19 and 22 for further details.
- All studies, including esophagram, EGD, manometry, and pH testing should be readily available and reviewed prior to and at the time of surgery. The esophagram should be displayed on a spare or dedicated monitor in the operating theater and EGD images be loaded as well for intraoperative reference.
- Attention to fine detail of the manometric report may avoid an unnecessary and detrimental 360-degree fundoplication, as a complete wrap may worsen symptoms in the light of the following findings[7]:
  - Severe esophageal dysmotility
  - Very low residual postrelaxation lower esophageal sphincter (LES) pressures less than 30 mmHg during wet swallow

Positioning

- Although there are many port placement techniques, the stapled Collis gastroplasty necessitates a left upper quadrant, endoscopic, angulating stapler by the surgeon's right hand through a 12-mm trocar. Steep reverse Trendelenburg is the position of choice (**FIG 2**).

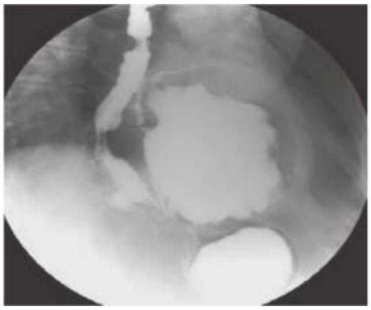

FIG 1 ● Esophagram demonstrating tortuous esophagus with shortening, distal narrowing or strictures, and a type III paraesophageal hiatal hernia.

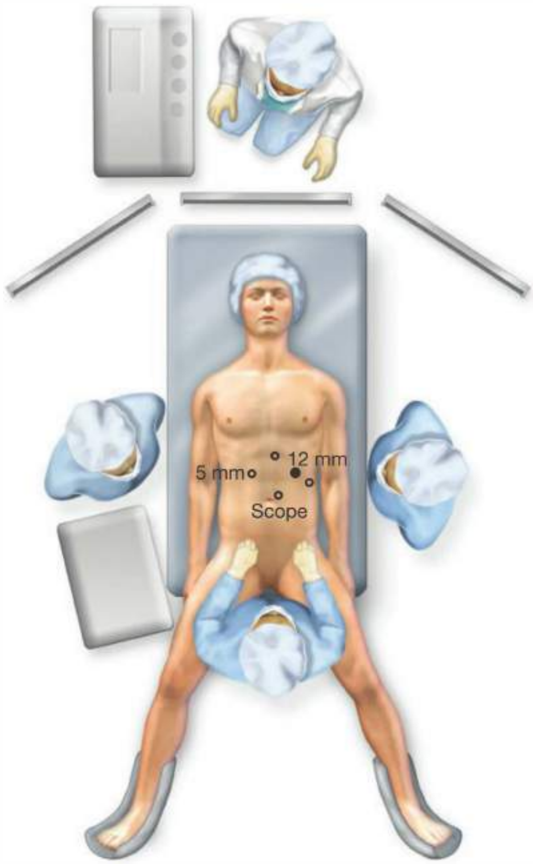

FIG 2 ● Patient positioning for foregut and antireflux procedures and trocar placement. The left upper quadrant 12-mm port is used for the angulated stapler in the surgeon's right hand.

- Assume extensive mediastinal dissection will be warranted, and therefore, risk of pleural compromise (FIG 3). The sterile skin preparation must be wide enough on either flank in case tube thoracostomies are necessary from resultant pneumothorax. However, a red rubber catheter between 10 and 14 Fr may be placed in a witnessed pleural defect intraabdominally spanning the diaphragm to the hemithorax in question. This reduces the resultant pneumothorax and peak ventilatory pressures with the aid of lowering insufflation pressures as well as anesthesia-assisted ventilatory Valsalva.

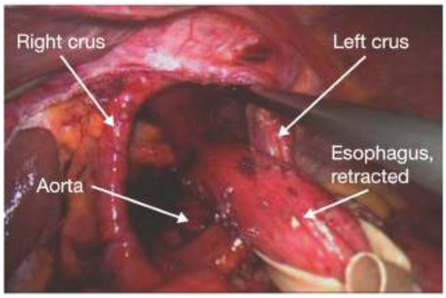

FIG 3 ● Demonstration of adequate dissection of the mediastinum with clear visibility of the left and right crura, aorta posteriorly, and proximal length achieved of the distal esophagus.

MEASUREMENT OF GASTROPLASTY

- As mentioned in the "Positioning" section, this is an adjunctive maneuver, and thus, as previously described, adequate mediastinal, hiatal, and perigastric dissection should have already taken place.
- Dissect the fat pad from the GEJ to expose the trajectories of stapler firing (FIG 4).
- Remove any orogastric, nasogastric, or bougie first to recreate the nascent relaxed anatomy of the GEJ. From a posterior gastric approach, pull the left crus to the right, approximating it with the right crus. This demonstrates the relaxed position of the crura upon closure of the hiatus.

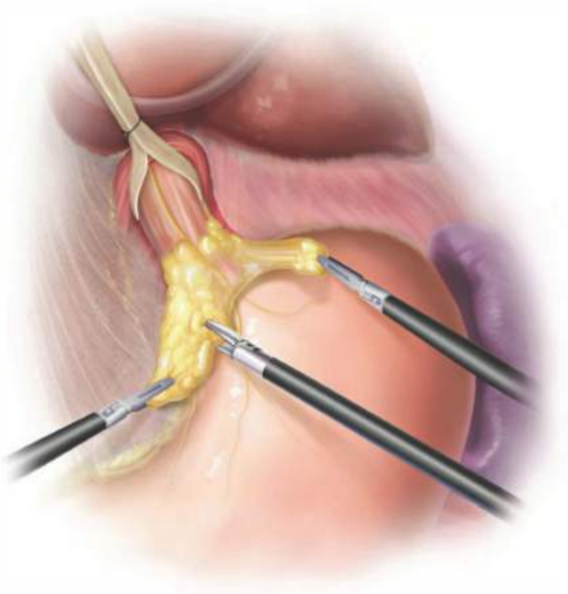

FIG 4 ● GEJ fat pad dissection. The fat pad is elevated with an atraumatic grasper by the first assistant while the surgeon, with his left hand, defines the gastric wall, thus providing countertraction.

- With an open, premeasured grasper, the intraabdominal length for the gastroplasty is then estimated (**FIG 5**). A distance from the anterior hiatus to the GEJ of less than 2.5 to 3 cm warrants the Collis gastroplasty. Measure from the relaxed hiatus 3 cm distally along a trajectory past the GEJ, if a bougie were inserted endoluminally, and 1 cm laterally. Here, mark with electrocautery the placement of the first perpendicular staple firing.

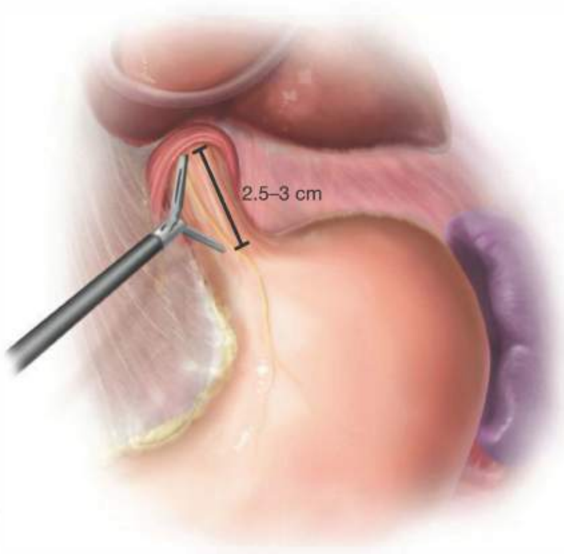

FIG 5 ● Measurement of intraabdominal length of esophagus. With a closed crura, the minimum distance between the GEJ and the diaphragm should be at least 2.5 cm, or the approximate length of an opened atraumatic grasper.

INTRAABDOMINAL RETRACTION AND BOUGIE PLACEMENT

- A 48-Fr dilator is placed transorally up to 55 cm from the incisors (**FIG 6**). This serves as the stent about which the Collis gastroplasty is performed. The surgeon's left hand retracts the cardia toward the patient's left shoulder while the assistant retracts the greater curve laterally to the left flank.

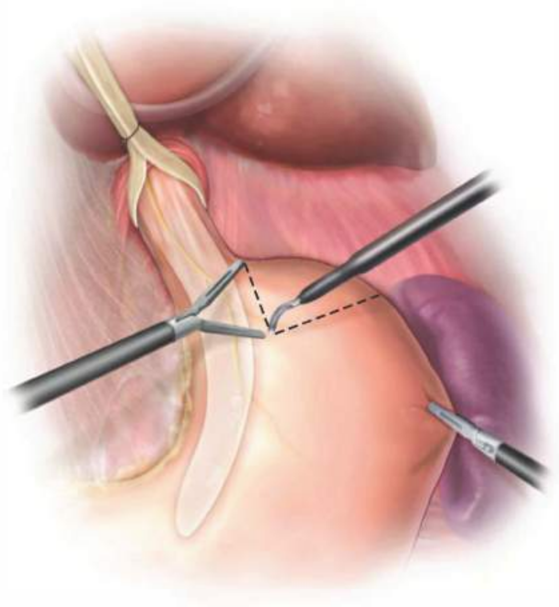

FIG 6 ● Marking of Collis gastroplasty. With a 48-Fr dilator in place and Penrose drain released, measure 2.5 to 3 cm distal to the closed diaphragm from the angle of His and then due left laterally.

FIRST STAPLE TRAJECTORY

- The first stapled trajectory is usually performed with one or two firings of a rotating and articulating endoscopic stapler with medium-sized loads (3 to 4 mm) using a 45-mm length Endo GIA purple load (Covidien, Mansfield, MA). With the endoscopic stapler articulated to the maximum degree in the surgeon's right hand, a 90-degree stapling is performed up to the body of the dilator on the left side of the patient just distal to the point predetermined and marked with electrocautery (**FIG 7A–C**).

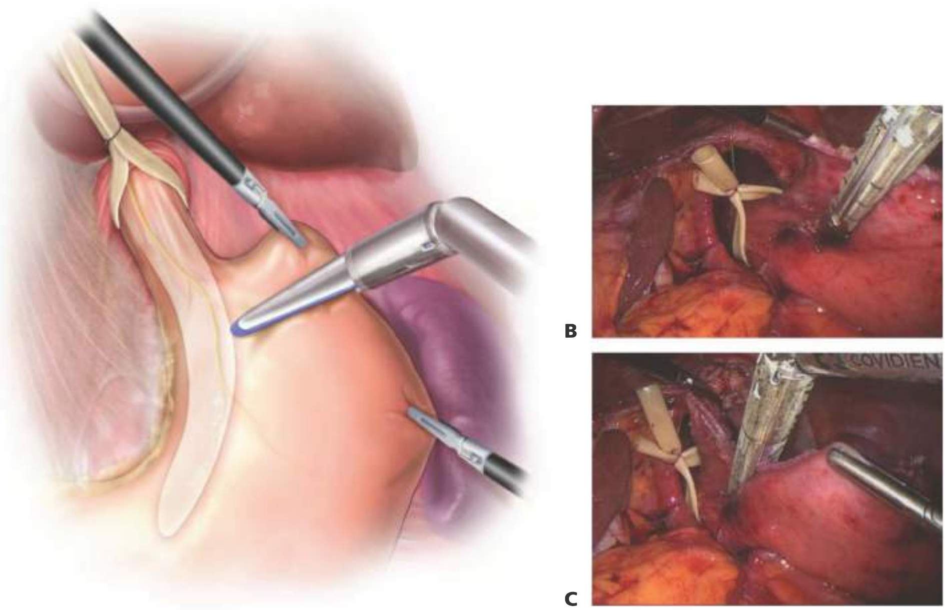

FIG 7 ● **A.** First staple trajectory. **B.** Maximal articulation of the stapler to the surgeon's left, aiming toward the previously marked spot adjacent to the dilator. This may take one or two firings to approximate the staple line so it abuts the inserted dilator **(C)**.

SECOND STAPLE TRAJECTORY

- The second stapled trajectory is parallel to the dilator and cephalad (**FIG 8A,B**). Again, one or two medium-sized staple loads might be needed. Be careful to not include the Penrose drain in the staple line; it may be placed into the mediastinum temporarily during the second set of staple firings. The proper Collis gastroplasty juxtaposes the resultant parallel staple line abutting the esophagus (**FIG 8C**).

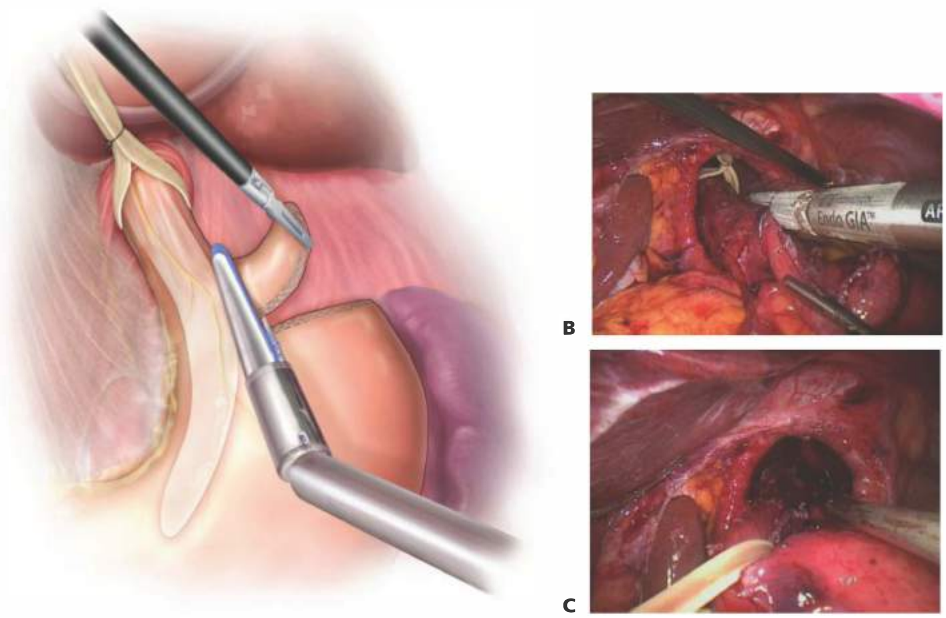

FIG 8 ● **A.** Second staple trajectory. **B.** The vertical staple line is created by firing the gastrointestinal anastomosis (GIA) stapler parallel and flush against the upward dilator to create a tight tube. **C.** The resultant gastric staple line abuts the esophagus.

TECHNIQUES

REMOVAL OF THE STOMACH WEDGE

- Remove the wedge of stomach through any means, whether directly through the trocar, via an endoscopic bag, or by removing the entire trocar. This concludes the Collis gastroplasty portion of the procedure.

COMPLETION OF THE FUNDOPLICATION

- Perform the intended complete or partial wrap as described in other chapters, along with crural closure. Whether a complete (Nissen; 360 degrees) or partial (Toupet; 270 degrees) fundoplication is performed (**FIG 9**), the stapled wedge Collis gastroplasty should eventually orient the staple line posteriorly as assessed on EGD.

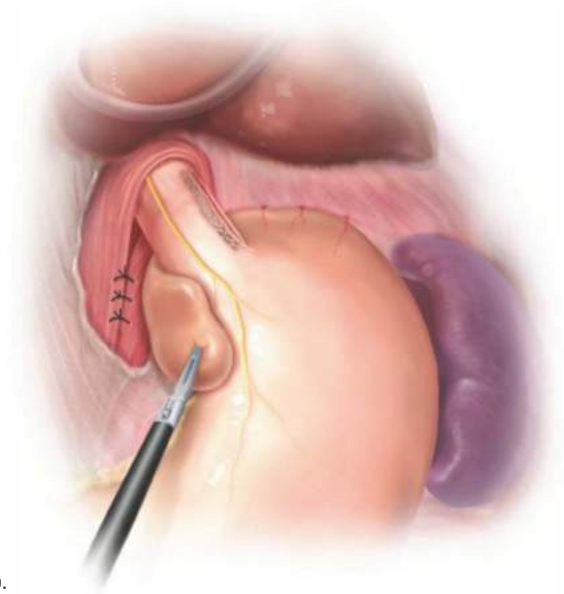

FIG 9 ● Completion of the antireflux procedure (fundoplication).

PEARLS AND PITFALLS

Inadequate first staple firing	■ It is sometimes disconcerting to staple onto an endoluminal foreign body (dilator), but it is virtually impossible to staple across a 48-Fr dilator. Failure to staple up to and abutting the dilator will result in a floppy distal esophagus and decrease the efficacy of the fundoplication.
Use of short staple loads for first staple firing	■ The region of the esophageal hiatus is tight quarters. The articulating stapler of 45 mm is preferred over a longer stapler because of the steep angulation needed in these tight spaces. Multiple firings may be needed.
Mismeasure of intraabdominal length	■ Key to the measurement of true intraabdominal length is the natural lay of the esophagus in the steep reverse Trendelenburg position. Do not insert a dilator, nasogastric, or orogastric tube during this step. Remember to close the crura manually and assess the lay of the esophagus before measuring this length.
Inadequate mediastinal dissection	■ Inadequate mediastinal dissection results in incomplete abdominal length of the esophagus. Hence, the use of a Collis gastroplasty, and therefore risk of staple line leak, can be avoided with intraoperative diligence.
Pneumothorax	■ Prep into the field the bilateral lower chest cavities that would access each hemithorax in case a percutaneous tube thoracostomy is needed. Our first recommendation, however, if peak ventilatory pressures are high from a pneumothorax, is to decompress the affected side with the placement of a red rubber catheter through a working 12-mm port and lay it from the hemithorax in question with the opposite end intraabdominally. The anesthesiologist can assist with manual bagging Valsalva maneuvers. If this step is refractory, place the tip of the red rubber catheter intrathoracically and pull the end through a trocar port into a bowl of sterile saline, desufflate the abdomen, and again, ask the anesthesiologist to assist with Valsalva.
Left lateral wedge	■ Upon full dissection, the wedge removed should lie on the left lateral aspect along the GEJ, that is, the angle of His, in a plane parallel to the operating table.

POSTOPERATIVE CARE

- Nasogastric tube decompression is not routine. Even if injury or perforation occurs to the stomach during dissection, as long as the tissue is repaired properly and a resultant negative intraoperative leak test (methylene blue infusion through the intraoperative orogastric tube or EGD air insufflation in pooled intracorporeal saline in Trendelenburg position) occurs, nasogastric decompression is not a necessity.
- With extensive mediastinal dissection and stapled gastroplasty, the risk of (missed) perforation and leak should be assessed. Strict *nil per os* (NPO) status overnight, followed by a postoperative day (POD) 1 water-soluble contrast esophagram is performed to assess leak as well as functional clearance of contrast material. If negative, the patient is advanced to a clear liquid diet on POD 1 and discharged on either the eve of POD 1 or on POD 2 with a full liquid or pureed diet.
- Acid suppression therapy is warranted as the gastroplasty involved gastric mucosa in the region of the newly reconstructed GEJ.

OUTCOMES

- The use of the Collis gastroplasty is usually relegated to the foreshortened esophagus during antireflux surgery, with etiology including large type III paraesophageal hernias and acid-related strictures. This procedure has historically evolved, especially with the advent of laparoscopy. The outcomes of the procedure are difficult to quantify in terms of efficacy because the procedure is often combined with fundoplication (partial and complete) and/or hiatal hernia repair (types I to IV). In general, in experienced hands, the rate of recurrence of hernia, postoperative leak rate, and stricture are low[8,9] and can be quantified as low as 0% in 4-year follow-up to low double-digit percentages in longer studies.

COMPLICATIONS

- Recurrent hiatal hernia
- "Slipped" Nissen
- Postoperative staple line leak
- Leak from extensive mediastinal dissection
- Esophageal stricture

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Chapter 21

Transthoracic Hiatal Hernia Repair

Jules Lin Mark Orringer

DEFINITION

- The combined Collis-Nissen transthoracic hiatal hernia repair described in this chapter involves mobilization of the distal esophagus, herniated stomach and hernia sac, preservation of the vagus nerves, and a fundoplication through a left posterolateral thoracotomy with an esophageal lengthening procedure when necessary (to allow a 3- to 5-cm tension-free intraabdominal segment of distal "esophagus").
- The two major categories of hiatal hernias include sliding (type I) and paraesophageal (type II, pure paraesophageal hernia with the gastroesophageal junction fixed at the hiatus; type III, combined hiatal hernia where the cardia is above the diaphragm and the fundus is herniated alongside the esophagus; and type IV, with herniation of the stomach along with the colon, small bowel, or spleen) (**FIG 1**).[1–3]

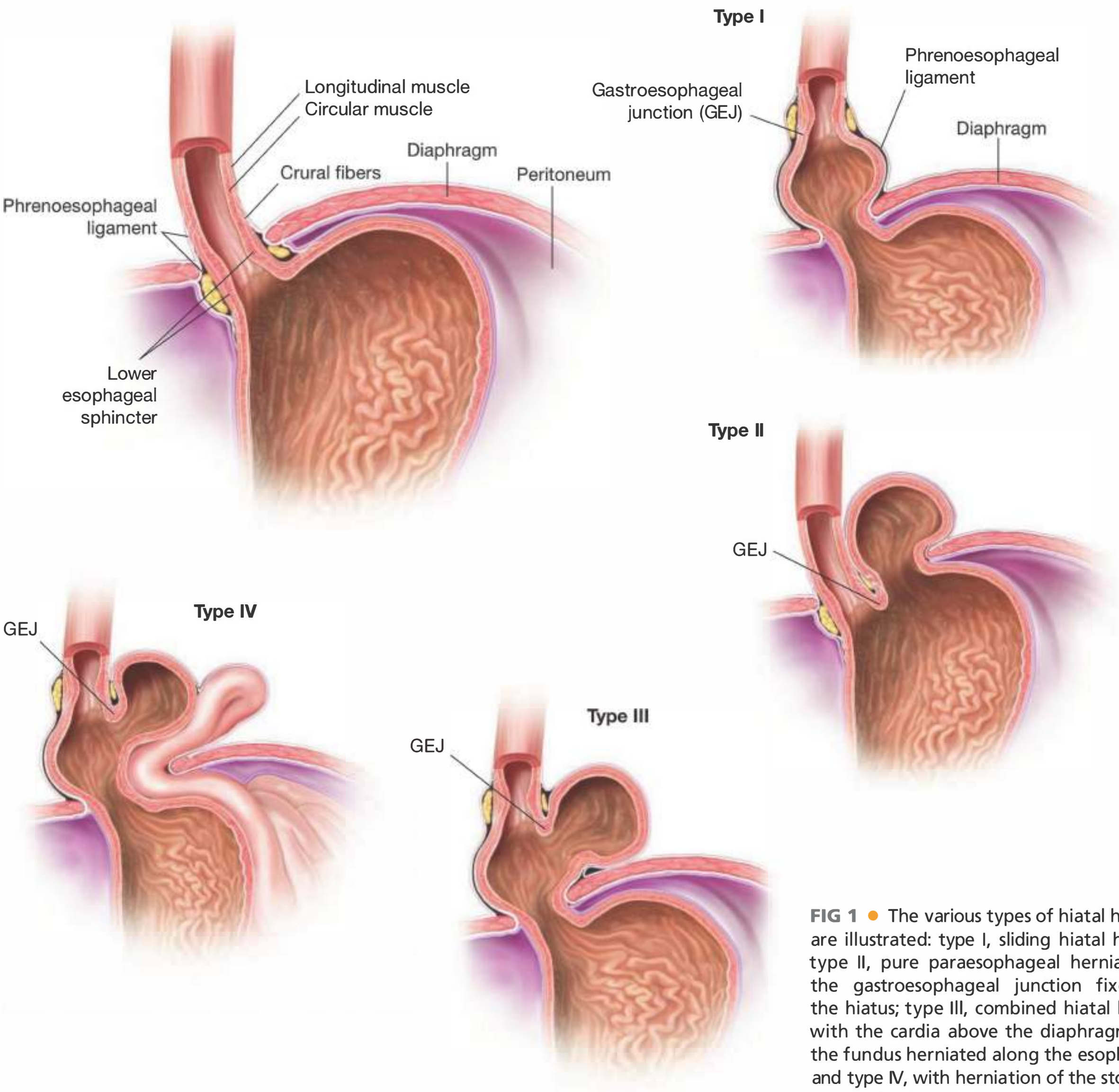


FIG 1 ● The various types of hiatal hernias are illustrated: type I, sliding hiatal hernia; type II, pure paraesophageal hernia with the gastroesophageal junction fixed at the hiatus; type III, combined hiatal hernia with the cardia above the diaphragm and the fundus herniated along the esophagus; and type IV, with herniation of the stomach along with the colon, small bowel, or spleen.

PATIENT HISTORY AND PHYSICAL FINDINGS

- A detailed history and physical must be performed focusing on heartburn and reflux symptoms, response to medical treatment as well as the characteristics and degree of dysphagia, regurgitation, pain, bloating, or anemia. In a series of 240 patients with a paraesophageal hernia, Patel et al.[4] found that 68% of patients had reflux symptoms, 67% abdominal or chest pain, 33% anemia, and 33% dysphagia. The absence of severe reflux symptoms in most patients with paraesophageal hiatal hernias does not diminish the seriousness of this problem with its unpredictable potential for strangulation, perforation, bleeding, and aspiration pneumonia. More subtle symptoms may include early satiety and/or left shoulder and back pain with eating, loud borborygmi often heard across the room by the patient's family, or acute shortness of breath with bending forward.
- Any previous chest or abdominal operations or endoscopic dilations should be noted.
- The history should include the patient's current functional status and exercise tolerance.
- A complete physical examination should be performed with attention to auscultation of the heart and lungs and palpation of the abdomen.
- Routine laboratory studies, including a complete blood count and a basic chemistry panel, should be included as part of the preoperative evaluation.

IMAGING AND OTHER DIAGNOSTIC STUDIES

- A chest x-ray (**FIG 2**) may show a mediastinal air fluid level, suggesting the presence of a paraesophageal hernia.
- A barium swallow (**FIG 3**) should be performed to delineate the esophageal and gastric anatomy and may show reflux, although this is not a reliable finding. Accompanying esophageal dysmotility from the "accordioned" esophagus is common. The esophagram can also be useful when obstruction from gastric volvulus is suspected (**FIG 4**).

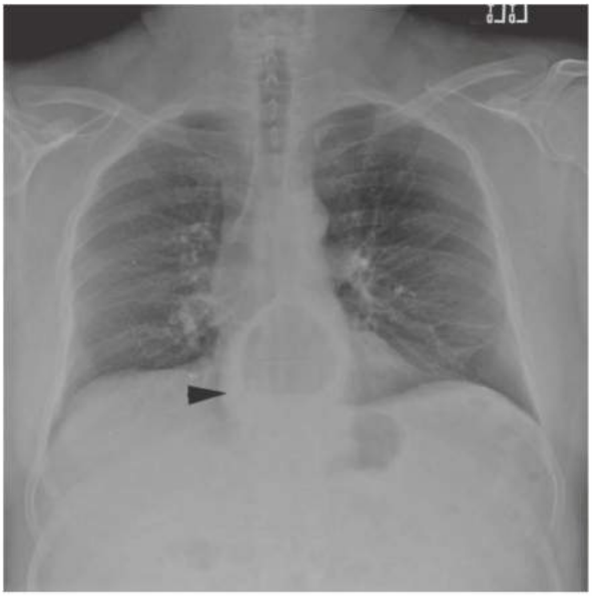


FIG 2 ● Chest x-ray demonstrates an air fluid level *(arrowhead)* consistent with a type III hiatal hernia.

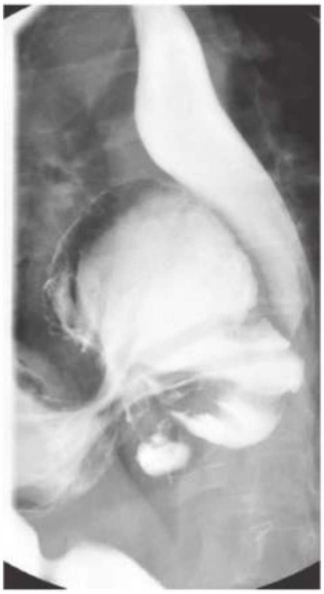


FIG 3 ● Barium swallow demonstrating a type III paraesophageal hernia.

- An esophagoscopy (**FIG 5**) should be performed to evaluate for evidence of esophagitis, Barrett's mucosa, esophageal carcinoma, or esophageal shortening. Suspicious areas should be biopsied. The gastric mucosa should also be examined for Cameron erosions, especially when there is a history of anemia. Caution should be exercised to avoid excessive air insufflation during flexible esophagogastroscopy in the patient with a paraesophageal hiatal hernia lest the intrathoracic stomach becomes overdistended, resulting in hemodynamic instability.
- For patients complaining of persistent nausea, a gastric emptying study may be obtained to evaluate for gastroparesis.
- When there is no hiatal hernia or a small sliding hiatal hernia, esophageal manometry and 24-hour pH probe monitoring with impedance are performed, with antireflux medications discontinued for 72 hours, to document the presence of gastroesophageal reflux, association with the patient's symptoms, and to evaluate for esophageal dysmotility. However, in the presence of a paraesophageal hernia, we do not routinely perform these studies. Many of these patients will have some degree of dysmotility in the presence of a chronic hiatal hernia that frequently improves after hiatal hernia repair. The presence of a symptomatic hiatal hernia is a mechanical issue, and the indication for repair is the paraesophageal hernia itself regardless of the presence of acid reflux.
- Patients suspected of having an incarcerated hiatal hernia (**FIG 4**) with severe epigastric pain and regurgitation should undergo an esophagram and nasogastric tube decompression followed by an emergent hiatal hernia repair.

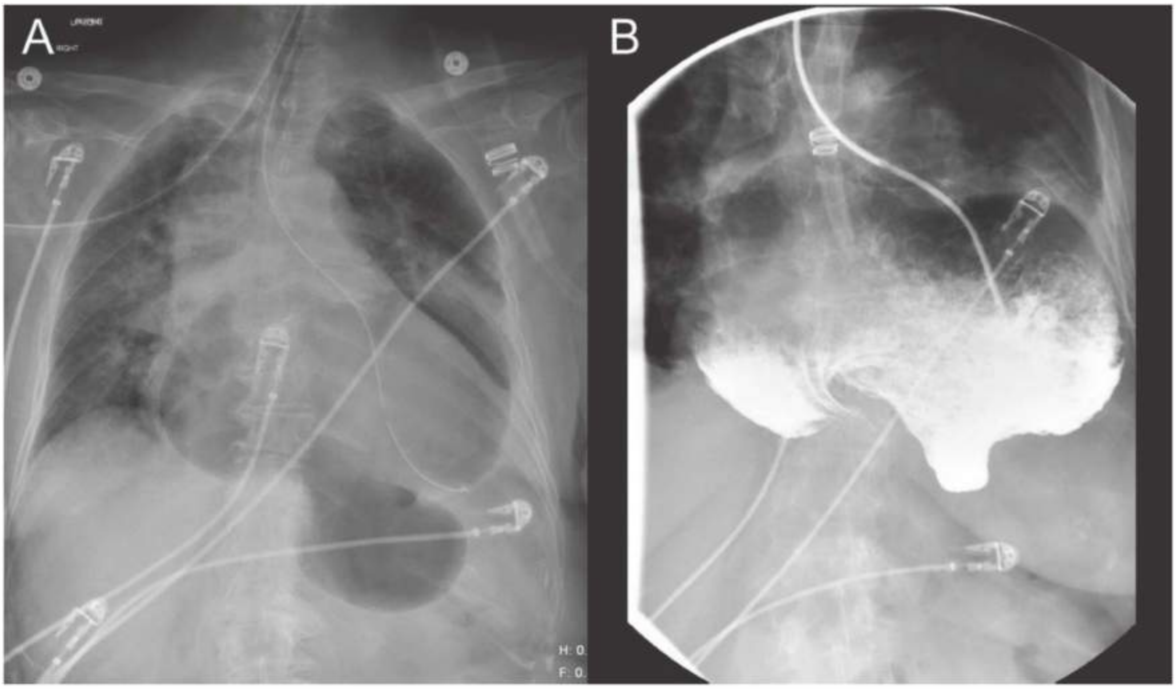


FIG 4 ● **A.** Chest x-ray and **(B)** barium esophagram showing an incarcerated type III hiatal hernia with complete obstruction requiring emergent repair.

SURGICAL MANAGEMENT

Indications

- Sliding hiatal hernias are repaired when there has been incomplete control of reflux symptoms despite medical therapy (Table 1) and after confirmation of abnormal acid reflux on 24-hour pH probe. Other indications include complications of gastroesophageal reflux disease (GERD)—recurrent aspiration, the development of a reflux stricture, and recurrent bleeding from esophagitis.
- Paraesophageal hernias are more likely to present with obstructive symptoms due to the chronic gastric volvulus and repair is generally recommended in the functional patient.[3]
- There has been controversy regarding the optimal surgical approach (laparoscopic vs. transthoracic), the need for an antireflux procedure, and the assessment of esophageal shortening.[1,5–19] The pneumoperitoneum used during laparoscopic repair displaces the diaphragm upward, making intraoperative assessment of esophageal shortening more challenging. In addition, performing a lengthening procedure laparoscopically is more difficult due to the angle of the approach. Taking adequate bites of the attenuated crura is also more difficult due to the tension induced by the pneumoperitoneum, which could contribute to hernia recurrence after laparoscopic repair. A transthoracic approach with an esophageal lengthening procedure, similar to a relaxing incision for an inguinal hernia repair, may be optimal even for a small sliding hiatal hernia in morbidly obese patients due to the increased risk of recurrence. In a series of 240 patients with paraesophageal hiatal hernias, documented acid reflux decreased from 88% preoperatively to 4% after a transthoracic Collis-Nissen procedure, whereas Williamson et al.[6] reported an 18% incidence of postoperative reflux after a selective approach to adding an antireflux procedure. As a

FIG 5 ● Esophagoscopy with retroflexed views showing **(A)** a hiatal hernia, **(B)** erosive gastropathy, and **(C)** an intact Nissen fundoplication.

Table 1: Indications for Transthoracic Hiatal Hernia Repair

Sliding hiatal hernia
Reflux symptoms with incomplete control on medical therapy
Complications of gastroesophageal reflux
Recurrent aspiration
Development of a reflux stricture
Recurrent bleeding from esophagitis
Confirmation of acid reflux on 24-hour pH probe
Paraesophageal hernia
Repair should be considered in all physically fit patients due to risk of strangulation, perforation, or bleeding.
Esophageal lengthening procedure
Intraoperative assessment of esophageal shortening after complete mobilization of the hernia
Obesity
Reflux esophagitis or stricture

result, we advocate an antireflux procedure with all paraesophageal hiatal hernia repairs.[4,6]

- With larger paraesophageal hernias, transthoracic Collis-Nissen repair remains the standard against which other approaches must be compared.[4]

Preoperative Planning

- Preoperative risk assessment determines whether a patient will tolerate a thoracotomy based on exercise tolerance and pulmonary function testing (PFT) if there is a substantial smoking history or shortness of breath. Patients with cardiovascular risk factors or symptoms should undergo preoperative cardiac evaluation.
- Patients should be informed of changes in their diet after undergoing a fundoplication, including avoiding large pills and carbonated drinks and the possibility of gas bloat and dumping syndrome.
- In the preoperative area, the history and physical should be reviewed and consent should be obtained. The operative site on the left chest should be appropriately marked.
- For pain control, an epidural catheter can be placed in the preoperative area, or a paraspinous catheter can be inserted prior to thoracotomy closure.
- Once in the operating room (OR), a flexible esophagoscopy should be performed to evaluate the anatomy and any esophageal mucosal lesions. Overdistention of the stomach with air insufflation must be avoided. After the scope is removed, a 16-Fr nasogastric tube is placed to decompress the stomach.
- Single-lung ventilation is achieved with either a left-sided double lumen endotracheal tube or a bronchial blocker.

Positioning

- The patient should be placed in the right lateral decubitus position (**FIG 6**). The arms should be placed in an arm holder in neutral position. The bed is flexed and the patient should be secured with all pressure points padded.
- Following positioning, the endotracheal tube position should be confirmed again by the anesthesiologist.

FIG 6 ● The patient is placed in the right lateral decubitus position. The chest is entered through a standard posterolateral 6th or 7th intercostal space thoracotomy.

THORACOTOMY

- A standard posterolateral thoracotomy is generally performed through the 6th intercostal space, although the 7th intercostal space can be used with smaller hiatal hernias.
- The serratus anterior muscle can be spared, although dividing the muscle can provide more anterior exposure when needed and results in little, if any, functional impairment.
- After carefully counting the ribs to confirm the intercostal space, the chest is entered. If a paraspinous catheter will be used for postoperative pain control, a posterior pleural flap can be raised at this time to prevent tearing the pleura. Chest retractors such as a Finochietto or Rienhoff are used to provide exposure.

Exposure and Dissection of the Esophagus and Stomach

- The dome of the diaphragm is retracted downward to improve exposure using cloth-covered Harrington retractors. The inferior pulmonary ligament is divided, and the mediastinal pleura is opened (**FIG 7A**).
- The esophagus is identified by palpating the previously placed nasogastric tube and dissected free from surrounding tissues. Care is taken to identify and preserve the anterior and posterior vagus nerves, which, along with the esophagus, are encircled with a Penrose drain that is used to provide tension on the esophagus as needed (**FIG 7B**).
- The hernia sac is dissected from the right pleura, taking care not to enter the right chest.
- With upward traction on the Penrose drain, the hernia sac overlying the cardia is incised. The peritoneal cavity is entered anterolateral to the cardia, and the phrenoesophageal attachments and hernia sac surrounding the cardia are divided (**FIG 8A,B**).
- The cardia is retracted anteriorly and the peritoneum medial to the cardia is incised, entering the lesser sac. The cephalad portion of the lesser curvature is mobilized

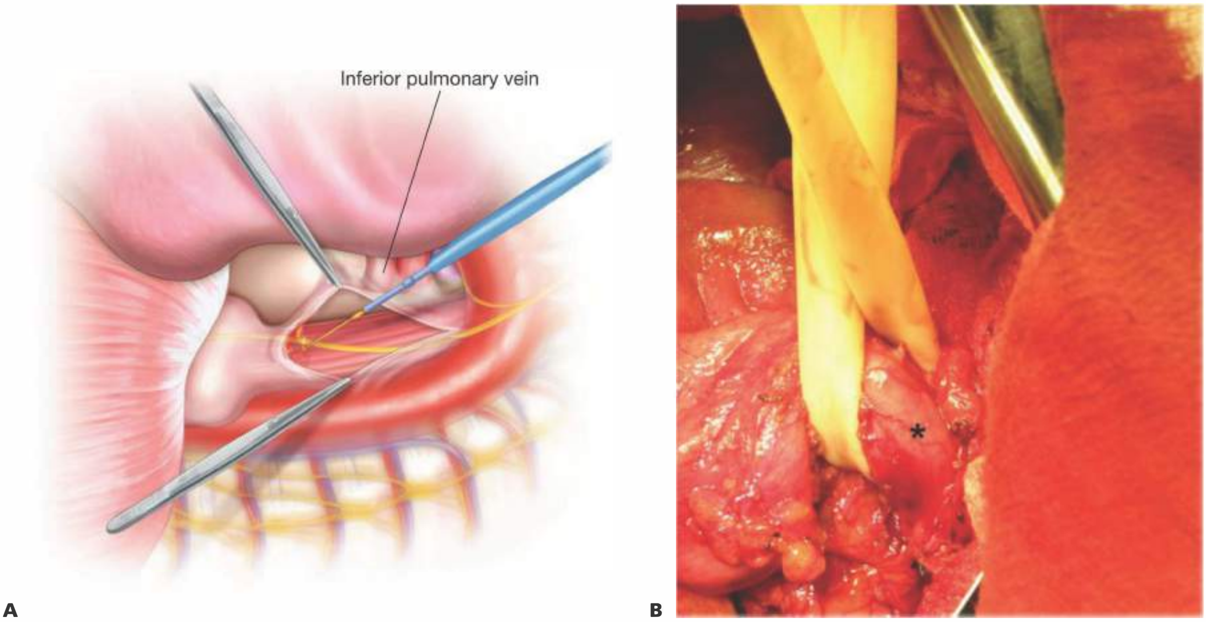


FIG 7 ● **A.** After the inferior pulmonary ligament is taken down with electrocautery, the mediastinal pleura is opened to the level of the interior pulmonary vein exposing the distal esophagus. **B.** The esophagus *(asterisk)* is mobilized, taking care to preserve the anterior and posterior vagus nerves, which are encircled along with the esophagus using a Penrose.

by partially dividing the gastrohepatic ligament, which allows the fundus to be passed posterior to the upper stomach for the fundoplication. These attachments are divided between clamps using 2-0 silk ties and may contain the ascending branch of the left gastric artery (**FIG 8C,D**). A finger is swept circumferentially underneath the diaphragm, confirming mobilization of the cardia away from the hiatus (**FIG 8E**).

- Four to six short gastric vessels are then divided between clamps and ligated with 2-0 silk sutures (**FIG 9**). Care must be taken to avoid excess tension on the stomach to prevent splenic injury. The short gastric vessels must be carefully tied. Once the vessels retract underneath the diaphragm, bleeding may be difficult to recognize and could require a laparotomy for control.
- The hernia sac is resected with electrocautery, taking care not to damage the blood supply to the proximal lesser curvature of the stomach. The gastroesophageal fat pad is excised to expose the gastroesophageal junction, taking care to protect the anterior and posterior vagus nerves (**FIG 10**).

Placement of the Crural Sutures

- The mobilized fundus is then reduced through the hiatus.
- An Allis clamp is placed on the tendinous portion of the medial crus. The esophagus is retracted anteriorly. Using a spoon retractor to protect the intraabdominal contents, interrupted no. 1 silk sutures are placed through the medial crus of the diaphragm approximately 1 cm apart starting posteriorly and proceeding toward the esophagus (**FIG 11A**). Sutures must be passed through the strong tendinous portion of the crus, which is identified by lifting the Allis clamp. All sutures are placed in the medial crus, snapped, and placed in an Allis clamp to keep them in order.

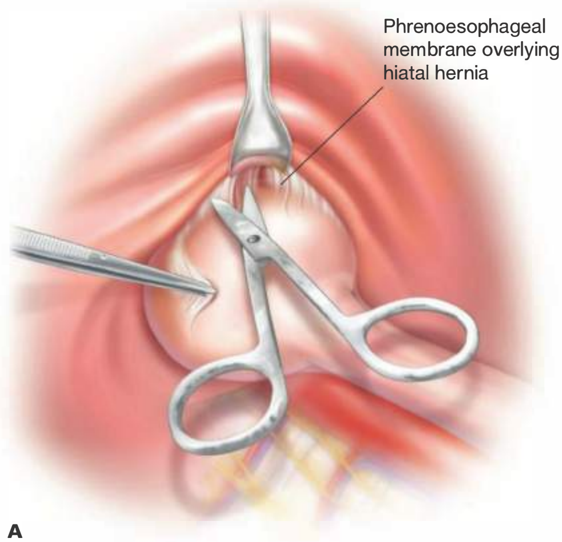
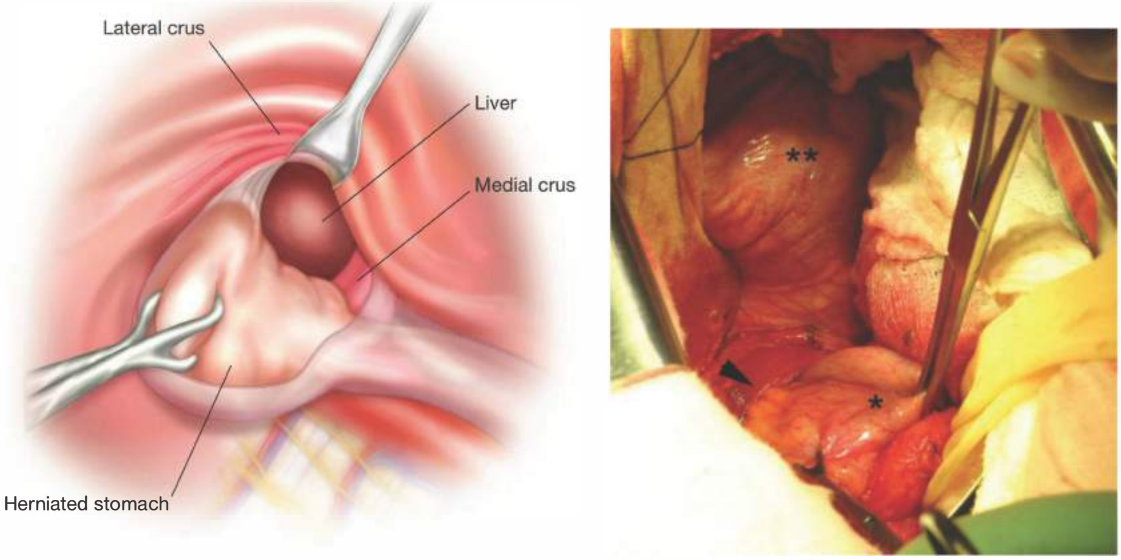


FIG 8 ● **A.** With upward traction on the Penrose drain encircling the esophagus and countertraction on the diaphragm, the phrenoesophageal ligament is incised. *(continued)*



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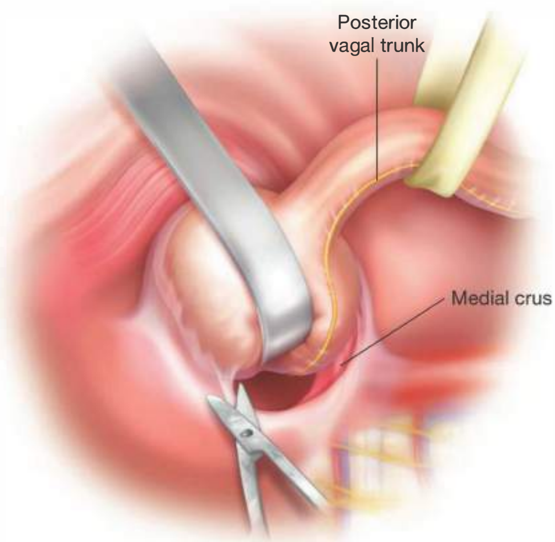

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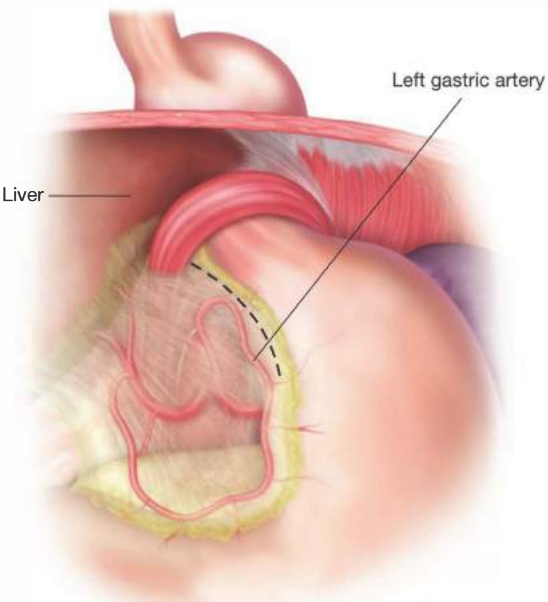

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FIG 8 ● *(continued)* **B.** The peritoneal cavity is entered and the left lobe of the liver is visible. The phrenoesophageal attachments and peritoneum surrounding the cardia are divided, exposing the lateral crus *(arrowhead)* (stomach, *asterisk*; diaphragm, *double asterisk*). **C.** The gastroesophageal junction is then retracted anteriorly and the medial crus exposed by incising the peritoneum along the posteromedial aspect of the cardia. **D.** The high lesser curvature is mobilized by partially dividing the gastrohepatic ligament *(dotted line)*, which allows the fundus to be passed posterior to the upper stomach for the fundoplication. These attachments are carefully ligated and may contain the ascending branch of the left gastric artery. *(continued)*

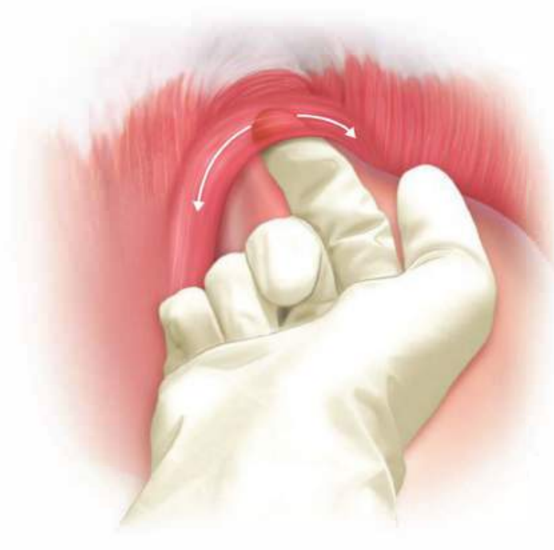


FIG 8 ● *(continued)* **E.** A finger is swept circumferentially along the underside of the hiatus to confirm that the cardia has been completely mobilized.

- The sutures are then each reloaded and passed through the lateral crus (**FIG 11B**). Again, the intraabdominal contents are protected with the spoon retractor and the spleen is displaced away from the lateral crus using a Harrington retractor, pulling downward on the dome of the diaphragm. The crural sutures are not tied at this point and are snapped and placed in an Allis clamp to keep them in order.
- Esophageal shortening is often present with large hiatal hernias, increasing the risk of a recurrent hernia, and is best assessed intraoperatively.[8,9,18] If the esophagogastric junction and distal 3 cm of esophagus do not reduce beneath the diaphragmatic hiatus without tension, an esophageal lengthening Collis gastroplasty is performed as described in the following text.

Collis Gastroplasty and Nissen Fundoplication

- A Maloney esophageal bougie (54 Fr in women and 56 Fr in men) is then placed by the first assistant or anesthesiologist (**FIG 12A**). It is essential at this stage to communicate with the person passing the bougie to ensure that the surgeon's hand is palpating and guiding the bougie as it is being passed to prevent perforation. The bougie is advanced until 6 in remains outside of the mouth as long as it is advancing without resistance.
- With upward traction on the fundus, which is mobilized back through the hiatus and into the chest, the dilator is displaced against the lesser curvature of the stomach. An angled ductus clamp is used to help apply the 3.5-mm gastrointestinal anastomosis (GIA) surgical stapler to the stomach adjacent to the dilator and parallel to the lesser curvature, lengthening the esophageal tube by approximately 5 cm (**FIG 12B**). Care should be taken not to apply the stapler either too tightly against the bougie, narrowing the gastroplasty tube or, so loosely, creating a pouch that empties poorly.
- The staple suture line is reinforced with two running 4-0 polydioxanone (PDS) Lembert sutures, each proceeding from the apex of the gastroplasty incision to either the stomach or esophagus (**FIG 12C**). Hemoclip markers are placed at the new esophagogastric junction for localization on imaging.
- The elongated gastric fundus is passed posteriorly to the left of the gastroplasty tube and positioned for the

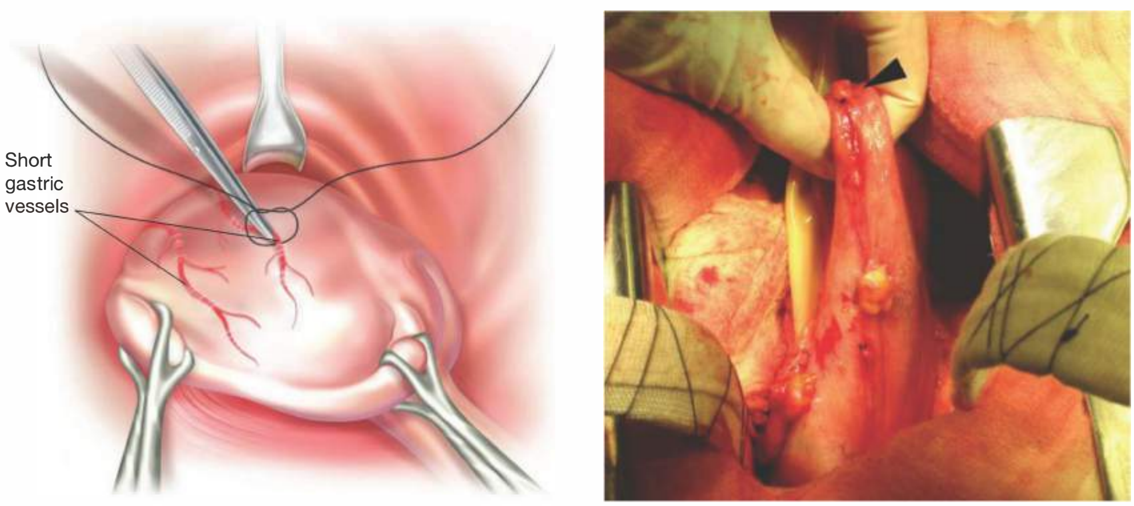


FIG 9 ● The gastric fundus is retracted with a Babcock clamp and four to six short gastric vessels are ligated and divided *(arrowhead)*, mobilizing 10 to 15 cm of the greater curvature.

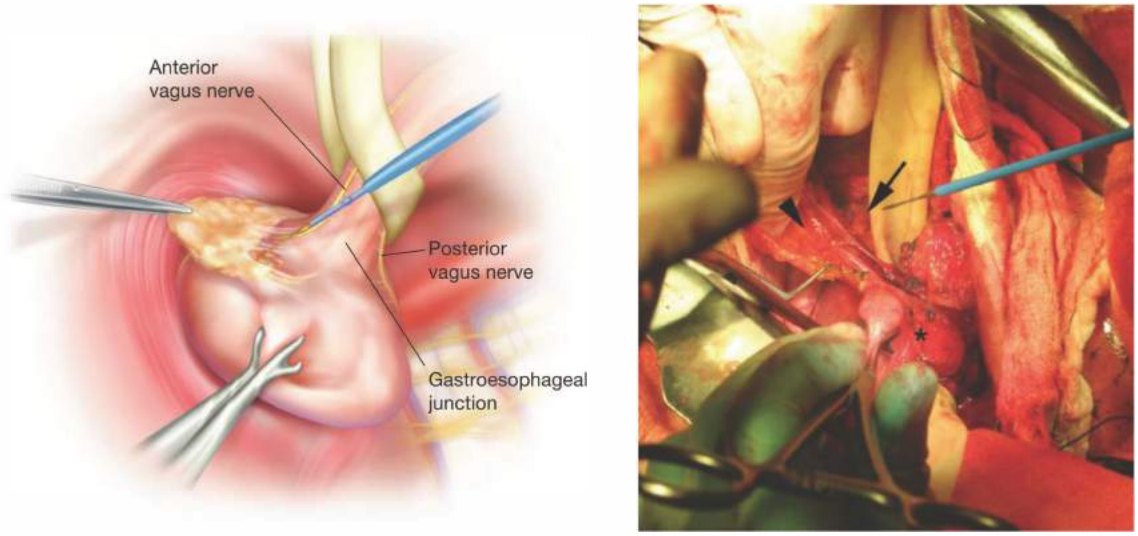


FIG 10 ● The fat pad *(arrowhead)* must be dissected from the anterolateral aspect of the esophagogastric junction to allow accurate localization of the gastroesophageal junction for the Collis gastroplasty and Nissen fundoplication (stomach, *asterisk*; esophagus, *arrow*). Care must be taken to identify and preserve the anterior vagal nerve.

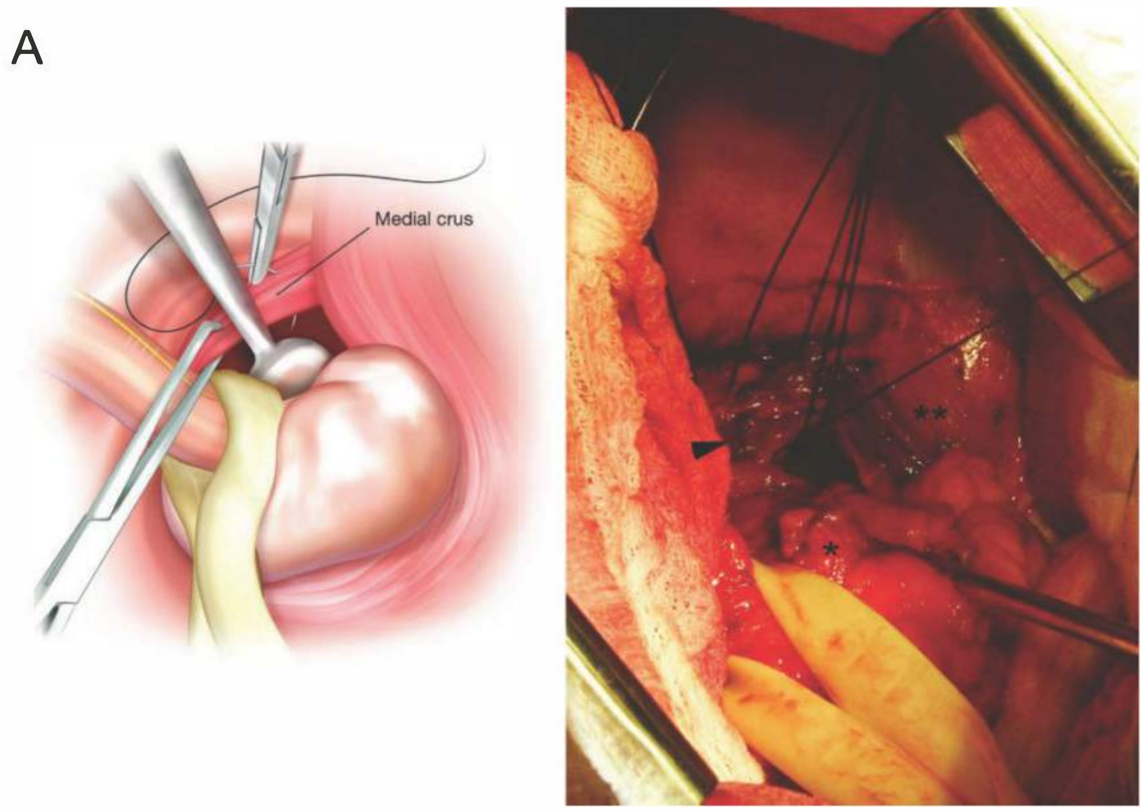
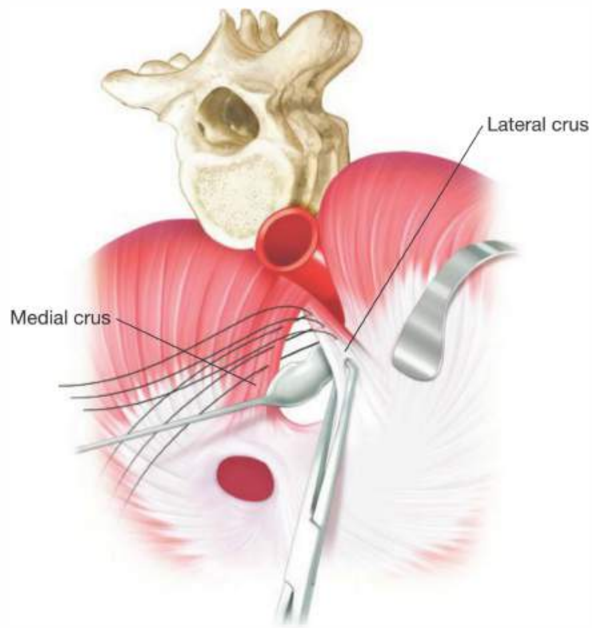
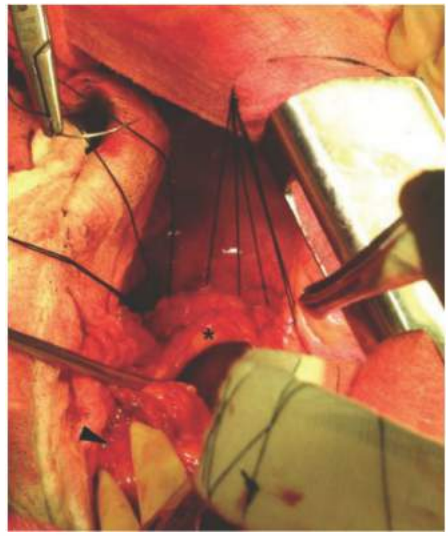


FIG 11 ● **A.** An Allis clamp is placed on the tendinous portion of the medial crus *(arrowhead)*. The esophagus is retracted anteriorly. Sutures must be passed through the strong tendinous portion of the crus, which is identified by lifting the Allis clamp. The sutures are placed through the medial crus starting posteriorly and proceeding toward the esophagus, spacing the sutures 1 cm apart (stomach, *asterisk*; diaphragm, *double asterisk*). *(continued)*





B

FIG 11 ● *(continued)* **B.** The sutures are then each reloaded and passed through the lateral crus *(asterisk)*. The intraabdominal contents are protected with the spoon retractor and the spleen is displaced away from the lateral crus using a Harrington retractor, pulling downward on the dome of the diaphragm (esophagus, *arrowhead*).

Nissen fundoplication. A 2- to 3-cm long fundoplication is constructed using interrupted 2-0 silk sutures placed 1 cm apart, with each stitch passing from the gastric fundus to the gastroplasty tube and then to gastric fundus again (**FIG 13A,B**).

- After tying these fundoplication sutures, the silk suture line is oversewn with a 4-0 PDS running Lembert suture to minimize the risk of a leak from the fundoplication sutures (**FIG 13C**).

Completion of the Hiatal Hernia Repair

- The esophageal dilator is removed and a 16-Fr nasogastric tube is placed.

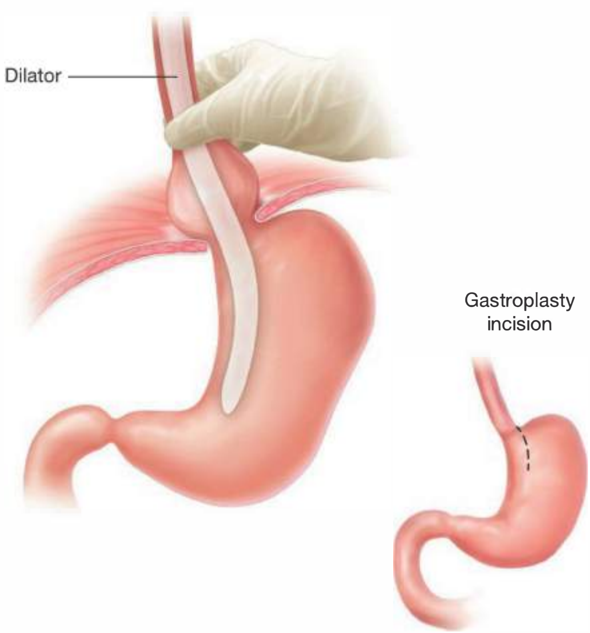
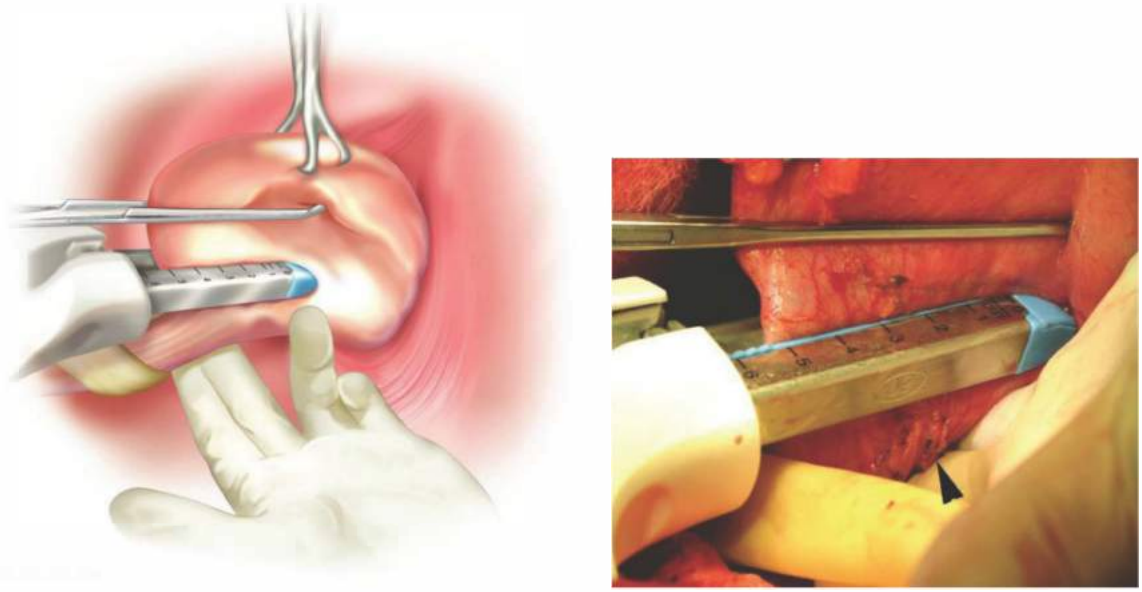


FIG 12 ● If esophageal shortening is present, a Collis gastroplasty is performed. **A.** An esophageal bougie (54 to 56 Fr) is placed with the surgeon's hand palpating and guiding the bougie as it is being passed to prevent perforation. *(continued)*



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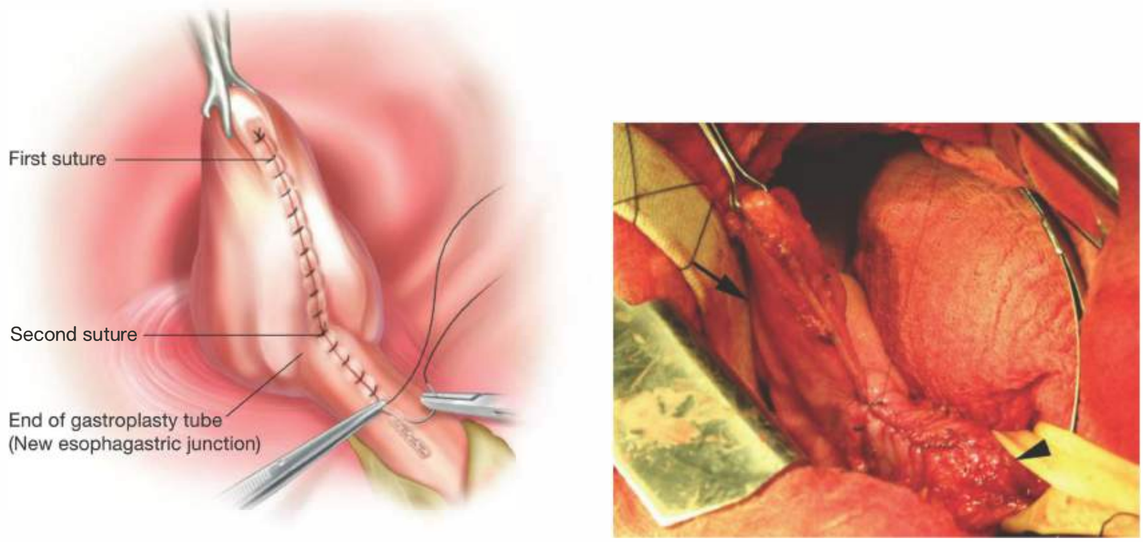


C

FIG 12 ● *(continued)* **B.** The esophageal dilator is displaced against the lesser curvature *(arrowhead)* of the stomach and an angled ductus clamp is used to help apply the 3.5-mm GIA stapler to the stomach adjacent to the dilator and parallel to lesser curvature, lengthening the esophageal tube by approximately 5 cm. **C.** The staple line is oversewn with two running 4-0 PDS Lembert sutures, each proceeding from the apex of the gastroplasty incision to either the stomach *(arrow)* or esophagus *(arrowhead)*. Hemoclip markers are placed at the new esophagogastric junction.

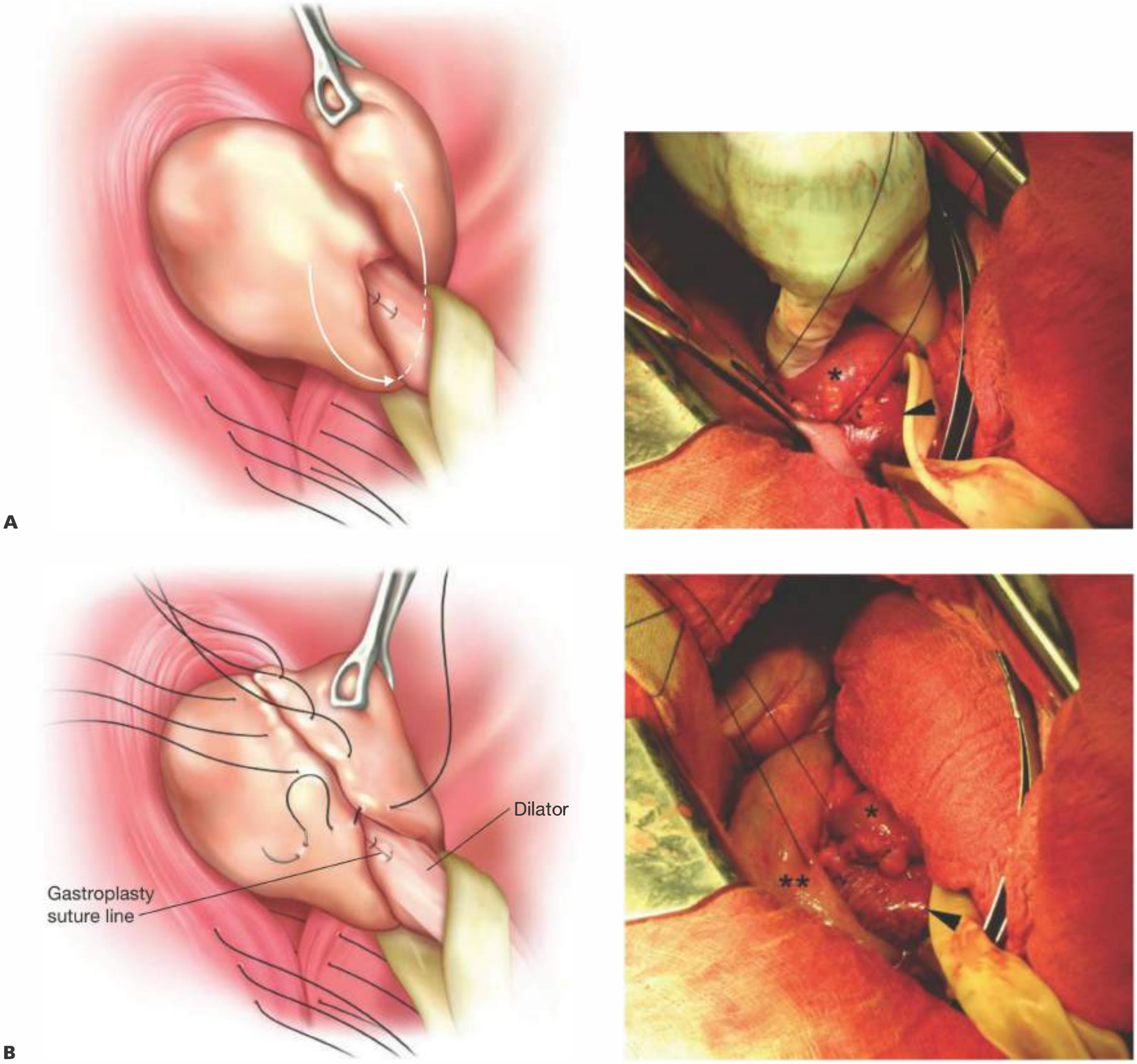
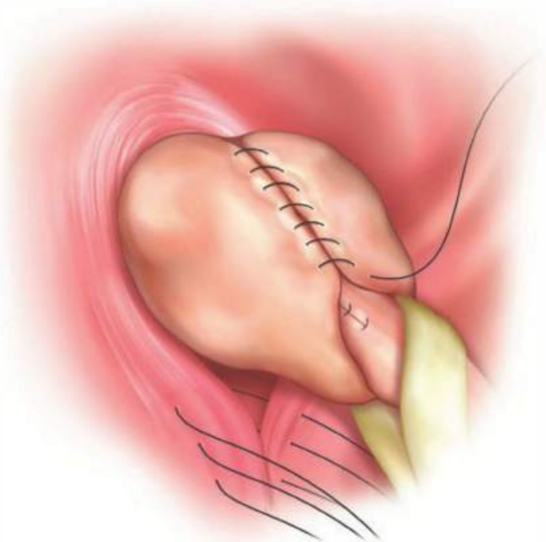


FIG 13 ● **A.** The fundus *(asterisk)* is passed behind the gastroplasty tube *(arrowhead)*. **B.** A floppy 2- to 3-cm Nissen fundoplication is performed with 2-0 silk sutures placed 1 cm apart, passing through the fundus *(asterisk)*, gastroplasty tube *(arrowhead)*, and the gastric fundus again *(double asterisk)*.*(continued)*



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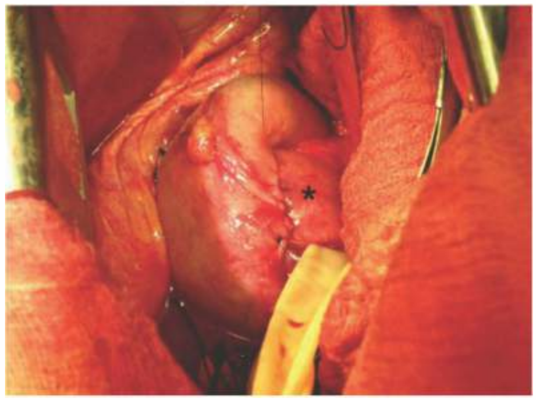

FIG 13 ● *(continued)* **C.** The suture line is oversewn with a 4-0 PDS running Lembert suture *(asterisk)*.

- The fundoplication is reduced through the hiatus and is secured to the undersurface of the diaphragm with three interrupted 2-0 Prolene horizontal seromuscular mattress "Belsey" sutures, which are passed through the diaphragm around the circumference of the hiatus (**FIG 14B,C**). Care must be taken during passage of the most anteromedial suture to prevent inadvertent injury to the heart and pericardial tamponade.
- The posterior crural sutures are tied until the diaphragmatic hiatus permits the passage of an index finger alongside the distal esophagus (**FIG 15A,B**). The Belsey sutures are then tied, and the completed fundoplication should rest below the diaphragm without tension (**FIG 15C**).
- Hemoclips are used to mark the hiatus for localization on imaging.

Thoracotomy Closure

- If a paraspinous catheter will be used for pain control, a pleural flap is raised posteriorly. A paraspinous catheter is placed percutaneously under the flap and secured to the skin with 2-0 nylon suture. The pleural flap is reapproximated to the chest wall with 4-0 Vicryl, allowing local anesthetic to be infused directly to the affected intercostal nerves.
- A 28-Fr chest tube is inserted through a low intercostal incision, advanced to the apex, secured to the skin, and connected to underwater seal drainage. The ribs are reapproximated with interrupted no. 2 Vicryl sutures placed around the 6th rib and through holes drilled in the 7th rib using a microdrill to avoid nerve entrapment against the lower rib.
- The wound is then closed in layers reapproximating the serratus and latissimus muscles with running 2-0 Vicryl, the subcutaneous tissues with 2-0 Vicryl, and the skin with a running 4-0 Monocryl subcuticular suture.

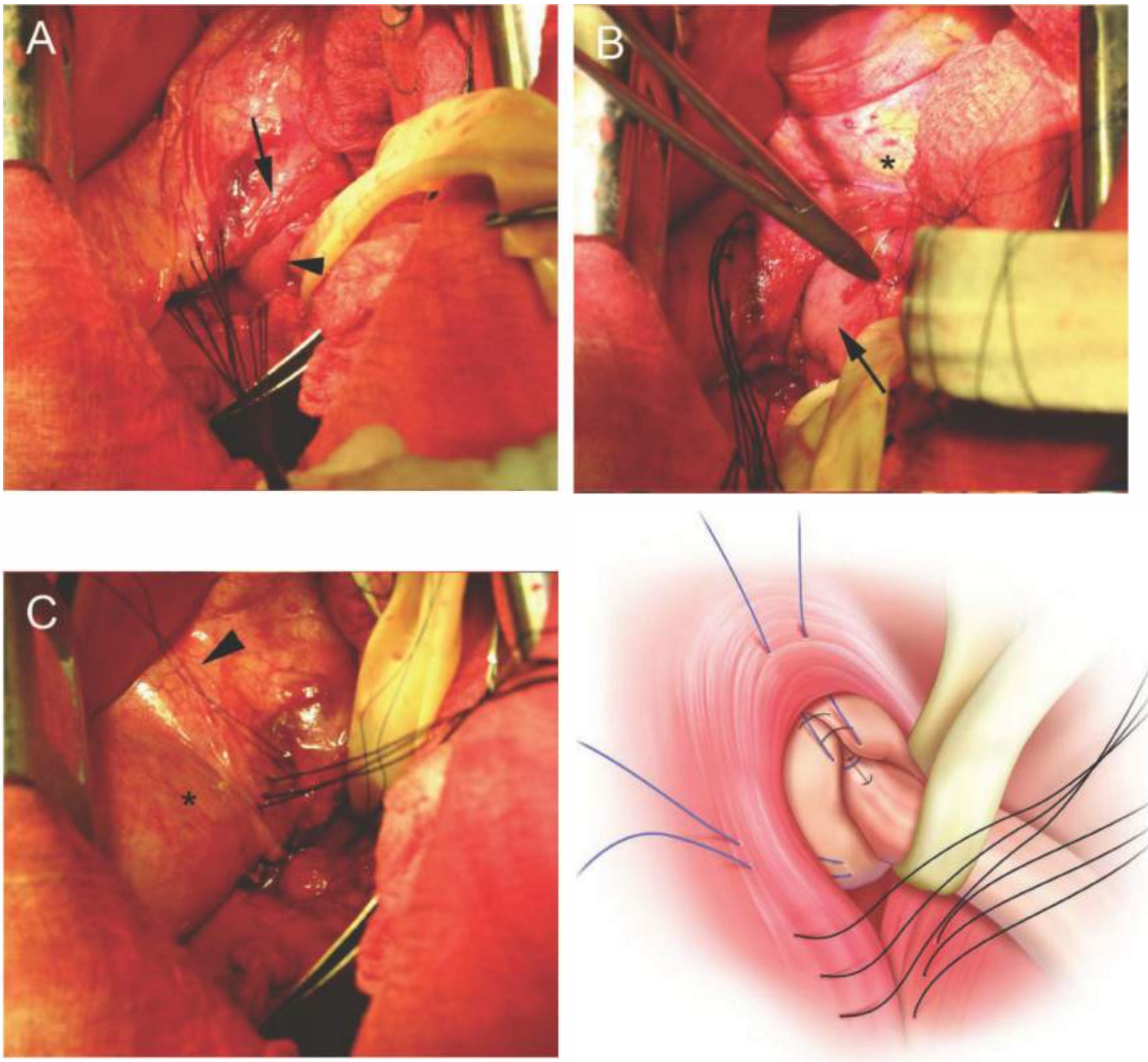

FIG 14 ● **A.** The previously placed silk crural sutures are retracted upward and the fundoplication *(arrowhead)* is reduced below the diaphragm (lateral crus, *arrow*). **B,C.** The fundoplication is secured to the undersurface of the diaphragm *(asterisk)* with three interrupted 2-0 Prolene horizontal seromuscular mattress sutures *(arrowhead)*, which are passed through the stomach *(arrow)* and then the diaphragm around the circumference of the hiatus.

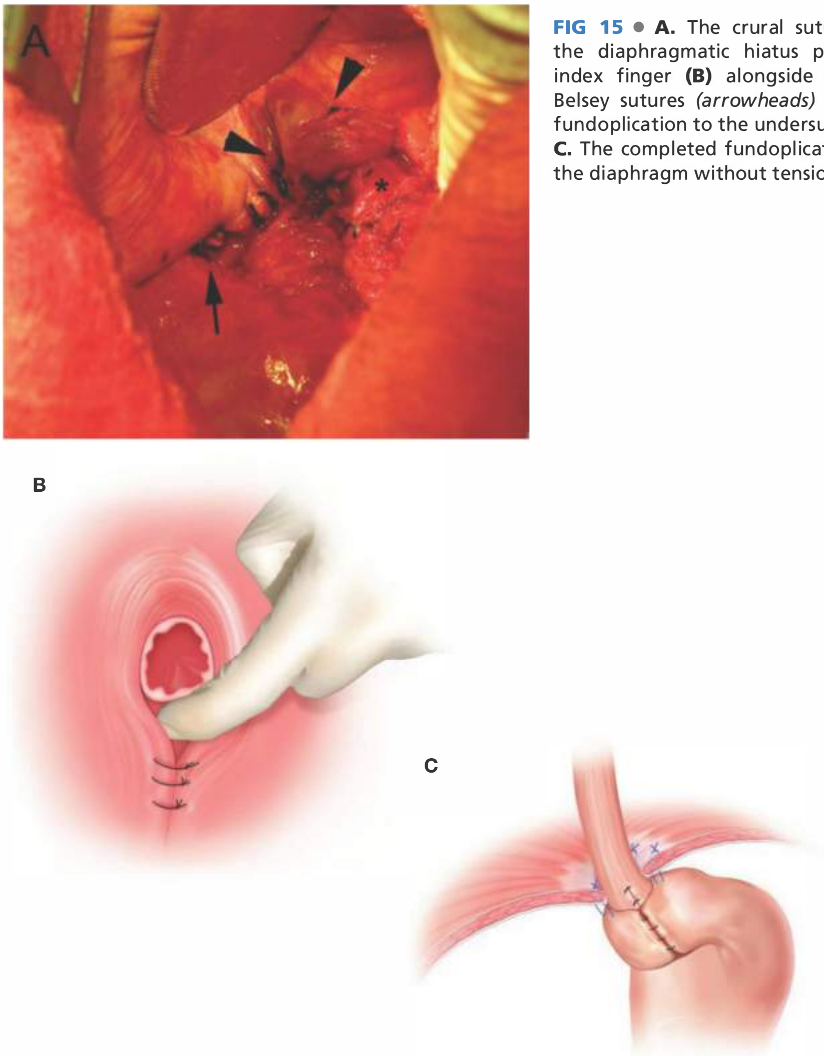

FIG 15 ● **A.** The crural sutures *(arrow)* are tied until the diaphragmatic hiatus permits the passage of an index finger **(B)** alongside the distal esophagus. The Belsey sutures *(arrowheads)* are then tied securing the fundoplication to the undersurface of the diaphragm **(A)**. **C.** The completed fundoplication is shown resting below the diaphragm without tension.

PEARLS AND PITFALLS

Preoperative evaluation	■ Discuss and modify risk factors for recurrent hernia preoperatively, especially weight loss with a goal body mass index (BMI) <32. ■ A transthoracic approach with an esophageal lengthening procedure, similar to a relaxing incision for an inguinal hernia repair, may be optimal even for small sliding hiatal hernias in morbidly obese patients due to the increased risk of recurrence.
Positioning	■ Due to the position of the liver, the hiatus cannot be adequately approached through the right chest. All transthoracic hiatal hernia repairs should be approached through a left thoracotomy even when the hernia is in the right chest.
Incisions	■ For smaller hernias, the hiatal hernia repair may be easier to perform through the 7th intercostal space, but the lower the interspace incision, the greater the degree of postthoracotomy pain because more chest wall sensory nerves are divided.

Intraoperative	■ Using a stockinette, a cloth-covered Harrington retractor is used to retract the diaphragm downward to improve exposure of the hiatus, and a spoon retractor is useful to protect the intraabdominal contents when placing the crural sutures. ■ The anterior attachments of the high lesser curvature may contain the ascending branch of the left gastric artery and should be ligated and divided. ■ A counterincision parallel to and 1 to 2 cm from the hiatus can be made in the diaphragm if additional exposure is needed during a redo hiatal hernia repair. ■ It is essential to communicate with the person passing the bougie to ensure that the surgeon's hand is palpating and guiding the bougie as it is being passed to prevent perforation. ■ Care should be taken during formation of the Collis gastroplasty not to apply the stapler either too tightly against the bougie, narrowing the gastroplasty tube or, so loosely, creating a pouch that empties poorly. ■ We do **not** recommend the routine use of mesh due to the risk of esophageal erosion. A transthoracic approach allows adequate bites to be taken of the crura, which are then tied without undue tension. ■ Hemoclip markers are placed at the new gastroesophageal junction and the diaphragmatic hiatus for localization on imaging. The distance between the two levels of clips represents the intraabdominal length of the distal "neoesophagus."
Closure	■ The ribs are reapproximated with interrupted no. 2 Vicryl sutures placed around the 6th rib and through holes drilled in the 7th rib using a microdrill to avoid nerve entrapment against the lower rib. ■ A chest x-ray is obtained in the OR at the end of the case to confirm reexpansion of the lungs and to evaluate for a right pneumothorax or effusion, which may require chest tube placement if the right pleura was entered.

POSTOPERATIVE CARE

- The nasogastric tube is placed to low continuous suction. On postoperative day 2, the nasogastric tube is placed to gravity and removed on postoperative day 3 if tolerated and the output remains less than 200 mL per shift. The patient is then started on clear liquids with no pills. On postoperative day 4, the diet is advanced to full liquids and then a soft diet.
- The chest tube is placed to 20 cm of water suction. Chest tubes may be removed on postoperative day 2 once the drainage has decreased to less than 60 mL per shift.
- Patients should be given an adequate pain control regimen and encouraged to ambulate and use the incentive spirometer.
- On postoperative day 5, a barium swallow is obtained to assess that contrast flows freely through the esophagus and into the stomach and duodenum and that the fundoplication is intact below the diaphragm. Patients are seen by a dietician for education on a post–Nissen fundoplication diet. They are discharged on a soft diet for 2 to 3 weeks and reminded to avoid large pills and carbonated beverages.
- Most patients are discharged home between postoperative days 5 and 7. At discharge, the importance of avoiding risk factors associated with hernia recurrence, including heavy lifting, constipation, or chronic coughing, is emphasized.
- Mild dysphagia occurs in less than 10% of patients and usually improves over 4 to 6 weeks as the postoperative edema subsides.[2]

OUTCOMES

- Transthoracic hiatal hernia repair remains the standard against which other approaches are compared. Patel et al.[4] described 240 patients undergoing repair of a paraesophageal hernia (92% type III and 8% type IV) with an antireflux procedure in all patients and a Collis gastroplasty in 96%. Five patients (2.1%) required an emergent repair. There were three perioperative deaths (1.7%), and the median length of stay was 7 days.[4] Early complications included recurrent hernia (four patients), leak (three patients), excessive narrowing of the hiatus (three patients), and bleeding (one patient). Eighty-six percent of patients were satisfied at last follow-up, with a mean follow-up of 42 months. An anatomic recurrence was found in 23 patients (10%), with four requiring early repair and four requiring late reoperation.
- Allen et al.[9] reported transthoracic hiatal hernia repairs in 147 patients with 81 patients (68.1%) undergoing a Collis-Nissen, 19 (16.0%) a Belsey-Mark IV, 17 a Nissen (14.3%), and 2 a Harrington repair (1.7%). There were no operative deaths, and complications occurred in 32 patients (26.9%). With a median follow-up of 42 months, results were excellent in 69 patients (60%), good in 38 patients (33%), fair in 6 patients (5.2%), and poor in 2 patients (1.7%). Of five patients who underwent emergent repair, three had gastric necrosis and one died.
- Maziak et al.[5] described 94 patients with massive, incarcerated paraesophageal hernias. Organoaxial volvulus was present in 50% of patients. A gastroplasty was performed in 75 patients (80%) because of a shortened esophagus. There were two operative deaths. The mean follow-up was 94 months, with 72 patients (80%) free of symptoms and 13 patients (13%) having inconsequential symptoms. Three patients (4%) required medical therapy or esophageal dilations and two patients had recurrent hernias or severe reflux successfully treated with a reoperation.
- Rogers et al.[20] reported a series of 60 patients with a paraesophageal hernia. Thirteen patients underwent emergent repair. A transthoracic hiatal hernia repair was performed in all patients with an antireflux procedure added selectively. There was one death after an emergent repair and one recurrence (1.5%). Seven patients (12%) required a single esophageal dilation and two patients (3%) developed symptomatic reflux.

COMPLICATIONS

- Bleeding
- Splenectomy
- Pericardial tamponade
- Right pneumothorax or pleural effusion
- Damage to the vagus nerves resulting in gastric outlet obstruction or dumping syndrome
- Gastric leak
- Persistent dysphagia requiring dilations
- Recurrent hernia

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Chapter 22

Laparoscopic Nissen Fundoplication

Elizabeth A. Warner Brant K. Oelschlager

DEFINITION

- Gastroesophageal reflux disease (GERD), as defined by the Montreal Consensus Group in 2006, is caused by gastric reflux, causing troublesome symptoms and/or complications to the patient that adversely affect their well-being.[1] Symptoms can include heartburn, acid brash, regurgitation, dysphagia, noncardiac chest pain, and pulmonary symptoms such as cough and hoarseness. Complications include esophagitis, Barrett's esophagus, esophageal stricture, and aspiration pneumonia.
- GERD results from incompetency or dysfunction of the lower esophageal sphincter (LES). Important factors for adequate LES function include esophageal contraction, gastric cardia sling fibers, diaphragmatic crus, and intraabdominal position of the LES complex. Hiatal hernias efface the natural valve anatomy, allowing the GE junction to be displaced into the chest, exposing the LES to negative intrathoracic pressure and increased gastroesophageal reflux. A certain amount of gastroesophageal reflux is physiologic and not pathologic. However, once symptoms become troublesome to the patient, a diagnosis of GERD can be made.
- GERD can also be due to inadequate esophageal motility resulting in poor clearance of physiologic reflux. Similarly, delayed gastric emptying can lead to GERD due to the increased volume and duration of gastric contents that can potentially reflux into the esophagus.
- A fundoplication is the use of the gastric fundus to recreate the LES valve function. Various fundoplication configurations exist (e.g., Nissen, Dor, Toupet) and differ by the number of degrees that encircle the esophagus, the location of the wrap, and the approach used to create the fundoplication.

DIFFERENTIAL DIAGNOSIS

- Peptic ulcer disease
- Esophageal motility disorder (e.g., achalasia)
- Malignancy (e.g., esophageal or gastric)
- Anatomic abnormality (e.g., hiatal hernia)
- Eosinophilic esophagitis
- Coronary artery disease
- Biliary colic
- Pancreatitis
- Functional heartburn
- Hypersensitive esophagus
- Functional dyspepsia
- Other functional bowel diseases (i.e., inflammatory bowel syndrome [IBS])

PATIENT HISTORY AND PHYSICAL FINDINGS

- The most common gastroesophageal reflux symptoms reported are heartburn, acid regurgitation, and dysphagia. There is a growing awareness of more atypical presentations, most of which are related to laryngeal or pulmonary manifestations such as cough, chest pain, hoarseness, wheezing, globus sensation, and aspiration.[2]
    - It is important to ask the patient to explain the sensations they are having when they use the term "heartburn." Heartburn, as related to GERD, is a retrosternal burning or caustic sensation. Some patients incorrectly use the term heartburn to describe epigastric pain (associated with peptic ulcer disease, gastritis, and functional dyspepsia), right upper quadrant pain (from cholelithiasis or other hepatobiliary diseases), or chest pain (from coronary artery disease). It is helpful to ask patients to point on their body as to where they have discomfort when they note that they have heartburn. Classic heartburn does not radiate to the back nor is it usually described as a pressure sensation.
    - Regurgitation symptoms can include gastric fluid regurgitation, known as water brash, and/or partially digested food. Regurgitation of food particles can also be associated with esophageal clearance problems such as an esophageal diverticulum or achalasia.
    - Dysphagia from a reflux-associated stricture is usually worse with solids than liquids. If both are equally bothersome, a neuromuscular disorder must also be considered.
    - Airway-related symptoms (e.g., cough, wheezing, voice changes) can be present alone or in conjunction with esophageal symptoms.
- Disease states that are sometimes related to GERD are idiopathic pulmonary fibrosis, asthma, and recurrent pneumonia.
- Patients presenting to a surgeon to discuss GERD treatment have often already trialed antacid medications. It is important to query the patient's response to these medications. If the patient does not have at least symptomatic improvement to antacid therapy, alternative diagnoses should be considered. Heartburn will almost always improve with antacid therapy, at least partially, within days to a few weeks. Similarly, they will notice worsening of heartburn symptoms with cessation of antacid therapy. Airway symptoms may take longer (2 to 3 months) and may not respond at all (even when GERD is the etiology).
- Physical examination findings are often limited in a patient with GERD. In all patients with gastroesophageal complaints, it is important to query about weight loss and hematemesis and to examine for lymphadenopathy, as these could represent an underlying malignancy.

IMAGING AND OTHER DIAGNOSTIC STUDIES

- Diagnostic testing to confirm objective evidence of abnormal gastroesophageal reflux is imperative before considering surgical management for GERD. A recent study revealed that 42% of patients referred for antireflux surgery had a normal pH study when tested objectively.[3] The following studies are

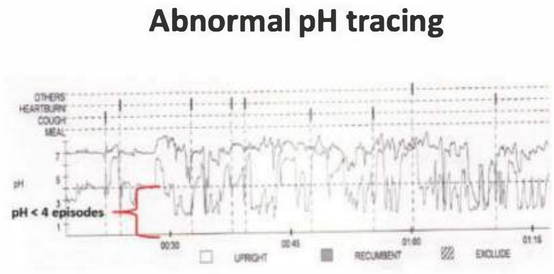

FIG 1 ● Sample of 24-hour pH tracing demonstrating significant acid reflux with good symptom correlation.

essential to confirm the diagnosis of GERD, the underlying functionality of the LES and esophagus, and investigate any anatomic considerations necessary for successful operative outcomes:

- pH monitoring (**FIG 1**) assesses distal esophageal pH over a period of time (routinely 24 to 48 hours) and a composite DeMeester score is calculated. An abnormal DeMeester score is greater than 14.7.[4] Factors contributing to this score include percent total time pH less than 4, percent upright time pH less than 4, percent supine time pH less than 4, number of reflux episodes, number of reflux episodes more than 5 minutes, and longest reflux episode.
- Upper endoscopy evaluates for esophageal injury and Barrett's esophagus secondary to GERD while excluding malignant pathology with biopsies as necessary. Endoscopy allows the surgeon to evaluate for the presence of a hiatal hernia as well as to visually inspect the LES.
- Esophageal manometry (**FIG 2**) assesses LES pressure and relaxation as well as esophageal motility. Patients with esophageal motility disorders can easily be mislabeled as having GERD based on symptoms. Understanding a patient's esophageal motility is necessary to plan successful antireflux surgery.
- Esophagogram evaluates gastroesophageal anatomy and abnormalities such as hernia, stricture, diverticula, motility, or tumors.

- Ancillary tests that may also be useful include laryngoscopy, gastric emptying scintigraphy, and impedance testing.

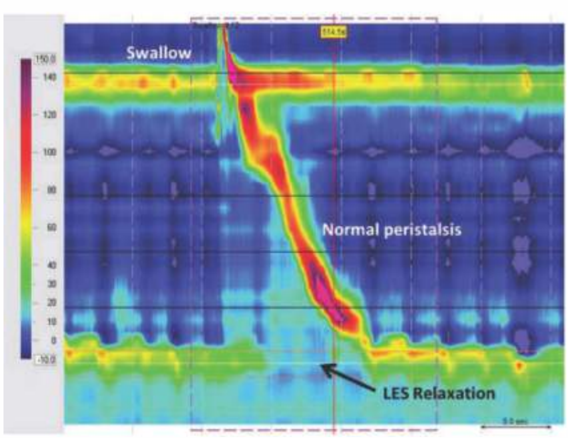

FIG 2 ● Normal high-resolution manometry.

SURGICAL MANAGEMENT

- There is rarely an absolute indication for antireflux surgery in a patient with GERD. Medical management, including acid suppression therapy and lifestyle modifications (e.g., dietary changes, weight loss), is usually sufficient to manage most patients' GERD symptoms. Many factors must be considered in making the decision to proceed with antireflux surgery. These include symptom severity, symptom control with medical therapy, complications of GERD (e.g., severe esophagitis, esophageal stricture, Barrett's esophagus, chronic respiratory complaints), and the generalized health of the patient.
- Patients best suited for an antireflux procedure are those with documented and confirmed GERD for whom medical and lifestyle changes are not providing adequate quality-of-life improvement. When the quality-of-life impairment justifies accepting the risk of surgery, antireflux surgery is indicated.

Preoperative Planning

Positioning

- Patient can be positioned in either modified lithotomy position or supine depending on surgeon preference. Lithotomy position requires more time and equipment and has more risks of nerve injury. However, lithotomy position provides superior ergonomics for the surgeon. Both arms should be tucked to not interfere with instrumentation and the patient should be adequately stabilized on the bed to safely accommodate steep reverse Trendelenburg (which allows organs to naturally fall away from the hiatus and left upper quadrant).
- Standard trocar placement includes three working trocars, a fourth trocar for the camera, and a fifth for liver retraction. **FIG 3** illustrates standard trocar placement, surgeon, and assistant positioning.
- Elevation of the left lateral lobe of the liver is necessary to visualize the esophageal hiatus. This is most commonly accomplished with a retraction device of the surgeon's choice.

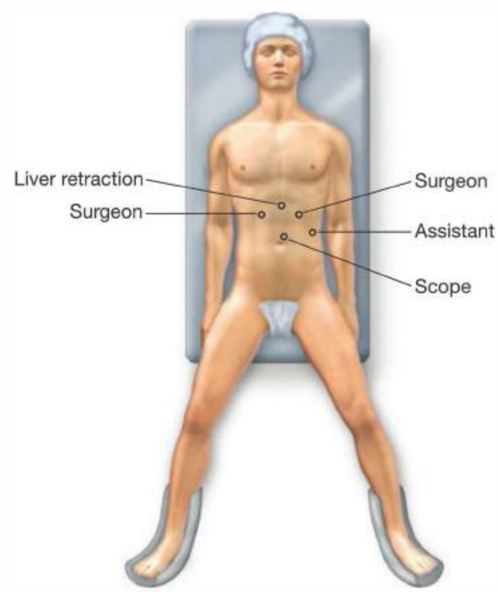

FIG 3 ● Typical port placement for laparoscopic foregut surgery using a split-leg approach.

TECHNIQUES

TAKE DOWN THE LEFT PHRENOGASTRIC LIGAMENT

- After obtaining laparoscopic access to the abdomen and placement of trocars and the liver retractor, the phrenogastric ligament is divided, exposing the left crus. This is most easily accomplished by traction on the gastroesophageal (GE) junction fat pad and the gastric fundus (**FIG 4**). Many surgeons start on the right side by dividing the gastrohepatic ligament and right phrenoesophageal ligament. We have found that it is safer to first approach the hiatus from the left, which provides better visualization, but both approaches are acceptable.

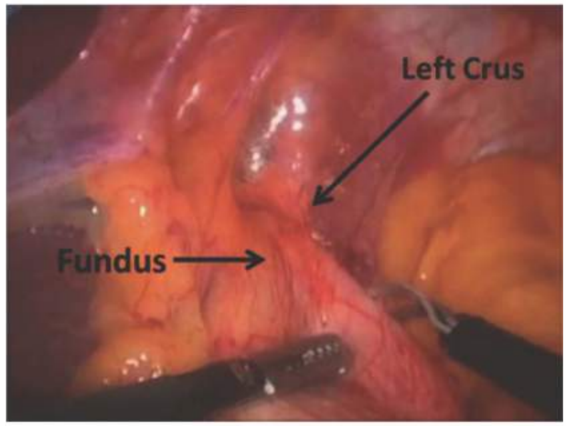

FIG 4 ● The dissection begins on the left side.

LIGATE AND DIVIDE THE SHORT GASTRIC VESSELS

- The short gastric vessels between the greater curvature of the stomach and the spleen are ligated and divided from the gastric midbody to the angle of His (**FIG 5**).

The most superior short gastric vessels can be difficult to expose. Care must be taken to avoid capsule tears to the spleen during this maneuver. More posterior short gastric vessels and retroperitoneal adhesions must also be released to facilitate full mobilization of the fundus (**FIG 6**).

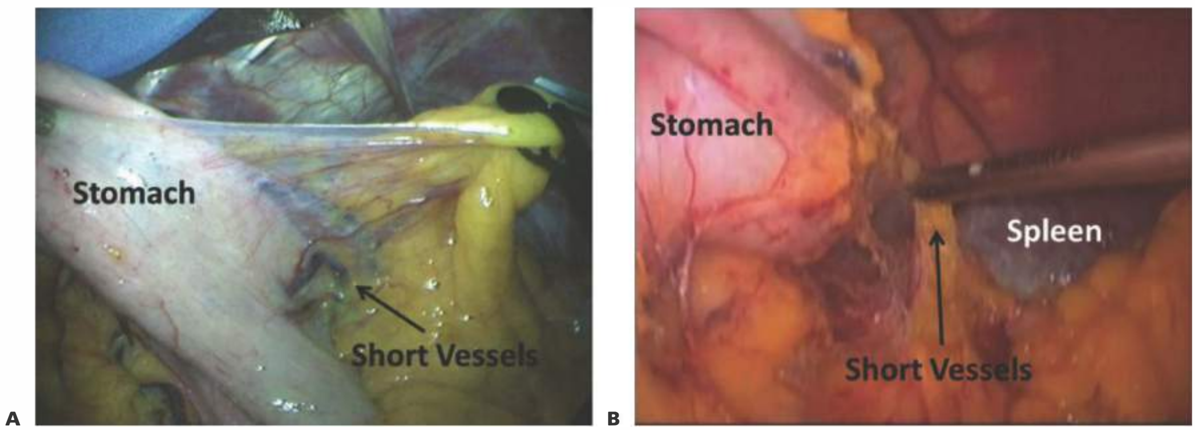

FIG 5 ● **A.** The short gastric vessels are placed on tension to allow for safe division without injury to the stomach. **B.** The short gastric vessels are divided close to the greater curve of the stomach.

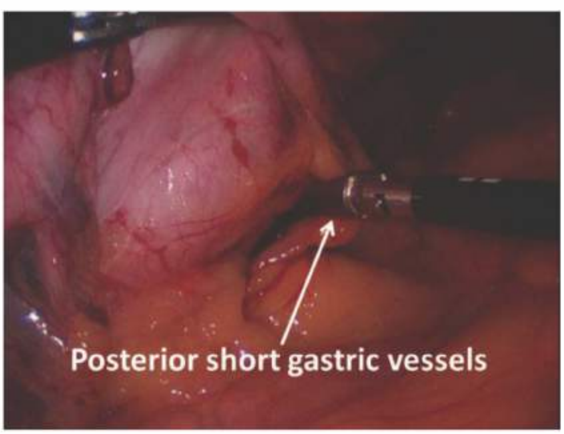

FIG 6 ● The most upper short gastric vessel is posterior and should be divided to free the fundus.

EXPOSE THE ENTIRE LEFT CRUS

- The left phrenoesophageal membrane is opened along its length (FIG 7).

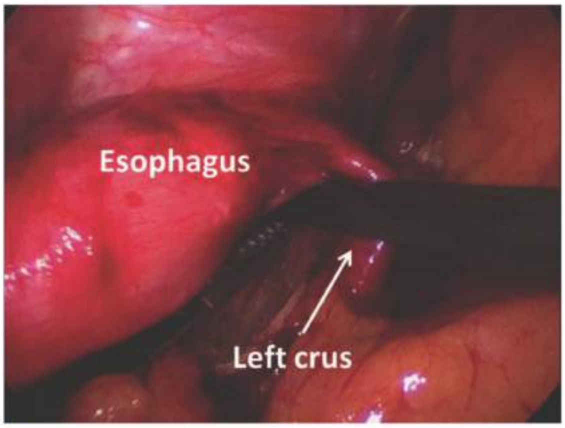

FIG 7 ● After division of the short gastric vessels, the peritoneal attachments along the left crus are incised.

OPEN GASTROHEPATIC LIGAMENT

- The right crus is exposed by opening the gastrohepatic ligament widely, taking care to avoid injury to nerve of Latarjet (FIG 8).

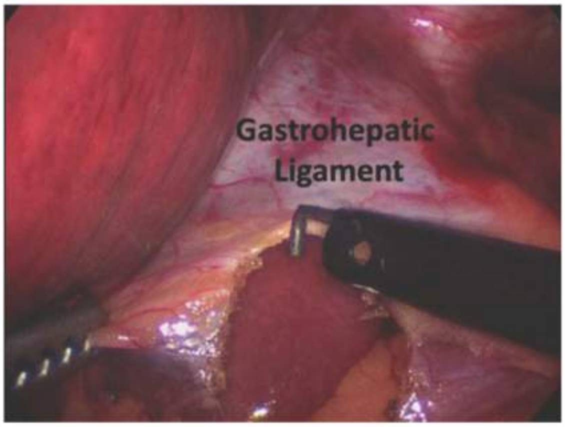

FIG 8 ● The gastrohepatic ligament is divided with cautery, exposing the caudate lobe of the liver.

ENTER THE RIGHT PHRENOESOPHAGEAL MEMBRANE

- The right phrenoesophageal membrane is identified overlying the right crus and is divided to expose the crural fibers beneath. The right phrenoesophageal membrane is opened along its length (FIG 9).

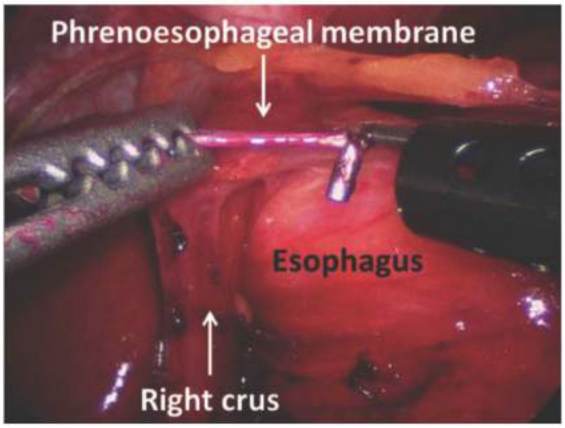

FIG 9 ● The peritoneal attachments along the right crus are incised.

TECHNIQUES

CONNECT LEFT AND RIGHT HIATAL DISSECTIONS

- The left and right dissections of the phrenoesophageal membrane are connected both anteriorly and posteriorly with caution so as not to injure the anterior and posterior vagus nerves. A Penrose drain is placed around the esophagus to aid in gastroesophageal junction retraction and esophageal exposure (**FIG 10**).

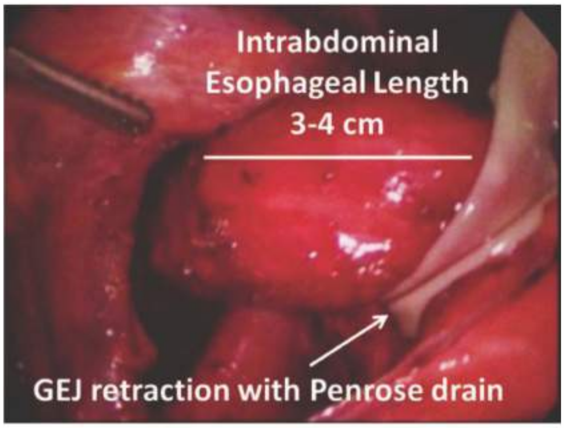

FIG 10 ● At least 3 cm of esophagus are mobilized into the abdominal cavity.

ESOPHAGEAL MOBILIZATION

- The areolar connective tissue surrounding the esophagus is exposed and dissected free by retracting the GE junction with the Penrose drain to mobilize adequate intraabdominal esophageal length (minimum of 3 cm) (**FIG 10**). The anterior and posterior vagus nerves as well as the pleura are protected during this dissection.

POSTERIOR CRUS REAPPROXIMATION

- The right and left crura are reapproximated posteriorly with heavy permanent suture (**FIG 11**) so that the hiatus comfortably accepts a 52-Fr intraesophageal bougie.

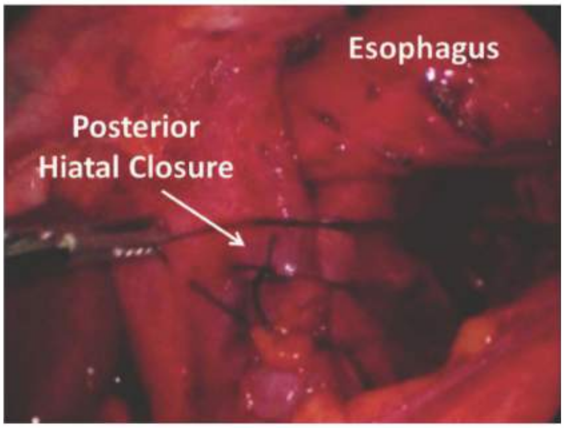

FIG 11 ● A posterior cruroplasty is performed with 0-0 silk sutures.

POSTERIOR STOMACH WALL MARKING STITCH

- Construction of the fundoplication itself is the single critical step where errors are made that affect the short- and long-term success of the operation. To combat this, we place a loose stitch on the posterior gastric wall to mark the proposed site for the first stitch of the fundoplication. Ideally, this stitch is placed 3 cm distal to the GE junction and 2 cm from the greater curvature (**FIG 12**).

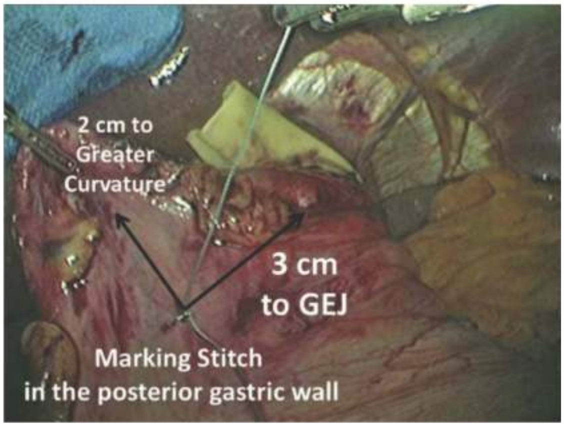

FIG 12 ● A marking stitch is placed on the posterior gastric wall to identify the portion of the fundus to be brought to the right of the esophagus.

PASS THE FUNDUS POSTERIOR TO THE GASTROESOPHAGEAL JUNCTION

- The GE junction is then retracted with the Penrose drain and the posterior gastric fundus is grasped from the patient's right and brought posterior to the GE junction (**FIG 13**). (Note: If the previously placed marking stitch was well placed, it will become visible as the fundus is passed from the patient's left to the right and will serve to mark the location of the first fundoplication stitch to be placed.)

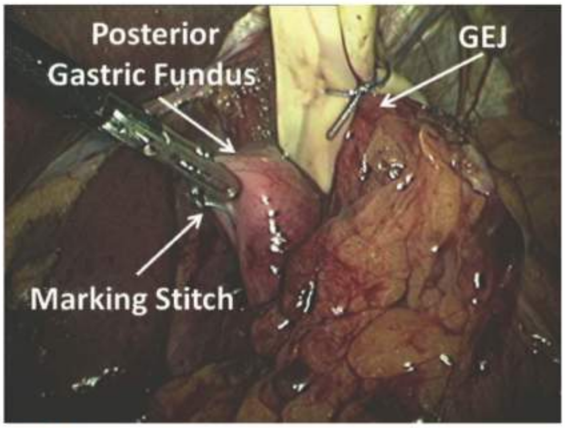

FIG 13 ● The fundus is brought posterior to the esophagus.

IDENTIFY AND GRASP THE ANTERIOR STOMACH

- An optimal fundoplication will be achieved by symmetric geometry. This is accomplished by identifying the place on the anterior gastric wall that is of similar distance from the GE junction and the greater curvature as the previously placed posterior gastric wall marking stitch (**FIG 14**). Once this location is identified, both the anterior and posterior gastric walls are approximated around the distal esophagus at the 10 o'clock position. The wrap should be snug without excessive redundancy but not too tight either.

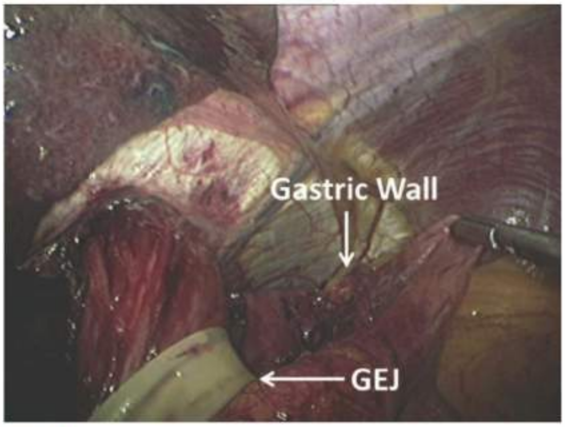

FIG 14 ● The relationship of the stomach to the esophagus for the fundoplication.

FUNDOPLICATION CREATION

- Once symmetric fundoplication geometry is confirmed, four seromuscular permanent sutures are placed from anterior fundus to posterior fundus to secure the fundoplication over a total of 3 cm. Once the first seromuscular stitch is placed, the Penrose drain is removed and a 52-Fr intraesophageal bougie is guided into the stomach to aid in fundoplication sizing. To orient the fundal folds appropriately for the second, third, and fourth fundus-to-fundus stitches, grasp the first fundus-to-fundus stitch and retract it cephalad to the right crus (**FIG 15**). This will result in appropriate alignment of the fundal suture line at the 10 o'clock to 11 o'clock positions (**FIG 16**).

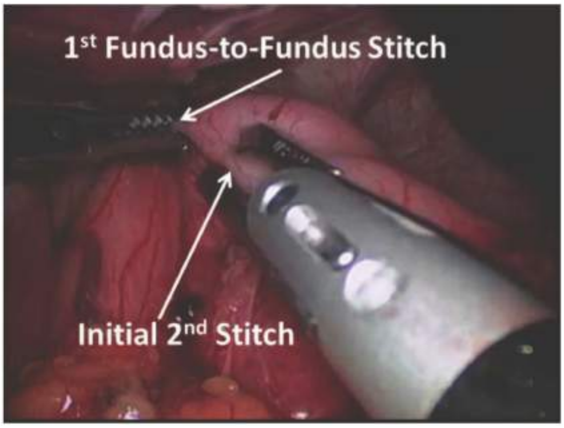

FIG 15 ● The first stitch of the fundoplication is placed most cephalad.

TECHNIQUES

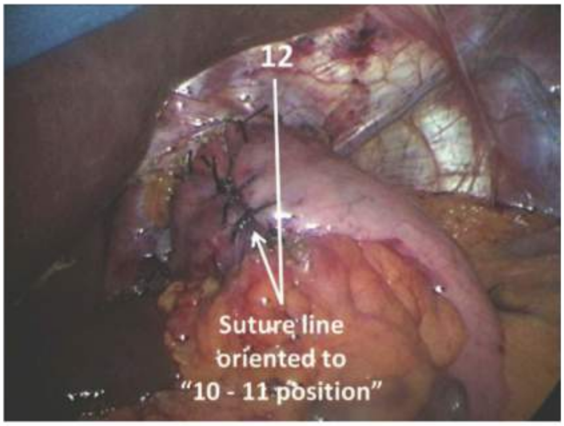

FIG 16 ● The completed fundoplication with the suture line at the 11 o'clock position.

FUNDOPLICATION ANCHORING

- The fundoplication is then anchored with separate stitches to the right and left crura as well as esophagus (fundus-esophagus-crus) to anchor the fundoplication in the abdomen and prevent herniation. Caution must be used so as not to tear the esophageal or crural fibers with these stitches. A final stitch from the posterior fundus to the crural closure can be placed to prevent posterior herniation. (The anterior space is protected by the left lateral lobe of the liver.)

INTRAOPERATIVE ENDOSCOPY

- Intraoperative endoscopy is used to confirm a well-positioned fundoplication prior to desufflation of the abdomen and removal of trocars.

PEARLS AND PITFALLS

Indications	■ Objective evidence of abnormal gastroesophageal reflux by 24-hour pH monitoring is essential to consider antireflux surgery because symptoms alone can be misleading. ■ Additional mandatory preoperative studies for operative planning: esophageal manometry, upper endoscopy, and esophagogram.
Hiatus dissection	■ Either a left-to-right or a right-to-left hiatal dissection is acceptable. We prefer starting the dissection on the left as it minimizes the risk of inadvertently tearing short gastric vessels and splenic injury when working from the right. ■ Mediastinal esophageal mobilization is necessary to gain adequate intraabdominal esophageal length for proper fundoplication creation.
Fundoplication calibration	■ A 52-Fr intraesophageal bougie is necessary to calibrate the fundoplication size. ■ The first fundoplication stitch is easier without the bougie in place. After the first stitch, advancing the bougie into the stomach must be done with caution as the bougie can perforate the GE junction.
Fundoplication orientation	■ An ideal fundoplication will lay so that the suture line is at the 10 o'clock to 11 o'clock positions on the esophagus.

POSTOPERATIVE CARE

- Postoperative dietary modifications: Clear liquids are started postoperatively and are advanced to full liquids the following day. The patient is typically discharged on the first postoperative day. Over 2 weeks, diet is advanced to a soft and then finally a regular diet as the patient's dysphagia resolves.
- Other postoperative instructions: To decrease postoperative bloating, no straws are used and carbonated beverages are avoided.
- Activity restrictions: No lifting greater than 10 to 15 lb or aggressive physical activity is strictly observed for 6 weeks to avoid stress to the diaphragmatic sutures.

OUTCOMES

- Long-term outcomes (median 69-month follow-up) for laparoscopic antireflux surgery reveal 90% of patients have resolved or improved heartburn and regurgitation. Seventy-five percent of patients have resolved or improved dysphagia. Sixty-nine percent of patients have resolved or improved cough and hoarseness.
- Postoperative side effects include new-onset bloating (9%), diarrhea (11%), and dysphagia (2%).
- Ninety percent of patients report that they were happy with their decision to undergo laparoscopic antireflux surgery.[2]

COMPLICATIONS

- Splenic or liver injury
- Hollow viscus perforation
- Dysphagia
- Pneumothorax

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Chapter 23

Laparoscopic Mesh Hiatal Hernia Repair

Ellen H. Morrow   Brant K. Oelschlager

DEFINITION

- A hiatal hernia is an enlarged diaphragmatic hiatus, allowing for passage of the stomach or other organs into the chest.
- Hiatal hernia is traditionally divided into several types; the principle difference is sliding versus paraesophageal. The sliding type is much more common. This is type I.
- Paraesophageal is type II. This involves herniation of the stomach above the gastroesophageal (GE) junction, which remains in the abdomen.
- Type III is a combination of types I and II, with the GE junction in the chest, but with stomach herniating above it. This is also referred to as a paraesophageal hernia (PEH) and is much more common than a type II.
- A type IV PEH involves herniation of additional organs other than stomach such as the transverse colon.

DIFFERENTIAL DIAGNOSIS

- The type of hiatal hernia should be discerned as described under definition and differentiated from other nonhiatal diaphragmatic hernias.
- This is a diagnosis that is often made with imaging prior to surgical referral. If imaging has not yet been performed, there are other entities that could have similar clinical presentation.
- These include gastroesophageal reflux disease (GERD), gastritis, peptic ulcer disease, chronic mesenteric ischemia, angina, myocardial infarction, or aortic dissection.

PATIENT HISTORY AND PHYSICAL FINDINGS

- Like type I hernias, these patients may present with GERD symptoms (e.g., heartburn, regurgitation, symptoms related to aspiration, etc.); however, at least half of patients will not complain of significant GERD. Patients will often present with a history of postprandial abdominal or chest pain, early satiety, dysphagia, and regurgitation. Symptoms are frequently related to the volume of food they have consumed. They may have associated weight loss.
- PEHs can also present with respiratory symptoms such as dyspnea or cough. Anemia is a common presenting symptom of a large hiatal hernia and is often the only finding in a gastrointestinal (GI) workup.
- Rarely, PEHs can present with acute obstruction.
  - This is often caused by gastric volvulus.
  - This will present with increased severity of symptoms; complete intolerance to oral intake; severe pain; and occasionally, even systemic inflammatory response or sepsis if the stomach becomes ischemic.
- There are not generally physical findings specific to this condition.
  - The patient can be examined for changes associated with GERD in the oropharynx.
  - Abdominal exam may reveal some epigastric tenderness.
  - There may be signs of weight loss or overall frailty.
  - There may be diminished breath sounds.

IMAGING AND OTHER DIAGNOSTIC STUDIES

- The workup for hiatal hernia is similar to the GERD workup.
- An esophagram is often the most valuable study; this provides images of the hernia in a dynamic fashion using fluoroscopy (**FIG 1**). This is the best study for getting an overall size and position of the stomach within the hernia.
- Hernias are frequently diagnosed on computed tomography (CT) for abdominal pain, although this is not the initial test to obtain if you are most suspicious of hiatal hernia. It will, however, usually make the diagnosis and can rule in or out other things.
- Upper endoscopy can be helpful for visualizing the size of the hernia and more for examining the mucosa for associated conditions.
  - Cameron's erosions are linear erosions that can be found in the stomach related to constriction by the diaphragm.
  - Changes related to associated GERD can also be seen in the esophagus such as erosive esophagitis and Barrett's esophagus.
  - Any neoplastic lesion should be ruled out prior to operative repair.

FIG 1 ● Upper GI study demonstrated large hiatal hernia with stomach in the chest.

- Manometry is valuable in planning the antireflux procedure that will be performed in conjunction with repair of the hernia. Normal motility will allow for creation of a full wrap, as opposed to partial.
- pH testing is not generally required, unless the patient is presenting primarily with GERD symptoms. In this case, it may be useful as a baseline.

SURGICAL MANAGEMENT

Preoperative Planning

- Indications for repair of hiatal hernias:
  - Sliding hiatal hernias (type I) should not be repaired unless the indication is associated GERD, in which case, they should be repaired at the time of planned fundoplication.
  - PEHs (types II to IV) should generally be repaired if symptomatic. In younger (<60 years of age) and healthier patients, repair of even relatively asymptomatic hernias is indicated given the risk of incarceration, although this risk is smaller than once thought.
  - Mesh hiatal hernia repairs generally need to be considered only in patients with PEHs (larger hernias).
- Many patients with hiatal hernias are elderly, and they may have serious comorbidities or frailty. In these patients, a thorough medical evaluation should be completed prior to any elective hernia repair.
- Some of them may be too frail or high risk for a full hiatal hernia repair with fundoplication but are very symptomatic and need intervention. In these patients, it may be more prudent to plan for a shorter procedure without full dissection of the hernia sac; hernia reduction with gastrostomy tube gastropexy may be more appropriate in these patients.

Positioning

- As for other foregut procedures, patients should be in low lithotomy with a beanbag support and both arms tucked (**FIG 2**).
- The patient will be in steep reverse Trendelenburg for most of the case.
- The surgeon can operate from the foot of the table, with the assistant on the patient's left.

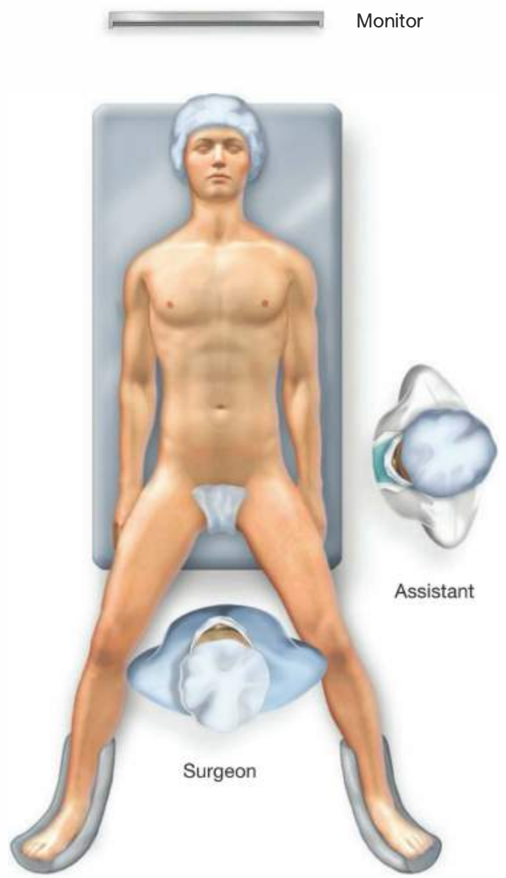


FIG 2 ● Patient positioning for hiatal hernia repair; low lithotomy. The surgeon stands between the patient's legs with the assistant on the patient's left.

SETUP AND PORT PLACEMENT

- After sterile prep, the upper abdomen is draped. Equipment for laparoscopy is passed off and secured.
- The peritoneal cavity is accessed using a Veress needle, and pneumoperitoneum is obtained.
- An 11-mm cutting optical trocar is inserted in the left subcostal position.
- Additional ports are placed under direct vision as follows (**FIG 3**):
  - Camera port (11 mm) in epigastric position; a 5-mm port can also be placed here depending on surgeon preference for scope size.
  - Assistant (5 mm) port in left lateral position
  - Surgeon's left hand port (5 mm) in right upper quadrant
- A Nathanson liver retractor is then placed in the upper midline for retraction of the left lobe.

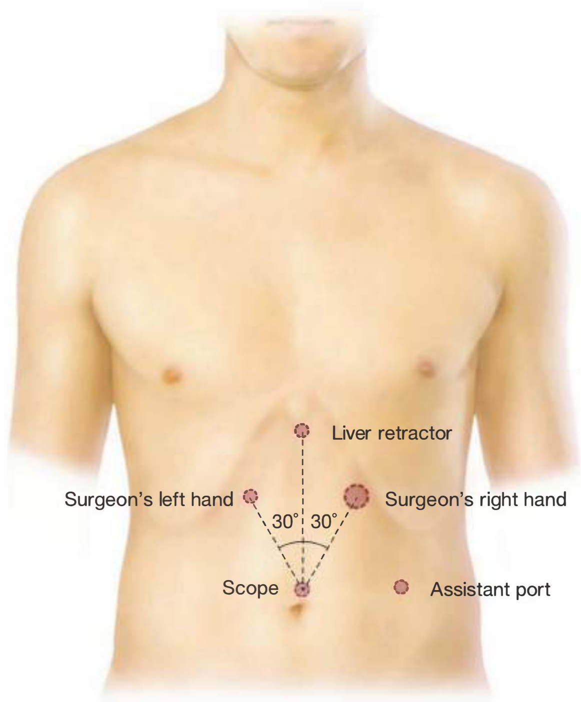


FIG 3 ● Port placement for hiatal hernia repair.

REDUCTION

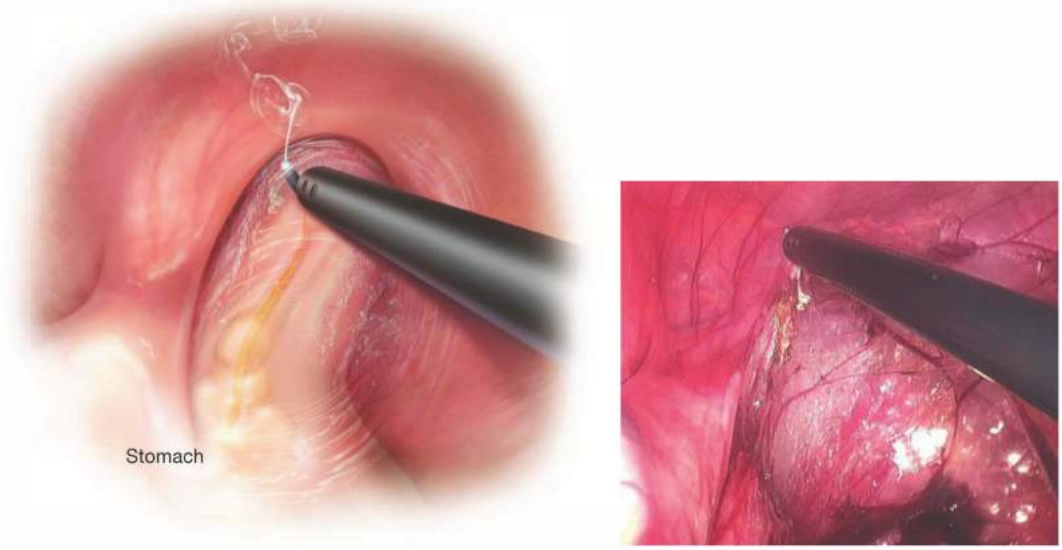
- The stomach and any other hernia contents are reduced into the abdominal cavity as possible; with a PEH, the stomach will almost never fully reduce and the surgeon should not attempt to do so. Just reduce the stomach that is free and not attached within the mediastinum.

MOBILIZATION

- The short gastric vessels are ligated with an electrical or ultrasonic sealing device in order to mobilize the fundus fully. Begin ligation near the inferior border of the spleen (see **FIG 3**).
- Care must be taken to also divide any attachments or vessels between the fundus and the retroperitoneum as adhesions are common.

DISSECTION OF HIATUS AND HERNIA SAC

- The phrenoesophageal membrane and hernia sac are divided at the muscular edge of the crus.
- Once the crus is visualized, the surgeon can be assured that all layers of the sac have been divided. In this way, the surgeon begins to develop a plane outside of the hernia sac and not within it.
- The attachment of the sac to the hiatus is divided until it is freed circumferentially. After this is complete, the sac is released from the mediastinum, with care to avoid the pleura (**FIGS 4** and **5**). This is facilitated with the use of gentle traction and the diffusion of carbon dioxide (CO_2) from the pneumoperitoneum.
- The appropriate plane should appear areolar and largely avascular.



A B

FIG 4 ● Line drawing **(A)** and intraoperative photo **(B)** of mediastinal dissection. The herniated stomach is seen on the left side of the screen. Electrocautery is used to divide the sac, revealing an areolar plane in the mediastinum outside the sac.

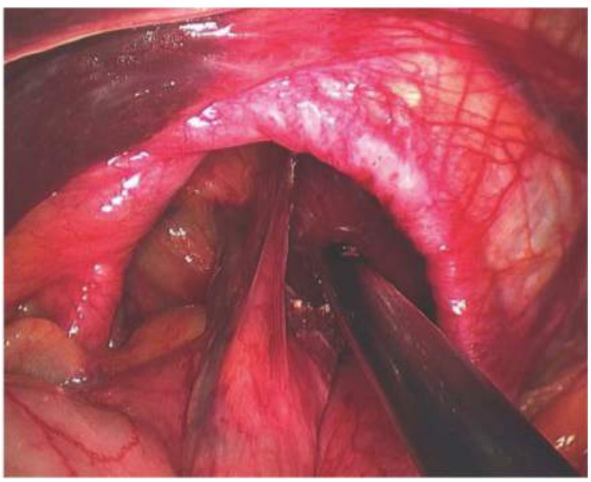


FIG 5 ● A large hiatal hernia defect. Dissection of the sac was begun from the patient's left side. The sac is still connected to the herniated stomach in the central anterior mediastinum.

ESOPHAGEAL MOBILIZATION

- A Penrose drain is then placed around the distal esophagus and used to place downward and alternating lateral traction on the esophagus as it is circumferentially mobilized in the mediastinum.
- Care is taken to ligate or cauterize small vessels in the mediastinum as needed.
- Mobilization is continued until the GE junction lies in the abdomen without tension, preferably with 3 cm of esophagus in the abdomen.
- In the setting of a large hiatal or PEH, the esophagus is always relatively foreshortened. If aggressive mobilization of the mediastinal esophagus is performed, in our experience, adequate esophageal length can be obtained. If not, then an esophageal lengthening procedure will be needed (see Part 1, Chapter 20).
- A lighted bougie is then placed into the esophagus and stomach by the anesthesia team. Careful communication between the anesthesia and surgical teams is required to avoid complications during placement of the bougie. The

anesthetist should be able to see one of the laparoscopy monitors. If there is any question as to the location of the esophagus earlier in the procedure, the lighted bougie can be helpful in locating it.

- The hernia sac is then amputated and removed. The anterior vagus nerve should be identified and preserved here as long as adequate esophageal mobilization has been obtained. This is done by only removing the anterior sac to the left of the vagus nerve.
- Adequate removal of the hernia sac facilitates the fundoplication later.
- If esophageal mobilization has been inadequate, the vagus can be ligated here,[1] or a Collis or wedge gastroplasty can be performed.[2]

CRURAL CLOSURE

- The crura are reapproximated using permanent suture (**FIG 6**).
- Most of the closure should be posterior, as the muscle is more robust there.
- Occasionally, adequate closure cannot be achieved with only posterior suturing due to the size of the defect; in this case, a relaxing incision or anterior sutures may be required.
- A relaxing incision can be made on the right side of the right crus to release the right crus toward the left and allow for hiatal closure.

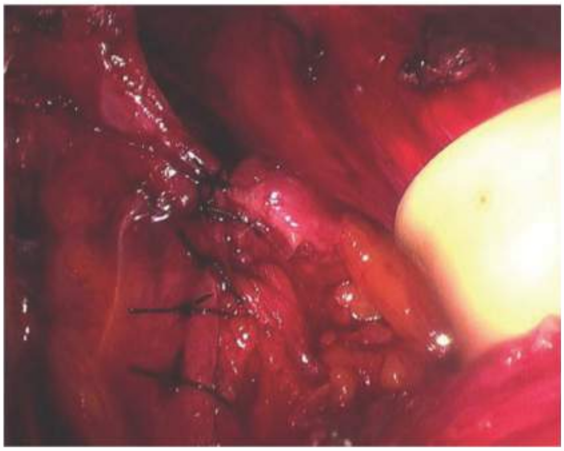


FIG 6 ● Primary repair of the crural defect posteriorly with interrupted sutures.

MESH PLACEMENT

- A biologic mesh is then cut to cover the defect, usually in a U or C shape.
- This is introduced through an 11-mm port and placed flat against the hiatus.
- Permanent sutures are then used to secure the superior aspects of the mesh to the crus on either side (**FIG 7**).
- The mesh can be completely secured with suture, or the remaining fixation can be performed with fibrin glue.
- If a relaxing incision was necessary, it should also be covered by the mesh.

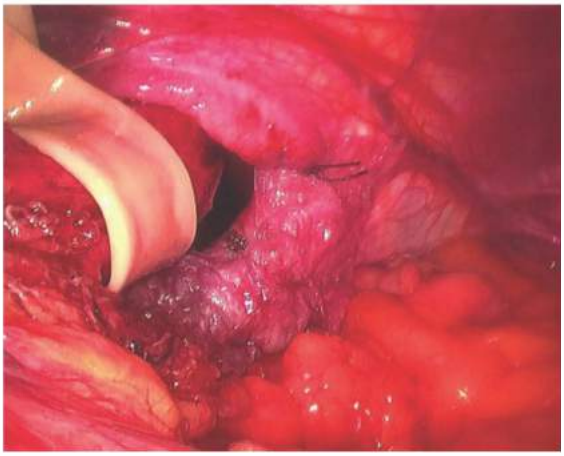
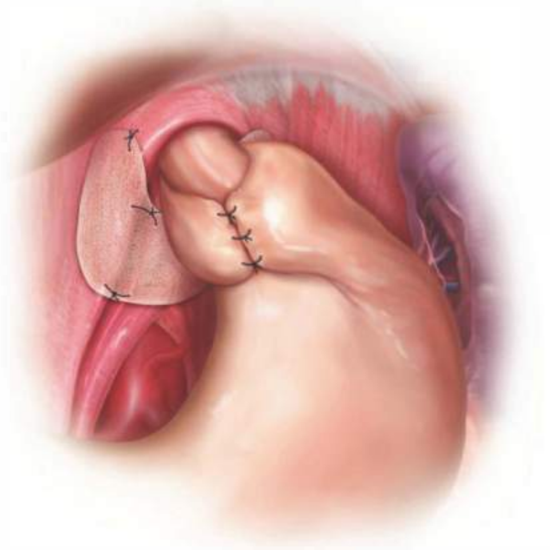


FIG 7 ● View of mesh placement from the patient's left side. It is secured with suture superiorly and fibrin glue inferiorly. The mesh covers the posterior defect.

FUNDOPLICATION

- Full fundoplication should be performed as long as the patient's esophageal motility allows, to treat reflux and to prevent reherniation. Fundoplication technique is described in another chapter (**FIG 8**).
- Intraoperative endoscopy should be performed at the conclusion of the case to confirm wrap positioning and location of the GE junction in the abdomen.



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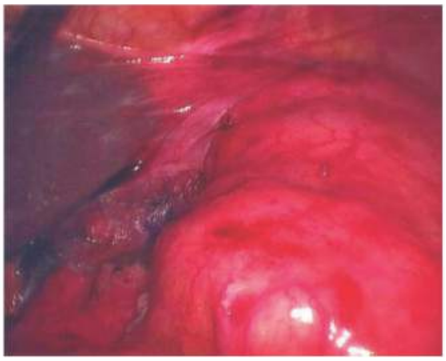

B

FIG 8 ● Line drawing **(A)** and intraoperative photo **(B)** of full fundoplication.

PEARLS AND PITFALLS

Indications	■ Only symptomatic (GERD associated) sliding hernias should be repaired. ■ All PEHs (types II to IV) can be considered for repair given the risks of volvulus and obstruction.
Patient selection	■ In elderly or infirm patients, consider gastropexy as an alternative to PEH repair. ■ In morbidly obese patients, consider laparoscopic sleeve gastrectomy or gastric bypass as an alternative operation.[3]
Dissection	■ Full dissection around the sac must be accomplished. Divide the sac off of the crus and then maintain an areolar plane in the mediastinum
Esophageal mobilization	■ Must be carried superiorly into the mediastinum to ensure adequate intraabdominal esophageal length (3 cm).
Mesh placement	■ After primary repair of a large hiatal defect, mesh reinforcement may be used. Biologic mesh has fewer potential complications[4] but may have a higher recurrence rate.[5]

POSTOPERATIVE CARE

- The patient generally has an overnight stay in the hospital.
- Patients should be given an incentive spirometer, have chemical deep vein thrombosis (DVT) prophylaxis, and prompt Foley catheter removal.
- Patients can be given clear liquids on the night of surgery and the diet can be advanced the following day. They should be discharged on a pureed diet and should progress to soft diet over the next month. Pills should be crushed or converted to elixirs for 1 month.
- Patients should anticipate at least 2 more weeks of recovery at home, depending on their age and comorbidities.
- Activity is largely unrestricted, but heavy lifting or other Valsalva maneuvers should be avoided to keep the intraabdominal pressure down and avoid early hernia recurrence.

OUTCOMES

- A recent randomized controlled trial of laparoscopic PEH repair with and without biologic mesh demonstrated a lower recurrence rate at 6 months with biologic mesh.[5]
- This difference in outcomes did not persist when patients were reexamined with upper GI series at a median follow-up time of 5 years.[6]
- At that time, the recurrence rate was found to be the same between the two groups; there was a 50% radiographic recurrence rate.
- Most of these recurrences were small and did not correlate with patient symptoms except a mildly increased rate of heartburn.[7]
- Despite the high rate of radiographic recurrence, all symptoms were improved at long-term follow-up.
- Only 3% of patients in this trial ultimately required reoperation for hernia recurrences.

COMPLICATIONS

- As with any major abdominal surgery, complications can include bleeding, infection (either at the surgical site or elsewhere), or thromboembolic events.
- Complications that are particular to PEH repair can include postoperative respiratory compromise.
  - Changing pulmonary physiology after reduction of the herniated stomach, general anesthesia, and postoperative abdominal pain can lead to increased dyspnea and oxygen requirement during the immediate postoperative period.
  - This generally stabilizes enough for discharge within 1 to 2 days or the patient can be discharged on a short course of home oxygen.
- Pneumothorax can occur intraoperatively during mediastinal dissection. The pleura should be repaired to prevent further insufflation of the pleural cavity with CO_2. Once the pleura is closed and the abdomen is desufflated, the CO_2 is reabsorbed quickly and decompression is not generally required.
- Following fundoplication, there can be some dysphagia during the early postoperative period. This can generally be managed with dietary modification. Bloating can also be a complaint early on.
- Hernia recurrence is a potential complication. Recurrence was covered in the "Outcomes" section.

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Chapter 24 | Redo Fundoplication

C. Daniel Smith

DEFINITION

- A variety of fundoplication procedures are used today (Table 1), primarily to treat gastroesophageal reflux disease (GERD).
- The 360-degree fundoplication (Nissen fundoplication) is the most popular of the various fundoplication techniques.
- Although fundoplication, when done by an experienced surgeon, results in control of GERD and significant improvement in quality of life in the majority of patients, this operation does fail, necessitating further surgery or a redo fundoplication.[1–3]
- Broadly speaking, there are three reasons that an operation will fail to control a patient's symptoms and/or GERD.
  - Errors in workup or patient selection
  - Errors in operative management
  - Natural history of the particular antireflux operation or condition being treated

DIFFERENTIAL DIAGNOSIS

- Fundoplication failure is defined as either recurrence of the condition or symptoms that necessitated the fundoplication (e.g., recurrent GERD or recurrent hiatal hernia) or the development of new symptoms not present preoperatively (e.g., dysphagia, nausea, or regurgitation).
- One typically sees failure of a fundoplication in a few distinct patterns.[4–6] These are outlined in Table 2 and **FIGS 1** and **2**.
- When considering these reasons for failure, hiatal hernia is the most common cause (44% of cases). Wrap disruption or breakdown is the next leading cause, accounting for 16% of failures. Slipped wraps account for 11.7% of failure, and finally, wraps improperly positioned at the time of their initial construction is found in 3.9% of cases.[7]
- Wrap or crural stenosis is a rare cause of failure and often times hard to determine as a primary etiology of failure.
- If mesh was used at the initial operation, a distinctly different pattern of failure and management strategy is needed.[8]

PATIENT HISTORY AND PHYSICAL FINDINGS

- Common symptoms of failure of fundoplication are outlined in Table 3.
- Recurrent GERD is the most common (59%) and dysphagia (31%) the next most common. Although these symptoms can occur with any or all of the patterns of failure, there are patterns of symptoms that correlate highly with a given mechanism of failure (**FIG 3**).

Table 1: Fundoplication Procedures

360-degree fundoplication (Nissen fundoplication)
180-degree posterior fundoplication (Toupet fundoplication)
180-degree anterior fundoplication (Dor fundoplication)
Posterior gastropexy (Hill procedure)
Transthoracic posterior plication (Belsey procedure)

Table 2: Patterns of Fundoplication Failure

Wrap disruption or loosening
Wrap migration or slip
Hiatal herniation or reherniation
Wrap or crural stenosis
Wrap too loose or misplaced at the initial operation

- Gross anatomic abnormalities such as hiatal hernia or severe wrap/crural stenosis are more likely to present with symptoms related to poor esophageal transit and emptying. These symptoms commonly include dysphagia, chest pain, and regurgitation.
- The wrap that has loosened or come undone more commonly presents with recurrent GERD symptoms, often identical to those being experienced before the first antireflux procedure. Commonly, this includes typical symptoms such as heartburn, regurgitation, and chest pain but can also be more atypical symptoms such as cough, laryngitis, or asthma. Again, the relationship and similarity of symptoms to those before the initial operation is strongly predictive of wrap disruption or loosening.
- A slipped wrap will often have a broad constellation of symptoms with more prevalence of nausea and epigastric pain than the other presentations.
- A favorable response to antisecretories and postural regurgitation predicts wrap loosening or incompetence, whereas poor tolerance of heavy dense foods or weight loss predicts hiatal herniation or esophageal outlet issues. Improvement

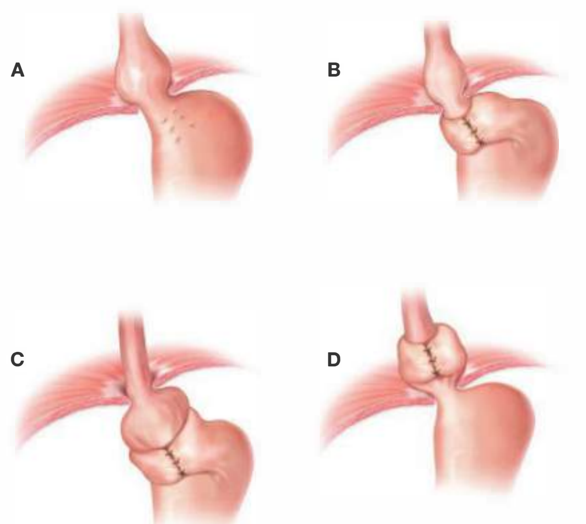

FIG 1 ● Common anatomic patterns of antireflux surgery failure: **(A)** fundoplication disruption, **(B)** tight fundoplication or crural stenosis, **(C)** slipped fundoplication, and **(D)** hiatal herniation.

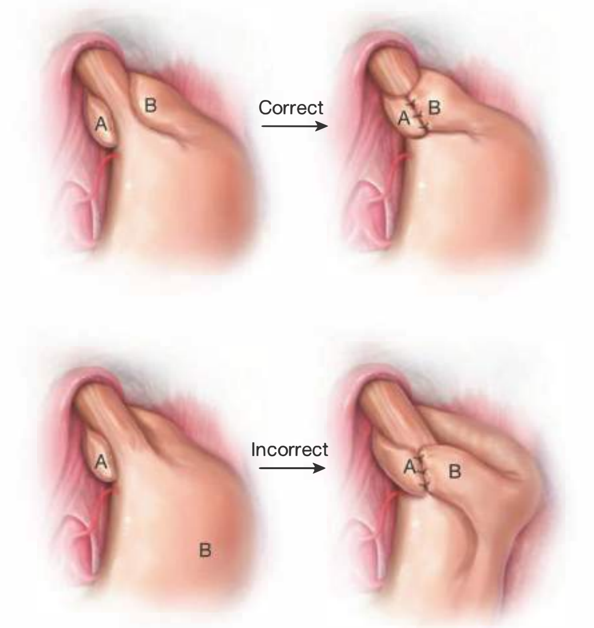

FIG 2 ● Illustration of incorrectly created fundoplication compared to correct creation.

with dilation supports esophageal outlet restriction. Failure of symptoms to respond to any intervention is more likely with wrap slippage.

- A confusing presentation is the patient with early postprandial bloating or meal-induced diarrhea. With this symptom constellation, one should be suspicious of vagal nerve injury or inflammation (dysfunctional gastric emptying). This symptom complex in the absence of an obvious anatomic abnormality or a positive pH test should lead one to pursue further workup rather than a redo antireflux operation.

Table 3: Common Symptoms of Fundoplication Failure

Heartburn
Chest pain
Regurgitation
Dysphagia
Nausea
Bloating
Shortness of breath (SOB)
Aspiration

IMAGING AND OTHER DIAGNOSTIC STUDIES

- Testing for suspected fundoplication failure falls into testing to secure a diagnosis or reason for failure and testing for operative planning. An algorithm for the workup of patients suspected to have failed a prior fundoplication is shown in **FIG 4**.

Establishing the Diagnosis

- In pursuit of a diagnosis of failure, the workup should start with an anatomic assessment. This usually includes an upper endoscopy (esophagogastroduodenoscopy [EGD]) and contrast esophagram.
- Often, a contrast esophagram is all that is needed to identify the pattern of failure. **FIG 5** depicts the esophagram findings corresponding to the various patterns of failure.
- Alternatively, an EGD may clearly show an anatomic abnormality. The common endoscopic findings of failure are outlined in Table 4.
- In many cases, if the presenting symptoms correlate with findings on an esophagram or EGD, this is all that is needed to diagnose failure and the need for reoperation.
- If recurrent GERD is the dominant presentation, then pH testing should be obtained.

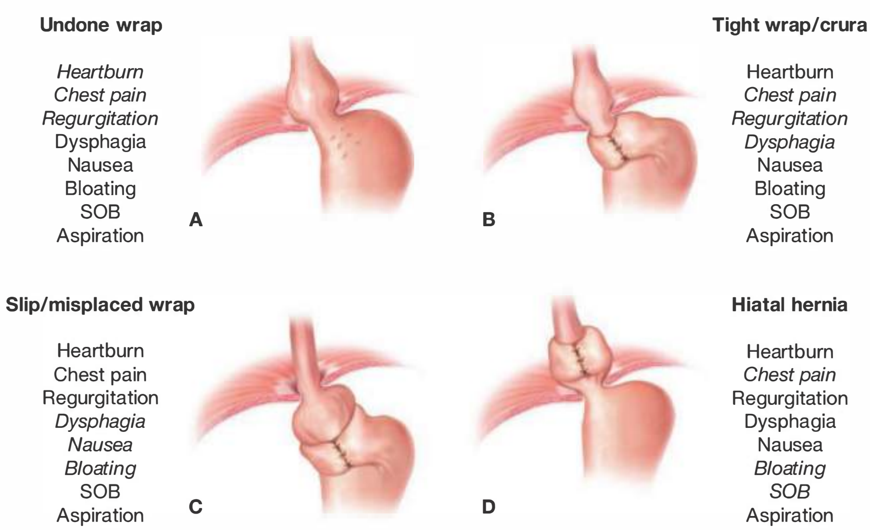

FIG 3 ● **A–D.** Symptoms of antireflux surgery failure correlated with anatomic pattern of failure. SOB, shortness of breath.

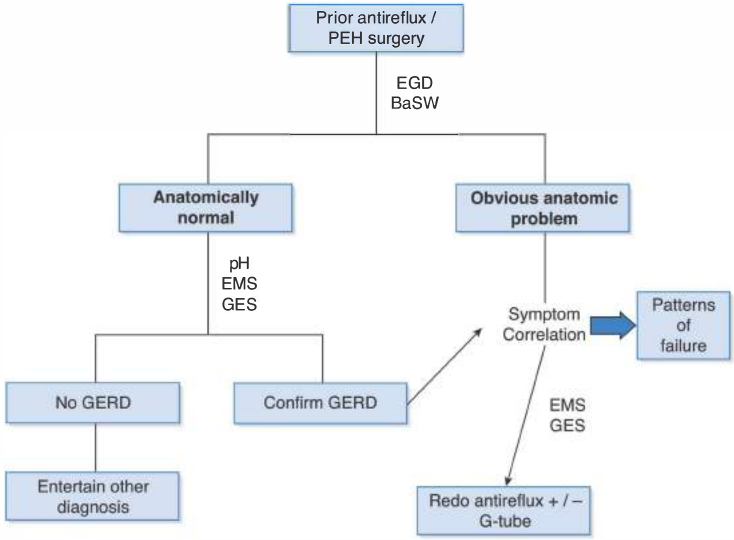

FIG 4 ● Flowchart of workup for possible antireflux surgery failure. *PEH*, paraesophageal hernia; *EMS*, esophageal motility study; *GES*, gastric emptying study.

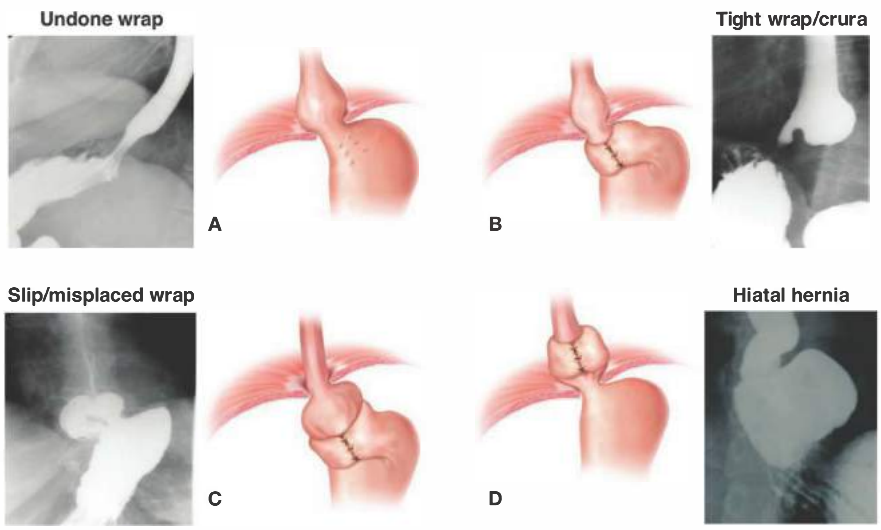

FIG 5 ● **A–D.** Contrast swallow examples for each common anatomic pattern of failure.

Table 4: Endoscopic Findings of Failed Fundoplication

Viewing Location	Findings (Pattern of Failure)
Retroflex view of distal esophagus	Gastric folds extending into wrap (slipped/misplaced fundoplication) Esophagogastric junction does not hug scope (loose or undone fundoplication) Gastric mucosa extending above hiatal indentation (hiatal hernia)
Forward view of distal esophagus	Narrowing that does not accept scope (tight wrap or crural stenosis) Esophagitis/esophageal ulcers (loose or undone fundoplication) Constriction on proximal stomach below constriction of wrap (hiatal hernia) Constriction of wrap distal to esophagogastric junction (slipped or misplaced wrap)

Planning for Operative Management

- With a diagnosis of fundoplication failure secured, further testing may be indicated to help plan the most effective reoperative strategy.
- The most common conditions associated with failure that need to be investigated are esophageal motility problems and impairment in gastric emptying. All patients should undergo an esophageal motility study and a gastric emptying study before redo surgery.
- Impairment in esophageal motility may indicate the need for a partial 270-degree fundoplication rather than a 360-degree fundoplication. Classically, a partial fundoplication should be considered if normal esophageal peristalsis is present in less than 70% of swallows or esophageal body pressure is less than 30 mmHg.
- Delayed gastric emptying may require the addition of a gastrostomy tube to provide gastric decompression in the early postoperative period, thereby preventing gastric distension–induced crural or wrap disruption.

SURGICAL MANAGEMENT

- Redo fundoplication can be both rewarding and challenging. Although the right diagnosis and proper preparation are important, they are no substitute for experience with all manner of foregut surgery. Redo fundoplication should not be undertaken by a general surgeon who occasionally performs elective fundoplication.

Preoperative Planning

- For a skilled laparoscopic surgeon, almost all redos can be approached laparoscopically. Early conversion to an open approach is more likely in the following situations:
  - Multiple prior foregut procedures, especially prior open repairs
  - Hiatal hernia with a significant amount of the stomach incarcerated in the chest, especially if mesh was used
  - Prior operations that were complicated by postoperative leak, fistula, or early reoperation
- In these situations where one may predict a higher likelihood of conversion, it is prudent to be prepared for not only an open approach but also a thoracoabdominal approach.
- EGD should be available intraoperatively for all redos, and an EGD performed by the surgeon before scrubbing provides valuable firsthand anatomic information that is useful intraoperatively. Leaving the scope in the stomach allows intraoperative identification of key anatomic structures such as the squamocolumnar junction or the location of the fundoplication.

Positioning

- A split-leg approach is used in nearly all cases (**FIG 6**). If conversion to an open approach is anticipated, one arm should be tucked so that a table-mounted retraction system can be secured at the patient's shoulder, well away from the surgeons' standing position at the patient's side for open access.

FIG 6 • Patient positioning for reoperative antireflux operation.

GAINING ABDOMINAL ACCESS AND PORT PLACEMENT

- If the prior fundoplication was performed laparoscopically, it is reasonable to attempt abdominal access by passing a Veress needle through an area in the upper abdomen free of prior incisions. The safest means of access is a visualized access using an open technique.
- A five-trocar technique as depicted in **FIG 7** is used.

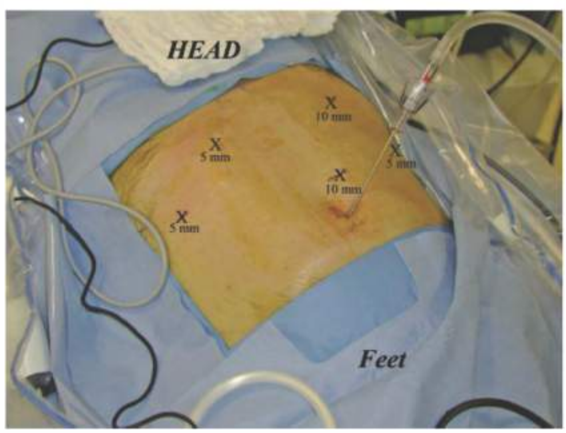

FIG 7 • Illustration or photo of trocar placement on abdomen.

IDENTIFY AND EXPOSE HIATAL ANATOMY

- The dissection commences by approaching the esophageal hiatus from the left. The greater curve of the stomach is found and followed upward toward the angle of His while using a tissue-sealing device to divide any remaining short gastric vessels or vascularized scar tissue (Table 5).
- Once the base of the left crus is found, the left crus is cleared of adhesions up to and around the crural arch as far as possible (**FIG 8**). Often, the left lobe of the liver is fused to the fundus starting along the crural arch limiting how much crural arch can be exposed at this point in the operation.
- The mediastinum is entered from the left as far posterior as possible. Usually, this opens a plane just anterior to the aorta and behind the esophagus (**FIG 9**). This plane is often very friendly allowing the posterior mediastinum to be cleared proximally and to the right, over the top of the aorta toward the spine. A ½-in Penrose drain cut 6-in long can be left in the posterior mediastinum (**FIG 10**) to be found later when the mediastinum is entered from the right posteriorly.
- With at least ½ of the esophageal hiatus exposed from the left, the more complicated dissection of the right crus can be undertaken more safely with some awareness of the esophageal hiatus relationship to the scar plate that tends to envelop the right side of the hiatus.
- Starting distal along the lesser curve of the stomach and well below the adhesions of the left lobe of the liver to the anterior surface of the stomach will often reveal a friendly dissection plane leading under the caudate lobe of the liver and to the base of the right crus (**FIG 11**).

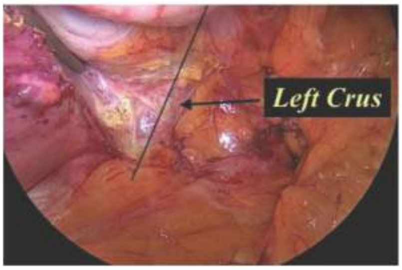

FIG 8 ● Photo of left crus exposure.

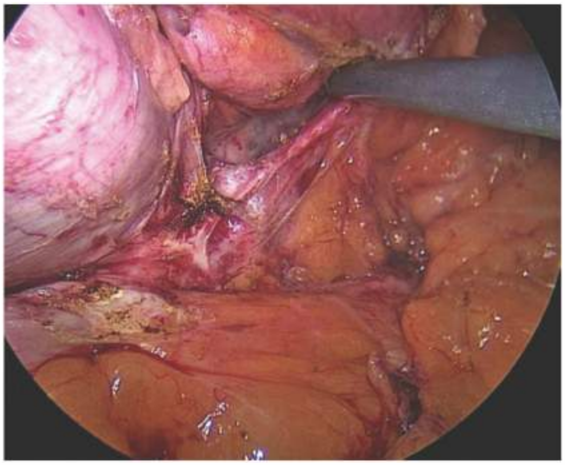

FIG 9 ● Posterior mediastinum opened from left.

Table 5: Sequence for Successful Hiatal Dissection

- Start along greater curve of stomach.
- Divide any remaining short gastric vessels (ideally none are encountered).
- Expose left crus from base through arch.
- Enter mediastinum from left and posterior to hiatal content.
- Dissect further proximal into mediastinum and from left to right along plane anterior to aorta until over spine
- Leave left side of hiatus and develop plane between anterior surface of stomach and undersurface of liver to find caudate lobe of liver.
- Following lower edge of caudate lobe of liver, expose right crus from base to arch (often need to free wrap adhesions to right crus).
- Enter mediastinum from right and complete retroesophageal window.
- Encircle esophagus with Penrose drain to manipulate and control esophagus during rest of mediastinal dissection and esophageal mobilization.
- After hiatus completely dissected and esophagus mobilized, take down prior wrap by releasing anterior fusion/sutures and dissect wrap from esophagus
- Intraoperative endoscopy to identify location of squamocolumnar junction (adequate esophageal length) and wrap has been completely taken down (retroflexed view)

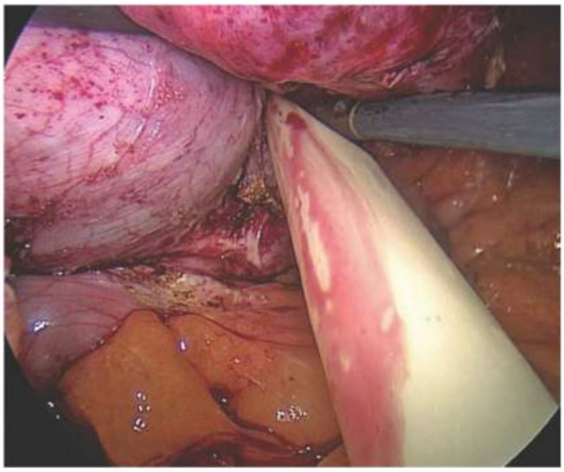

FIG 10 ● Penrose drain left in mediastinum from left.

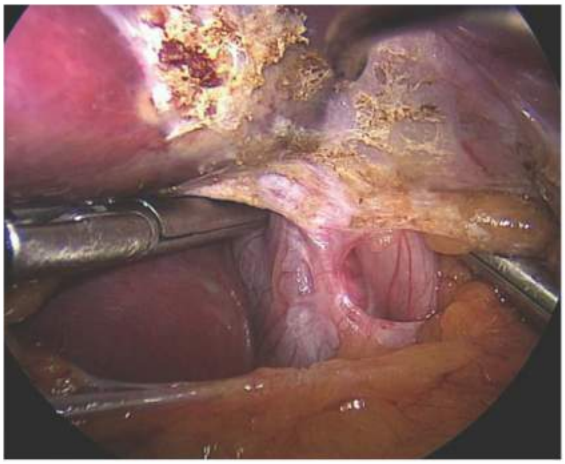

FIG 11 ● Approaching the base of right crus along caudate lobe of liver.

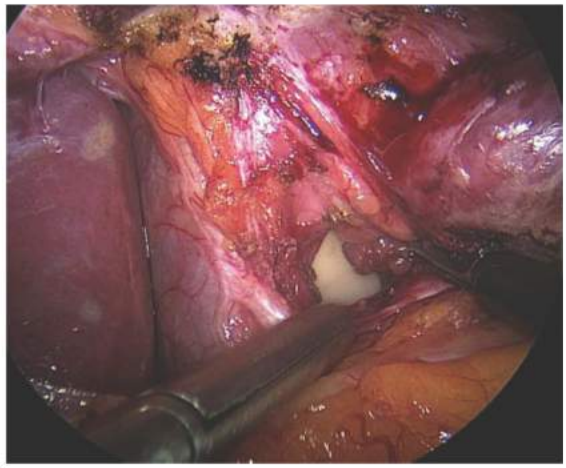

FIG 12 ● Penrose drain retrieved from right.

- Once the base of the right crus is exposed, the mediastinum is entered from the right and the Penrose drain left in the mediastinum from the right is retrieved (**FIG 12**). At this point, the Penrose drain can be brought around the entire hiatal contents and used as a retractor to facilitate the remainder of the hiatal dissection.
- This technique of starting on the left and using the crura as the edges of dissection assures safe isolation of hiatal content thereby minimizing the risk of esophagogastric perforation or vagal nerve injury (**FIG 13**).
- At this point, an EGD is useful to confirm anatomy, assess for any unsuspected perforation, and help localize the fundoplication in preparation for undoing the fundoplication.

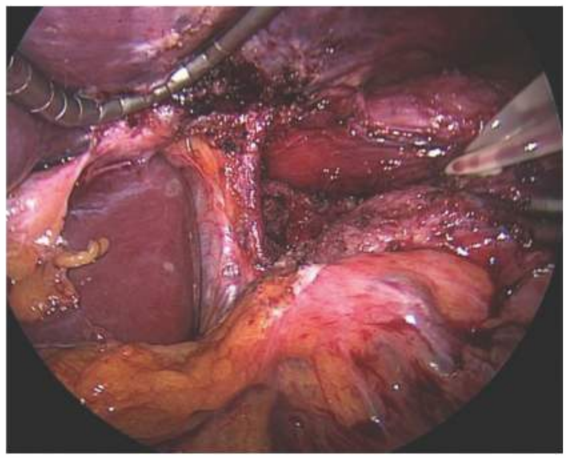

FIG 13 ● Completed hiatal dissection.

UNDO PREVIOUS FUNDOPLICATION

- Finding the inferior edges of the fundoplication where it drapes over the proximal stomach, especially on the left side of the gastric cardia, allows the edge to be traced toward the anterior fusion of a 360-degree fundoplication. A similar exposure on the left can also be accomplished, but the left lower edge of the fundoplication tends to be more fused along the neurovascular bundles of the lesser curve.
- Once the anterior fusion of the fundoplication is found, it can be isolated and either released with the aid of electrocautery or separated by firing a linear cutting stapler between the two limbs (**FIG 14**).

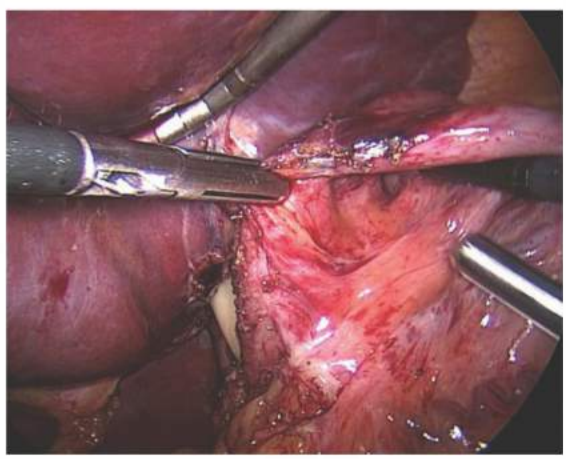

FIG 14 ● Exposed anterior fusion of wrap.

- With the anterior portion of the fundoplication released, the right limb is dissected away from the lesser curve of the stomach and right side of the esophagus and returned to its normal location in the left upper quadrant (FIG 15). As the fundoplication is dissected away posteriorly, the posterior vagus nerve should be sought and protected.
- With the fundoplication completely undone, an EGD is again performed to assure that the wrap is completely mobilized and assess for any perforation. This is done by submerging the area of the gastroesophageal junction (GEJ) under saline while inflating the lumen of the esophagus and stomach with air and looking for an air leak externally.

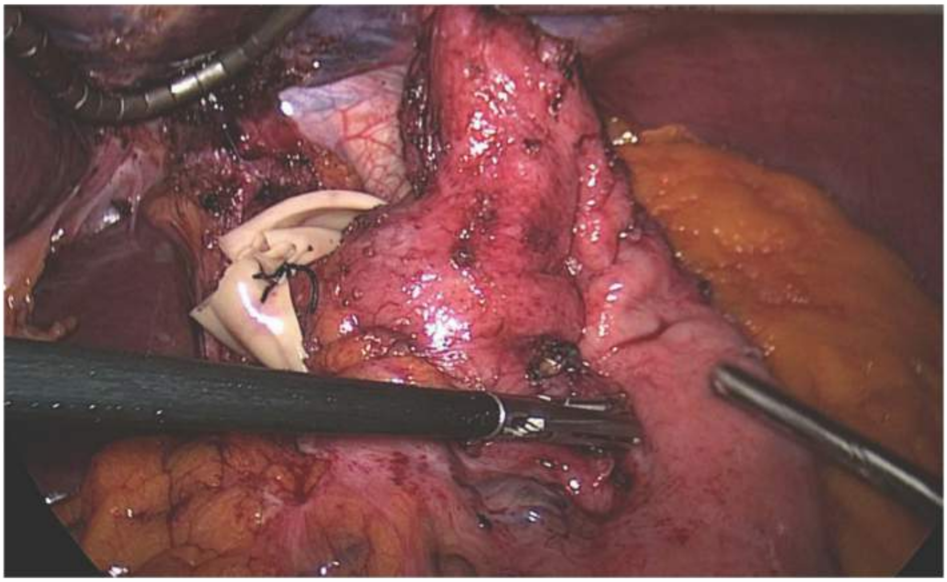

FIG 15 ● Gastric fundus returned to normal location.

RECONSTRUCT ESOPHAGEAL HIATUS

- The esophageal hiatus is reconstructed using permanent sutures to approximate the crura posteriorly. Pledgets can be used to limit the sawing effect of the suture over time (FIG 16).
- If the hiatal defect is large, the intraabdominal pressure is decreased to 10 to 12 mmHg, thereby unloading the pressure on the diaphragm and crural repair.
- Several anterior crural sutures may be needed if the defect is large and the posterior-only closure is creating an angle at the GEJ.
- The crural reconstruction should result in the crura effacing the esophagus circumferentially without impinging.

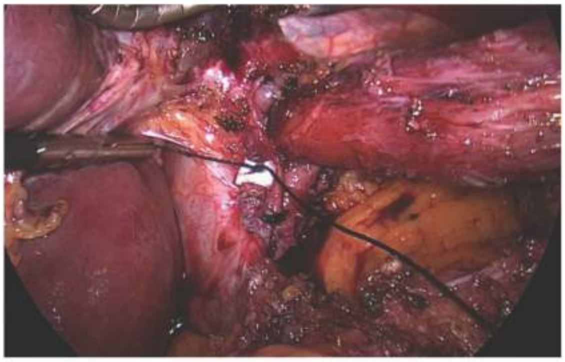

FIG 16 ● Hiatal reconstruction.

TECHNIQUES

REDO FUNDOPLICATION

- A standard technique for fundoplication can be used.[9,10] This entails a 360-degree fundoplication if there is adequate fundus and the preoperative esophageal motility is adequate (peristalsis in 70% or more of swallows or esophageal body pressure of 30 mmHg or greater).

Table 6: Options for Redo Fundoplication

Reconstruction Option	Uses
360-degree fundoplication	Adequate fundus and normal esophageal motility
270-degree fundoplication	Poor esophageal motility or inadequate fundus for 360-degree fundoplication
No fundoplication	Tight wrap or hiatal stenosis with inadequate fundus for any fundoplication
Proximal divided gastroplasty/gastrectomy with Roux-en-Y gastrojejunostomy	Recurrent GERD following multiple prior antireflux operations and/or no fundus for redo fundoplication with/without injury to gastric cardia/fundus during redo
Esophagogastric myotomy with/without partial fundoplication	Pseudoachalasia
Esophagectomy with gastric pull-up or colon interposition	Severe pseudoachalasia with massive esophageal dilation
Roux-en-Y esophagojejunostomy	Recurrent GERD following multiple prior antireflux operations and injury to gastric cardia or distal esophagus during redo

GERD, gastroesophageal reflux disease.

A 270-degree fundoplication should be used if these criteria are not met (Table 6).

- Fundoplication should be calibrated by completing the wrap around a 56- to 60-Fr dilator placed across the GEJ (**FIG 17**). It is best if the fundus is positioned for the fundoplication before this dilator is placed; otherwise, the wrap can be very difficult to bring around the esophagus posteriorly with the dilator in place.
- Two to three permanent sutures that include the anterior esophagus are placed to produce a 2-cm long fundoplication.

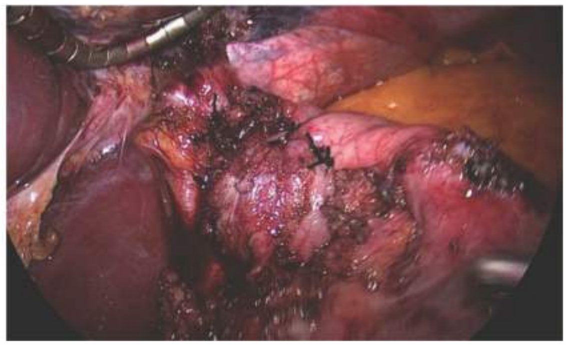

FIG 17 ● Completed redo fundoplication.

ASSESS FOR POTENTIAL COMPLICATIONS

- One final EGD is recommended to assess the location of the wrap and look for any potential complications. A retroflex view is very helpful to assure that the wrap is on the distal esophagus and not the proximal stomach (the appearance of gastric folds extending up and into the wrap suggests a wrap that is too low).

CONSIDER ADJUNCTS

- If the hiatal dissection or undoing the wrap was particularly difficult, a gastrostomy tube can be used to allow gastric decompression and possible gastric feeds while waiting for proximal gastrointestinal (GI) function to return and normalize.

PEARLS AND PITFALLS

Indications for surgery and diagnosis of failure	■ Functional reasons for symptoms after fundoplication (e.g., misdiagnosed GERD, other GI problems, vagal nerve injury) *cannot* be corrected with surgery. ■ Without evidence of an obvious anatomic failure or confirmation of recurrent GERD by pH testing, surgery should be avoided.
Preoperative testing	■ Preoperative tests are intended to assure that correct redo technique is performed (e.g., total vs. partial fundoplication). ■ Skipping testing may compromise redo success.

Identify and expose hiatal anatomy	■ Injury to the liver, lesser curve of the stomach, the wrap, and the esophagus is more likely if dissection is started on the right. ■ Starting on the left allows exposure of the hiatus before working in the more anatomically congested right side.
Intraoperative testing	■ Liberal use of intraoperative endoscopy to guide dissection by frequently assessing anatomy ■ Assess for potential luminal injury penetration.
Surgical technique	■ A standardized technique adhering to key technical principles will help assure successful outcomes (Table 7).
Postoperative care	■ Managing nausea to prevent retching starts in the operating and recovery room and is critical to minimizing trauma early postoperative that could disrupt the redo. ■ Gastric decompression avoids gastric distension that could disrupt a wrap or cruroplasty. ■ Tube access to the stomach may allow nonoperative management of a small leak found postoperatively.

POSTOPERATIVE CARE

- Postoperative management after reoperative antireflux surgery mirrors the care of any foregut surgery patient. A one- to two-night stay is pretty typical if the redo is laparoscopic, extra days if open. Key aspects of postoperative care are oral intake and return to activity.
- A preventable cause of antireflux surgery failure is early postoperative retching. The two most common reasons for early postoperative retching are nausea and dietary indiscretion.
- Patients should receive preemptive nausea control and antiemetics and be counseled carefully about maintaining a liquid and soft food diet for at least 1 month after surgery.
- Instructing patients to ingest only pourable liquids for the first week after surgery provides a simple rule to follow, and then providing a detailed menu of acceptable soft foods for another 3 weeks will help effect compliance with the postoperative diet.
- Too rapid advancement to activity that will result in increased intraabdominal pressure can put sutures and the reconstructed anatomy at risk. A full 30 days of limiting lifting to no more than 30 lb and no vigorous exercise during this time provides simple guidelines for patients to follow.
- Setting appropriate expectations for patients with regard to their overall recovery, diet progression, and resolution of preoperative symptoms is important. Dysphagia may linger for more than 4 weeks after a redo and preparing patients for this likelihood will allow them to accept this more readily.
- Early dilation may improve the dysphagia, but it also increases the risk of recurrent GERD and therefore should be avoided if possible. We reserve dilation within the first 3 months after any antireflux operation for only those patients whose difficulty swallowing makes it hard to handle their own saliva or maintain hydration.

Table 7: Standard Technique for Redo Fundoplication Success

- Full hiatal dissection (reduce and resect any hiatal hernia sac)
- Adequate esophageal mobilization—3–4 cm of esophagus below diaphragm
- Divide all short gastric vessels (be sure to mobilize fundus posteriorly to find and divide any high posterior vessel[s]).
- Resect any epiphrenic fat (careful to not undermine the anterior vagus).
- Determine esophageal length and location of EGJ (use endoscopy if unsure).
- Careful handling of crura during dissection and closure
- Decrease pneumoperitoneum to unload the diaphragm during closure.
- Anterior crural stitch if large hiatal defect
- Calibrate wrap (assure the fundus is in contact with the esophagus circumferentially—you can make a wrap too loose).
- Use gastrostomy tube for gastric decompression if large hiatal hernia or excessive manipulation of stomach/area of vagal nerves.
- Avoid postoperative nausea (use preemptive antiemetics).

EGJ, esophagogastric junction.

OUTCOMES

- The outcomes of redo fundoplication can be comparable to primary antireflux surgery, and in patients suffering with significant and debilitating symptoms, the operations can return patients to a nearly normal quality of life with low morbidity and virtually no mortality[11] (Table 8).
- The patient requiring multiple reoperations for failed fundoplication is a special situation that deserves special mention. When undertaking a fourth redo, the failure rate jumps from around 7% to over 17%.[7] We will rarely simply undertake a redo after three prior attempts. A divided gastroplasty and Roux-en-Y reconstruction for recurrent severe GERD, an esophagogastric myotomy for pseudoachalasia or esophagectomy for severe pseudoachalasia with massively dilated esophagus, or an esophagojejunostomy for poor esophageal emptying with severe GEJ distortion is instead advised.

COMPLICATIONS

- Complications can best be understood, identified, and managed considering their occurrence.

Intraoperative

- Bleeding
- Liver injury
- Esophagogastric perforation
- Pneumothorax
- Vagal nerve injury

Postoperative

- Pneumonia
- Esophageal obstruction (edema) with inability to swallow
- Delayed gastric emptying
- Atelectasis and hypoxemia

Table 8: Outcomes of Redo Fundoplication

Author	Date	No. Patients	Mortality	Morbidity	Success	Follow-up (Mon)
Vignal	2012	47	0	4.3%	78%	24
Musunuru	2012	38	0	18.4%	63%	35
Frantzides	2009	68	0	5.9%	86%	27
Smith	2005	259	0	15.4%	89%	14
Khajanchee	2007	176	0	9.8%	75%	9
Byrne	2005	118	0	1.7%	84%	12
Légner	2011	106	0	35.8%	90%	22
Dallemagne	2011	129	0	7%	83%	75

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Chapter 25

Laparoscopic Partial Fundoplication for Gastroesophageal Reflux Disease

Marco E. Allaix Marco G. Patti

DEFINITION

- Gastroesophageal reflux disease (GERD) is a chronic condition resulting from the reflux of gastric contents into the esophagus and is associated with a spectrum of symptoms, with or without tissue injury.[1,2]

DIFFERENTIAL DIAGNOSIS

- Several conditions, including irritable bowel syndrome, achalasia, gallbladder disease, coronary artery disease, or psychiatric disorders can present with heartburn as the main symptom.

PATIENT HISTORY AND PHYSICAL FINDINGS

- Heartburn, regurgitation, and dysphagia are considered *typical* symptoms of GERD.
- GERD can also cause *atypical* symptoms such as cough, wheezing, chest pain, hoarseness, and dental erosions.

IMAGING AND OTHER DIAGNOSTIC STUDIES

- Clinical history, based on *symptoms* only, has a low diagnostic accuracy of GERD in about 30% of patients.[3]
- *Upper endoscopy* is often the first test performed to confirm the diagnosis of GERD. However, about 50% of patients with clinical symptoms of GERD do not have endoscopic sign of esophagitis.[3] In addition, endoscopic evaluation is highly operator dependent, especially in the assessment of low-grade esophagitis.[4] Therefore, the major role of endoscopy is to detect Barrett's esophagus (usually present in 1% to 5% of patients with GERD) and to exclude gastric and duodenal pathology.
- *Barium swallow* is useful for detecting and characterizing the type and size of a hiatal hernia; for determining the location and size of a stricture; and for evaluating length, diameter, and function of the esophagus. This test, however, is not diagnostic of GERD as a hiatal hernia or reflux of barium can be present in the absence of abnormal reflux or absent in the presence of clinically significant GERD.
- *Esophageal manometry* provides information about the lower esophageal sphincter (LES) in terms of resting pressure, length, and relaxation and the amplitude and propagation of esophageal peristaltic waves. In addition, manometry is essential for proper placement of the pH probe for ambulatory pH monitoring (5 cm above the upper border of the LES).
- *24-hour ambulatory pH monitoring* is considered the gold standard for the diagnosis of GERD (**FIG 1**). Its role is key in the workup as it determines the presence and amount of abnormal reflux and it establishes a temporal correlation between symptoms and episodes of reflux (particularly important when cough or chest pain are present).[5] An abnormal score not only confirms the diagnosis but also is an independent predictor for the successful outcome of antireflux surgery.[6] Finally, pH monitoring is mandatory for the proper evaluation of patients who have recurrent symptoms after antireflux surgery.[7]
- *Combined multichannel intraluminal impedance and pH testing* (MII-pH) detects episodes of reflux, regardless of the pH of the refluxate, by identifying changes inducted by the presence of liquids and gas in the esophagus. The episodes are classified as acid, weakly acid, or nonacid on the basis of concomitant pH monitoring. This test is useful in identifying bile reflux and does not require cessation of proton pump inhibitors for testing.

SURGICAL MANAGEMENT

- A laparoscopic fundoplication is currently considered the procedure of choice for the treatment of GERD.
- Even though several eponyms are used to describe different antireflux procedures, we believe that it is more important to focus on the technical elements that make a fundoplication effective and long lasting.
- The type of fundoplication (total vs. partial) is tailored to the quality of esophageal peristalsis as documented by the preoperative manometry. In the United States, a partial fundoplication is proposed only to patients with very impaired or absent esophageal peristalsis in order to reduce the risk of postoperative dysphagia (**FIG 2**).

Preoperative Planning

- A careful symptomatic evaluation testing is performed in every patient before surgical intervention.

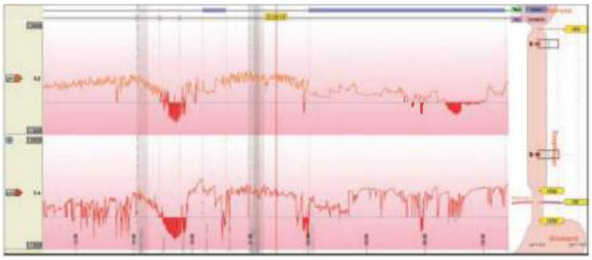

FIG 1 • Ambulatory 24-hour pH monitoring.

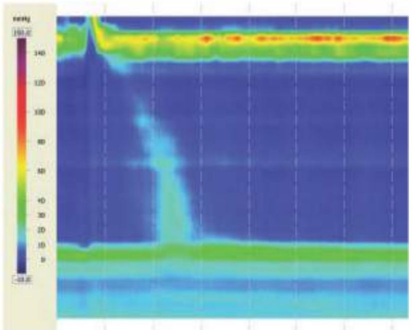

FIG 2 ● High-resolution esophageal manometry: ineffective esophageal motility.

Positioning

- After induction of general endotracheal anesthesia, the patient is positioned in low lithotomy position with the lower extremities extended on stirrups with knees flexed 20 to 30 degrees. Alternatively, a split-leg table may be used.
- To avoid sliding as a consequence of the steep reverse Trendelenburg position used during the entire procedure, a beanbag is inflated to create a "saddle" under the perineum.
- Because increased abdominal pressure from pneumoperitoneum and the steep reverse Trendelenburg position decrease venous return, pneumatic compression stockings are always used as prophylaxis against deep venous thrombosis.
- An orogastric tube is placed to keep the stomach decompressed during the procedure.
- A Foley catheter is inserted at the beginning of the operation and removed at the end.
- The surgeon stands between the patient's legs. The first and second assistants stand on the right and left side of operative table (**FIG 3**).

FIG 3 ● Position of the patient and surgical team in the operating room.

PLACEMENT OF PORTS

- Five 10-mm trocars are used for the procedure (**FIG 4**).
  - The first incision is made in the midline 14 cm distal to the xiphoid process and a Veress needle is introduced into the peritoneal cavity. The peritoneal cavity is initially insufflated to a pressure of 15 mmHg. Subsequently, under direct vision, an optical port with a 0-degree scope (**port 1**) is placed. Once this port is placed, the 0-degree scope is replaced with a 30-degree scope and the other trocars are inserted under laparoscopic vision.
- **Port 2** is placed in the left midclavicular line at the same level of port 1. It is used by the assistant for

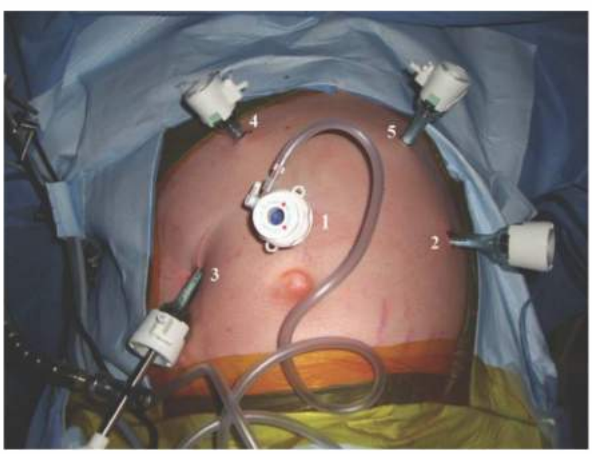

FIG 4 ● Placement of the ports *(1–5)*.

traction on the gastroesophageal junction and to take down the short gastric vessels.
  - **Port 3** is placed in the right midclavicular line at the same level of the other two ports. A retractor is used through this port to lift the left lateral segment of the liver to expose the gastroesophageal junction. The retractor is held in place by a self-retaining system fixed to the operating table.
  - **Ports 4** and **5** are placed under the right and left costal margins so that their axes and the camera form an angle of about 120 degrees. These ports are used by the operating surgeon for the insertion of graspers, scissors, and dissecting and suturing instruments.
- The instrumentation necessary for laparoscopic partial fundoplication is reported in Table 1.

Table 1: Instrumentation for Laparoscopic Partial Fundoplication

Five 10-mm ports
0- and 30-degree scope
Graspers and needle holder
Babcock clamp
L-shaped hook cautery with suction–irrigation capacity
Scissors
Laparoscopic clip applier
Electrothermal bipolar vessel-sealing system
Liver retractor
Suturing device
2-0 silk sutures
Penrose drain
56-Fr esophageal bougie

DISSECTION

- The gastrohepatic ligament is divided, beginning the dissection above the caudate lobe of the liver, where the ligament is thinner, and continuing toward the diaphragm until the right pillar of the crus is identified (**FIG 5**).
- The right pillar of the crus is separated from the esophagus by blunt dissection until the left crus is recognized and the posterior vagus nerve is identified (**FIG 6**).
- Subsequently, the peritoneum and the phrenoesophageal membrane overlying the esophagus are divided, and the anterior vagus nerve is identified.
- The left pillar of the crus is then separated from the esophagus and dissected toward the junction with the right pillar of the crus (**FIG 7**).

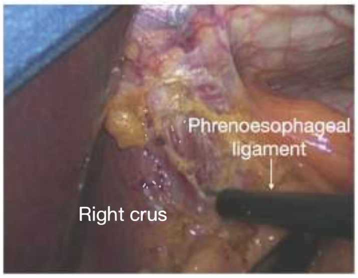

FIG 6 ● Dissection of the right pillar of the crus.

FIG 7 ● Dissection of the left pillar of the crus.

FIG 5 ● Gastrohepatic ligament division.

DIVISION OF THE SHORT GASTRIC VESSELS

- The short gastric vessels are taken down all the way to the left pillar of the crus, starting from a point midway along the greater curvature of the stomach (**FIG 8**).[8]

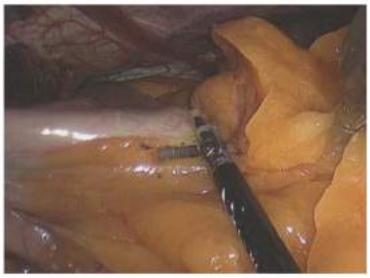

FIG 8 ● Division of short gastric vessels.

CREATION OF A WINDOW AND PLACEMENT OF A PENROSE DRAIN AROUND THE ESOPHAGUS

- The esophagus is retracted upward with a Babcock clamp applied at the level of the esophagogastric junction.
- A window is opened by a blunt and sharp dissection under the esophagus, between the gastric fundus, the esophagus, and the left pillar of the crus (**FIG 9**).
- The window is enlarged, and a Penrose drain is passed around the esophagus.
- Any hiatal hernia is completely reduced and a minimum of 3 cm of intraabdominal esophageal length is achieved.

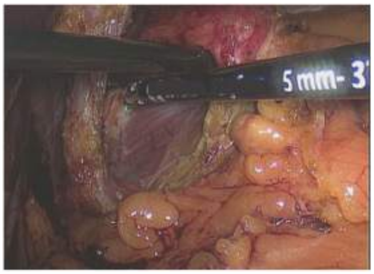

FIG 9 ● Creation of a window between the gastric fundus, the esophagus, and the left pillar of the crus.

CLOSURE OF THE CRURA

- Interrupted 2-0 silk sutures that are tied intracorporeally with an Endo Stitch device (Covidien, Norwalk, CT) are used to close the diaphragmatic crura (**FIG 10a**).
- Retraction of the esophagus upward and toward the patient's left with the Penrose drain provides proper exposure.
- The first stitch should be placed just above the junction of the two pillars.
- Additional stitches are placed 1 cm apart, and a space of about 1 cm is left between the uppermost stitch and the esophagus.

FIG 10 ● Crura closure *(a)*; posterior partial fundoplication *(b)*; two coronal stitches placed between the top of the wrap, the esophagus, and the right or left pillar of the crus *(c)*; and one additional stitch placed between the right side of the wrap and the closed crura *(d)*.

INSERTION OF THE BOUGIE INTO THE ESOPHAGUS AND THROUGH THE ESOPHAGEAL JUNCTION

- The orogastric tube is removed, and a 56-Fr bougie down the esophagus through the esophagogastric junction is inserted.[9]
- The crura must be snug around the esophagus but not too tight: A closed grasper should slide easily between the esophagus and the crura.

PARTIAL FUNDOPLICATION

- *Partial posterior fundoplication*
  - The gastric fundus is gently pulled under the esophagus with two graspers.
  - The right and left sides of the wrap are separately sutured to the esophagus, leaving 80 to 120 degrees of the anterior esophageal wall uncovered.
  - Three 2-0 silk sutures are placed on each side between the muscular layers of the esophageal wall and the gastric fundus (**FIG 10b**).
  - Two coronal stitches are then placed between the top of the wrap, the esophagus, and the right or left pillar of the crus (**FIG 10c**).
  - One additional stitch is placed between the right side of the wrap and the closed crura (**FIG 10d**).

- The resulting wrap measures about 240 to 280 degrees.
- *Partial anterior fundoplication (See Part 1, Chapter 16 for more details.)*
  - It is a 180-degree anterior fundoplication.
  - Two rows of sutures (2-0 silk) are used. The first row is on the left side of the esophagus and has three stitches. The top stitch incorporates the fundus of the stomach, the muscular layer of the left side of the esophagus, and the left pillar of the crus.
  - The second and third stitches incorporate the gastric fundus and the muscular layer of the left side of the esophagus.
  - The fundus is then folded over the esophagus so that the greater curvature of the stomach is next to the right pillar of the crus.
  - The second row of sutures on the right side of the esophagus consists of three stitches between the fundus and the right pillar of the crus.
  - Finally, two additional stitches are placed between the fundus and the rim of the esophageal hiatus to eliminate any tension from the fundoplication.

PEARLS AND PITFALLS

Indications	■ A careful evaluation, including manometry, 24-hour pH monitoring, upper endoscopy, and barium swallow must be done.
Placement of ports	■ Extreme care must be taken when positioning port 1, because the site of insertion is just above the aorta. ■ We recommend using an optical trocar with a 0-degree scope to obtain access. ■ If port 3 is too low, the left lateral segment of the liver will not be properly retracted, resulting in inadequate exposure of the esophagogastric junction. ■ If port 2 is too low, the esophagogastric junction or the upper short gastric vessels will be difficult to reach. ■ If ports 4 and 5 are too low, the dissection at the beginning of the procedure and the suturing at the end will be challenging. ■ If port 3 is too medial, the liver retractor may interfere with the instrument used through port 4.
Dissection	■ An accessory left hepatic artery originating from the left gastric artery is frequently present in the gastrohepatic ligament. If this vessel limits the exposure, it may be safely divided. ■ The electrocautery should be used with extreme caution. Because of the lateral spread of the monopolar current, vagus nerves may be damaged even without direct contact. A bipolar instrument represents a safer alternative.
Short gastric vessels division	■ Bleeding, either from the short gastric vessels or from the spleen, and damage to the gastric wall are possible complications. ■ Excessive traction and division of a vessel not completely coagulated are usually the main causes of bleeding. ■ A burn caused during dissection of the short gastric vessels or traction applied with the graspers or the Babcock clamp are the most common mechanisms of damage to the gastric wall.
Creation of a window and placement of a Penrose drain around the esophagus	■ Left pneumothorax and perforation of the gastric fundus are two main complications that can occur during this step of the procedure. ■ Left pneumothorax is usually created when the dissection is performed in the mediastinum above the left pillar of the crus rather than between the crus and the gastric fundus. ■ Proper identification and dissection of the left pillar of the crus are crucial. ■ Perforation of the gastric fundus is usually caused by pushing a blunt instrument under the esophagus or by using monopolar electrocautery for dissection.
Closure of the crura	■ The bougie is not placed inside the esophagus during this step of the procedure in order to have a proper exposure for suturing.
Insertion of the bougie into esophagus and through esophageal junction	■ The most serious complication during this step is an esophageal perforation. ■ Lubrication of the bougie and instruction to the anesthesiologist to advance the bougie slowly and to stop if any resistance is encountered help to prevent this complication. ■ All instruments must be removed from the esophagogastric junction and the Penrose drain must be opened. In this way, the creation of an angle between the stomach and the esophagus, which increases the risk of perforation, is prevented.
Partial fundoplication	■ Atraumatic graspers must be used to reduce the risk of injury to the gastric wall.

POSTOPERATIVE CARE

- Patients are usually discharged after 23 to 48 hours.
- Patients start clear liquids and then a soft diet the morning after surgery.
- They are instructed to avoid meat, bread, and carbonated beverages for the following 2 weeks.
- The time to full recovery ranges between 2 and 3 weeks.

OUTCOMES

- Long-term studies conducted in United States have reported a less effective control of GERD with a partial fundoplication rather than a total fundoplication.[10–12]
- At 5-year follow-up, recurrence of GERD confirmed by pH monitoring is reported in more than 50% of patients after partial fundoplication.[10]

COMPLICATIONS

- Esophageal or gastric perforation can be caused either by traction or by an inadvertent electrocautery burn during any step of the dissection.
- A leak usually manifests itself during the first 48 hours.
- Peritoneal signs will be present if the spillage is limited to the abdomen; shortness of breath and a pleural effusion will be noted if spillage also occurs in the chest.
- The site of the leak must always be confirmed by a contrast study using a water-soluble contrast agent.
- Optimal management consists of a reoperation and direct repair. An esophagectomy may be indicated in case of a too extensive damage or when the extent of the inflammatory reaction makes the direct repair impossible. Wide drainage, feeding jejunostomy tube, and use of a covered esophageal stent may also assist in healing the injury when it cannot be directly repaired.
- Gastroesophageal junction and wrap slippage into the chest rarely occurs when coronal suture is placed and the crura are closed.[8] The main symptoms of recurrence are dysphagia and regurgitation. A barium swallow confirms the diagnosis.
- The incidence of paraesophageal hernia may be increased if the closure of the crura is not performed or if it is too loose.[8]

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Chapter 26

The Minimally Invasive Surgical Approach to Gastroesophageal Reflux Disease

W. Scott Melvin   Luke M. Funk

DEFINITION

- Endoscopic therapies for gastroesophageal reflux disease (GERD) include transoral incisionless fundoplication (TIF) and the application of radiofrequency energy to the lower esophageal sphincter (LES). Minimally invasive LES augmentation surgery involves the placement of a magnetic band across the LES. All three therapies are designed to reduce GERD symptoms by minimizing the reflux of gastric contents into the esophagus and are alternatives to traditional surgical fundoplication techniques.

DIFFERENTIAL DIAGNOSIS

- Typical GERD symptoms
  - Achalasia
  - Biliary colic/cholecystitis
  - Delayed gastric emptying
  - Esophageal cancer, esophagitis, esophageal motility disorders
  - Gastritis
  - Hiatal hernia
  - *Helicobacter pylori* infection
  - Irritable bowel syndrome
- Atypical GERD symptoms
  - Coronary artery disease
  - Asthma
  - Bronchogenic carcinoma

PATIENT HISTORY AND PHYSICAL FINDINGS

- History taking should focus on identifying both typical and atypical symptoms associated with GERD.
  - Typical symptoms include heartburn, regurgitation, water brash (salty taste related to salivary secretion), and dysphagia.
  - Atypical symptoms include dyspnea, cough, wheezing, chest pain, recurrent pneumonias, hoarseness, and dental erosions.
- Response to antireflux medications, such as proton pump inhibitors and H_2 blockers is important to illicit, as the majority of patients with typical GERD symptoms will respond to these medications. Failure to respond to these medications should heighten the surgeon's concern that the patient's symptoms may be unrelated to GERD.
- Once the diagnosis of GERD is confirmed with objective testing, several key points should be discussed with the patient:
  - Medical therapy, including lifestyle modifications (i.e., diet modification, weight loss, smoking cessation) and antireflux medications, should control typical GERD symptoms for most patients. Surgical intervention is indicated for GERD patients who (1) cannot take antireflux medications due to side effects, (2) would prefer not to take antireflux medications due to cost or lifestyle impact, or (3) continue to experience symptoms despite antireflux medications.
  - Laparoscopic gastric fundoplication (i.e., Nissen fundoplication) is considered to be the gold standard surgical therapy for the treatment of GERD. Endoscopic therapies and laparoscopic LES augmentation surgery should probably be reserved for GERD patients who are candidates for surgical intervention and (1) would prefer a less invasive option than laparoscopic fundoplication surgery or (2) would be considered too high risk for laparoscopic fundoplication due to comorbidities or previous abdominal surgery, including prior laparoscopic fundoplication.
- Of the three procedures discussed in this chapter, laparoscopic LES augmentation surgery is the only one that requires general anesthesia, although TIF also involves general anesthesia in the vast majority of cases. Conscious sedation is usually adequate for radiofrequency therapy. Thus, poor candidates for general anesthesia (i.e., those with cardiopulmonary conditions such as severe chronic obstructive pulmonary disease [COPD] or congestive heart failure [CHF]) may be better candidates for radiofrequency therapy. The presence of these comorbid conditions should be sought out in the history. Additional contraindications for these procedures are listed in Table 1.
- Because there are few physical exam findings associated with GERD, the physical exam should focus on conditions that might suggest an alternative explanation for the

Table 1: Contraindications for Undergoing Treatment

For all three procedures
Barrett's esophagus
Dysphagia (i.e., multiple times per week)
Esophageal dysmotility, strictures, varices
Esophagitis (grade C or D esophagitis according to the Los Angeles classification)
Hiatal hernia (>2–3 cm)
Obesity (BMI >35)
Specific to transoral incisionless fundoplication
Inability to tolerate general anesthesia
Specific to laparoscopic LES augmentation surgery
Inability to tolerate general anesthesia
Titanium, stainless steel, nickel, or ferrous allergy
Patients who may need to undergo an MRI (LINX considered not safe for MRI)

BMI, body mass index; LES, lower esophageal sphincter; MRI, magnetic resonance imaging.

patient's symptoms. These include recent weight loss or progressive inability to tolerate solids and liquids (malignancy), atypical symptoms associated with exertion (coronary artery disease or asthma), or diarrhea (irritable bowel syndrome).

- The presence of abdominal surgical scars or abdominal wall hernias is important to identify if laparoscopic LES augmentation surgery is being considered as they may make access to the peritoneal cavity and the gastroesophageal (GE) junction challenging.
- Laparoscopic LES augmentation surgery, which involves placement of a magnetic device around the GE junction, is considered not safe for magnetic resonance imaging (MRI). Patients should be aware of this contraindication prior to surgery.

IMAGING AND OTHER DIAGNOSTIC STUDIES

- Establishing GERD as the etiology of the patient's symptoms is critical before proceeding with any intervention. Patients may have subjective complaints of heartburn or dysphagia that are unrelated to their reflux disease. The four diagnostic tests that are most commonly used to establish a diagnosis are upper endoscopy, barium esophagram, pH testing, and manometry.
- Upper endoscopy (esophagogastroduodenoscopy [EGD])
  - All patients undergoing an antireflux procedure should have an EGD.
  - EGDs can identify the presence of hiatal hernias and rule out other pathology, which may be contributing to the patient's symptoms, such as peptic ulcer disease or malignancy.
  - GERD-related complications such as esophagitis, Barrett's esophagus, and esophageal strictures can also be identified (**FIG 1**).
- Ambulatory pH testing
  - This is considered to be the gold standard test for diagnosing the presence of symptomatic GERD.
  - Patients should typically not be taking their antireflux medications when the study is performed.
  - pH testing can be performed via catheter-based systems (i.e., 24-hour pH probe testing) or wireless systems (i.e., 48-hour Bravo testing).
  - Both catheter-based and wireless systems allow for the quantification of six variables including total/upright/supine time that the pH is less than 4, number of reflux episodes, number of episodes longer than 5 minutes, and longest episode. These variables can be combined to calculate the "DeMeester score," which is used by many surgeons as definitive evidence for the presence of GERD.[1]
- Barium esophagram
  - This is a dynamic fluoroscopic study that characterizes both anatomic and functional aspects of the esophagus. It involves multiple swallows of barium and barium-coated solid food.
  - The two most important things to characterize with a barium esophagram are the position of the GE junction relative to the diaphragmatic hiatus and overall esophageal motility. The presence of a large hiatal hernia (**FIG 2**) or significant esophageal dysmotility is a contraindication for any of the three procedures.[2]
  - Esophagrams can also identify the presence of reflux that is characterized by the spontaneous reflux of barium back into the esophagus. However, they are less sensitive than pH studies and thus a negative finding here does not rule out GERD.
  - Video recording of this study is crucial because it allows the surgeon to actively assess esophageal peristalsis and the functional significance of hiatal hernias.
- Manometry
  - Esophageal manometry uses pressure transducers within a transnasal catheter to provide data regarding the LES resting pressure, LES abdominal and total length, and adequacy of LES relaxation. It also characterizes esophageal motility by quantifying the amplitude, duration, and propagation of each contraction.
  - The presence of significant esophageal dysmotility is a contraindication for all three procedures.
- Multichannel impedance testing and gastric emptying studies are also used on occasion to identify nonacidic GERD and assess gastric functionality, respectively.

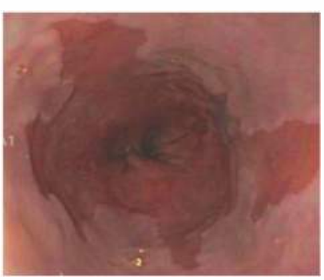


FIG 1 ● The presence of Barrett's esophagus is a contraindication to TIF, radiofrequency energy application, and laparoscopic LES augmentation surgery.

FIG 2 ● A lateral view of a barium esophagram. A large hiatal hernia is present with a significant portion of the stomach herniated into the chest. A small distal esophageal diverticulum is seen. All three procedures would be contraindicated in the presence of this hernia.

TRANSORAL INCISIONLESS FUNDOPLICATION

- Approved by the U.S. Food and Drug Administration (FDA) in 2007, the only TIF device that is currently available for use in the United States is the EsophyX device (EndoGastric Solutions, Redmond, WA).
- EsophyX re-creates the LES by plicating the distal esophagus and the gastric cardia together, thus creating an antireflux valve similar to that of a laparoscopic Nissen fundoplication.
- The device consists of a handle, an 18-mm diameter shaft, a tissue invaginator composed of holes in the side of the device (which are connected to a suction device), an articulating arm, which approximates gastric and esophageal tissue and deploys the tissue fasteners, a helical screw, two stylets, and 20 polypropylene H-fasteners (10 plication sets) (**FIG 3**).

Preoperative Planning

- At our institution, general anesthesia is administered and the procedure is performed in the operating room.
- Nasotracheal intubation is performed so the oropharynx can be used entirely for the EsophyX device. A bite block is placed to protect the teeth from the device and scope.
- Two physicians perform the procedure. One manipulates the endoscope while the other controls the device.

Positioning

- After intubation, the patient is placed into the left lateral decubitus position with the head elevated slightly (**FIG 4**).

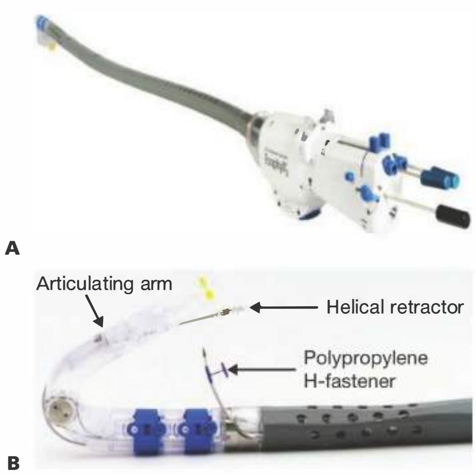


FIG 3 ● **A.** EsophyX device with the articulating arm fully extended. **B.** Articulating arm is flexed with the H fasteners visible between the shaft and the distal end of the articulating arm. The helical retractor is visible as well (images © 2015 EndoGastric Solutions, Inc).

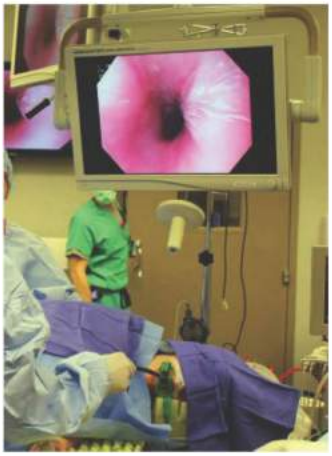


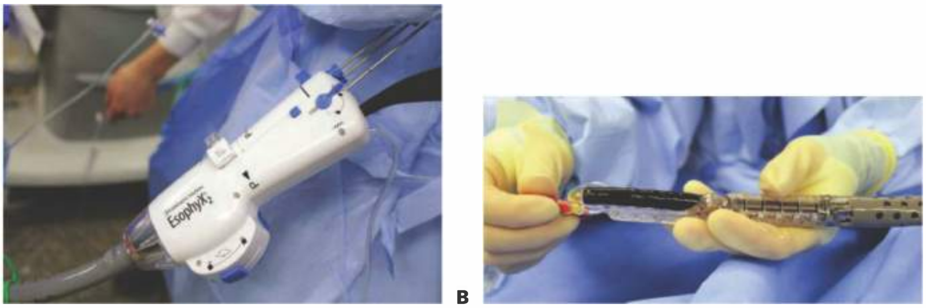
FIG 4 ● With the patient in the left lateral decubitus position and a nasotracheal tube present, a bite block is placed to facilitate passage of the endoscope and subsequently the EsophyX device.

- Prophylactic antibiotics are administered before the procedure begins because transluminal fasteners are placed, which may increase the risk of postoperative infections.

Placement of the Transoral Incisionless Fundoplication Device into the Stomach

- Preprocedure endoscopy is performed to verify anatomic landmarks.
- A 56-Fr bougie is inserted into the esophagus and then removed to facilitate subsequent passage of the EsophyX device (**FIG 5**).
- The EsophyX device is lubricated and a standard endoscope is threaded through the device (**FIG 6**). Both are placed through a bite block and advanced through the esophagus into the stomach.
- The scope is advanced into the gastric lumen and then retroflexed to examine the GE junction. Using a standard, high-flow insufflator, the stomach is insufflated with

FIG 5 ● Passage of a large Bougie after diagnostic endoscopy facilitates advancement of the EsophyX device into the stomach and minimizes the likelihood of esophageal injury during passage of the device.



A B

FIG 6 ● **A.** The endoscope is passed through the handle of the EsophyX device and can be seen exiting the distal end of the device **(B)**. The articulating arm is fully extended in this image. Once the scope and device are advanced into the stomach, the scope is withdrawn into the body of the device and the articulating arm is flexed. The scope is advanced back into the stomach and retroflexed to obtain a view of the GE junction.

carbon dioxide to a pressure of 15 mmHg via the working channel of the endoscope. Once the articulating arm is visualized within the stomach, the scope is withdrawn into the device, the articulating arm is flexed, and the scope is then advanced back into the retroflexed position within the gastric lumen (**FIG 7**).

- Using the retroflexed view, the GE junction is envisioned as a clock face with the 12 o'clock position located at the lesser curvature, the 6 o'clock position at the greater curvature, and the 9 o'clock position located along the posterior gastric wall (**FIG 8**).[3]

Anterior Rotational Plication Fasteners

- The closed articulating arm is placed at the 12 o'clock position (**FIG 9A**). The helix retractor portion of the device is also at the 12 o'clock position and advanced into the squamocolumnar junction (**FIG 9B**). The entire device is then advanced distally a couple of centimeters and rotated clockwise on the screen. This allows the articulating arm to be opened and the helical retractor disengaged from the articulating arm.
- The articulating arm is then rotated back to the 6 o'clock position, partially closed, and pulled back 1 to 2 cm (**FIG 9C**). The GE junction is advanced caudally by applying tension to the helical retractor.
- The stomach is then desufflated and the articulating arm is rotated toward the 1 o'clock position. This maneuver rotates the fundus anteriorly around the esophagus thereby initiating the fundoplication. Externally, the handle of the device is rotated approximately 180 degrees (**FIG 10**). This has been described in the literature as the "Bell Roll maneuver."[3]
- The helical retractor and articulating arm are secured in place and the suction is applied.

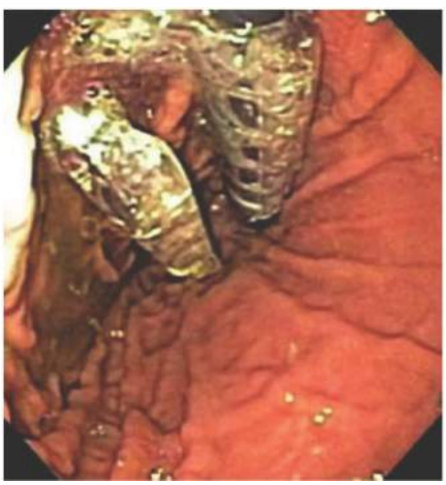
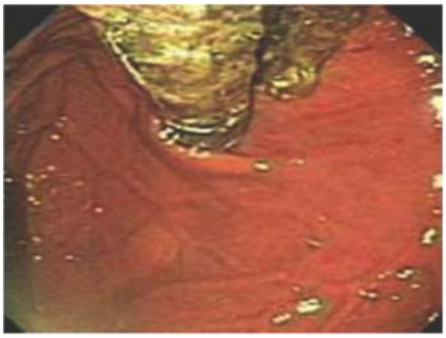


FIG 7 ● The articulating arm of the device is flexed within the gastric lumen. The arm will subsequently be rotated into the 12 o'clock position at the lesser curve to facilitate placement of the helix retractor.

FIG 8 ● Using a clock face to describe the anatomy of the GE junction in a retroflexed view, the lesser curvature is at 12 o'clock while the greater curvature is a 6 o'clock.



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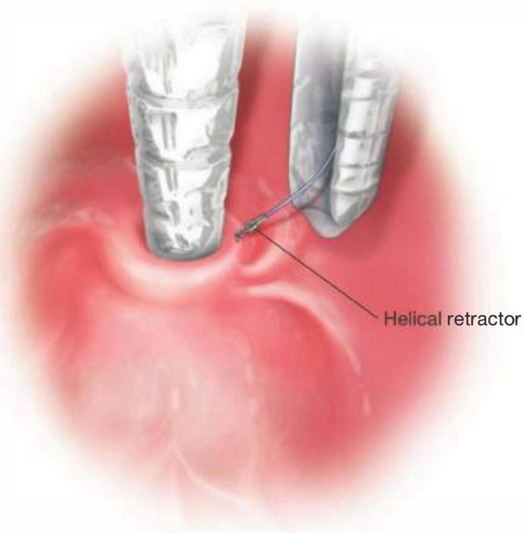

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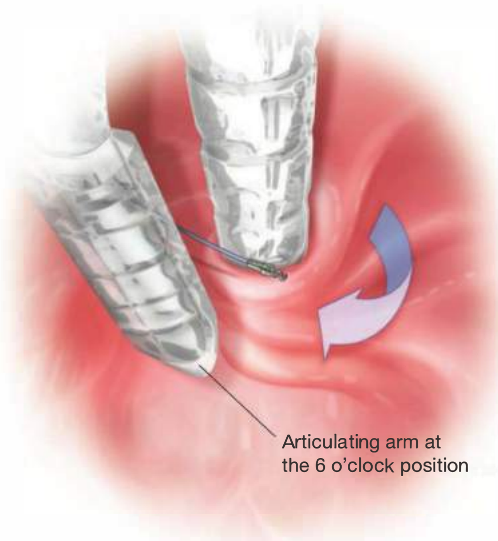


C

FIG 9 ● **A.** With the articulating arm at 12 o'clock, the helix retractor is placed into the squamocolumnar junction. **B.** The helix retractor can be seen as a thin, horizontally oriented wire entering the gastric lumen. The device is then advanced distally into the stomach and rotated clockwise on the screen so that the articulating arm is at 6 o'clock **(C)**.

FIG 10 ● The articulating arm is rotated counterclockwise back toward the 1 o'clock position (the tip is thus not visible in this view). The fundus is thus anteriorly rotated around the esophagus. This completes the anterior portion of the fundoplication.

- The first H-fastener set is then deployed.
- The stomach is then reinsufflated to visualize deployment of a pair of H fasteners. Two sets of additional H fasteners are subsequently placed at varying distances from the GE junction.
- This will result in the placement of six fasteners 1 to 3 cm above the squamocolumnar junction.

Posterior Rotational Plication Fasteners

- The helix retractor portion of the device is maintained at the 12 o'clock position.
- The articulating arm is rotated counterclockwise through the lesser curve to the 8 o'clock position, partially closed, and pulled back 1 to 2 cm. The GE junction is advanced caudally by applying tension to the helical retractor.
- The "Bell Roll" maneuver is again performed, but this time in the clockwise direction (clockwise on the screen).

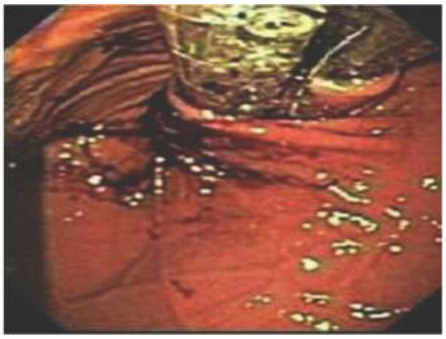


FIG 11 ● To perform the posterior component of the fundoplication, the articulating arm is rotated clockwise to the 11 o'clock position. This maneuver is a mirror image of the maneuver used to create the anterior component of the fundoplication.

The stomach is desufflated and the articulating arm is rotated clockwise to the 11 o'clock position. This maneuver rotates the fundus posteriorly around the esophagus (FIG 11).

- The first set of posterior rotational plication fasteners is then deployed.
- The process is then repeated to place two additional sets of H fasteners at varying distances from the GE junction.

Anterior Corner Longitudinal Plication

- To address a gap in the anterior component of the plication that is often appreciated only after the anterior and posterior sets have been placed, an anterior corner plication set is often placed.
- The articulating arm is rotated counterclockwise through the lesser curve toward the 1 o'clock position.
- Tension is applied to the helical retractor caudally and the approximating arm is pulled proximally while desufflating the stomach.
- Two additional sets of H-fasteners are deployed around the 1 o'clock position.

Greater Curve Deep Plication

- The purpose of this maneuver is to fixate the greater curvature slightly more proximally on the esophagus. This lengthens the antireflux valve.
- The helix retractor is disengaged from the 12 o'clock position and re-engaged at the squamocolumnar junction at the 6 o'clock position.
- The reticulating arm is moved into the 5 o'clock position and one or two sets of fasteners are 2 to 4 cm proximal to the squamocolumnar junction (FIG 12).
- The newly constructed antireflux valve should be 200 to 300 degrees in circumference.

Inspection of the Newly Created Antireflux Valve

- The device and endoscope are withdrawn together and then endoscope is removed from the EsophyX device.
- The endoscope is then advanced back into the stomach to allow inspection of the antireflux valve and to assess for any bleeding or injuries to the esophagus and stomach. The fasteners are visualized in the distal esophagus (FIG 13).
- The fundoplication created by the EsophyX device should have a similar endoscopic appearance as one created by a laparoscopic Nissen fundoplication.

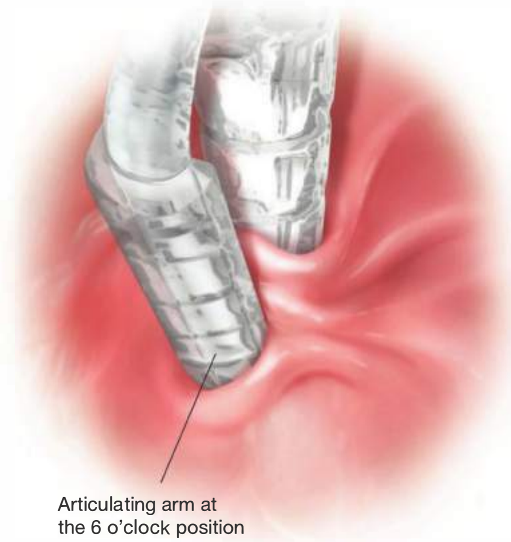


FIG 12 ● The shaft of the device has been pulled back into the esophagus 3 to 4 cm. This allows placement of the greater curve plication sutures with the articulating arm near the 6 o'clock position. This move adds length to the antireflux valve.

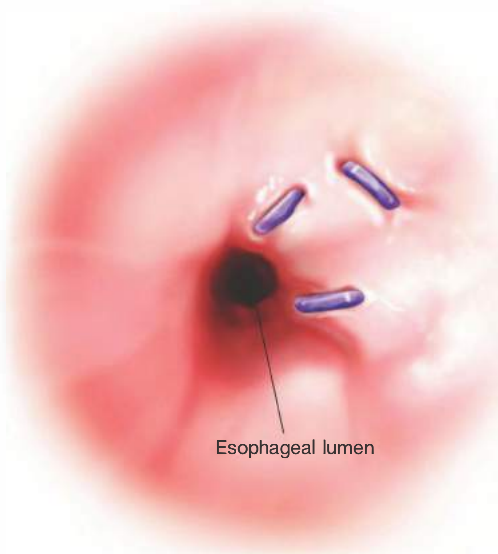


FIG 13 ● Multiple purple polypropylene fasteners are visualized with the distal esophagus after TIF is completed. These fasteners are not typically seen when retroflexing from within the stomach.

RADIOFREQUENCY ENERGY APPLICATION TO THE LOWER ESOPHAGEAL SPHINCTER

- Approved by the FDA in 2000, the Stretta system (Mederi Therapeutics Inc, Greenwich, CT) is currently the only device on the market that uses radiofrequency energy for the treatment of GERD.[4]
- The application of radiofrequency energy to the GE junction results in thermal injury and subsequent scarring, which reduces LES compliance, decreases the number of transient LES relaxations, and thereby decreases the incidence of reflux symptoms.
- The Stretta system is composed of two main components: a radiofrequency generator and a catheter system that connects to the generator. The catheter system is composed of an outer sheath, a 30-Fr bougie tip, and four nickel-titanium 22-gauge needle electrodes surrounding a balloon. The system also includes a channel for suction and another for irrigation (**FIG 14**).

A

B

FIG 14 ● **A.** Schematic representation of the Stretta catheter system. The distal end is composed of a 30-Fr bougie tip. The nickel-titanium needle electrodes can be seen pointing outward surrounding the balloon. **B.** Radiofrequency generator (images © 2015 Mederi Therapeutics Inc).

Preoperative Planning

- Conscious sedation is usually adequate for use of the Stretta system. At our institution, Stretta is usually performed in the endoscopy suite as opposed to the operating room.
- Only one physician is typically needed to perform the procedure.

Positioning

- After administration of conscious sedation medications, the patient is placed into the left lateral decubitus position and a bite block is placed.

Placement of the Stretta Device into the Distal Esophagus

- A standard endoscope is advanced down to the GE junction. The distance from the patient's lips to the squamocolumnar junction is measured.
- A guidewire is inserted through the working channel of the endoscope and the endoscope is removed.
- Under fluoroscopic guidance, the catheter system is then passed over the guidewire into the stomach. The catheter tip is then positioned 1 cm above the squamocolumnar junction based on measurements obtained from the endoscopic evaluation.

Application of Radiofrequency Energy

- The balloon is inflated to a pressure of 2 lb/in^2.
- The electrodes are then deployed through the mucosa and into the muscularis propria. Suction and irrigation are initiated through their respective working channels.
- The generator is activated and radiofrequency energy is applied for approximately 90 seconds per application. During this process, the muscularis propria is heated to a temperature of 85°C, whereas the esophageal mucosa is maintained below 50°C via cold water that is instilled through the catheter system. This creates four ablation sites that are distributed 90 degrees apart from each other.
- After the 90-second interval is complete, the catheter system is rotated 45 degrees and another cycle of radiofrequency energy is delivered for 90 seconds. Following this cycle, eight lesions approximately 45 degrees apart are created in a circumferential fashion at that level.
- The catheter system is advanced approximately 5 mm and the process is repeated to create another 8 sites of ablation. In total, this process is performed at six levels (from 1 cm proximal to the squamocolumnar junction to the proximal gastric cardia), creating 48 ablation sites (**FIG 15**).
- The Stretta system is then removed.

Inspection of the Gastroesophageal Junction

- The endoscope is advanced back down to the GE junction to allow inspection of the radiofrequency energy application site (**FIG 16**).

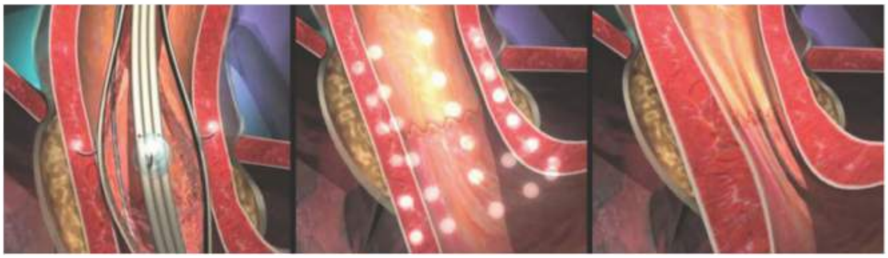


FIG 15 ● Coronal section through the esophagus with the electrodes positioned 1 cm proximal to the squamocolumnar junction. Two electrodes can be seen entering the muscularis propria. After the tissue has been ablated at six levels (indicated by white), the GE junction will eventually scar down as a result of the thermal injury (images © 2015 Mederi Therapeutics Inc).

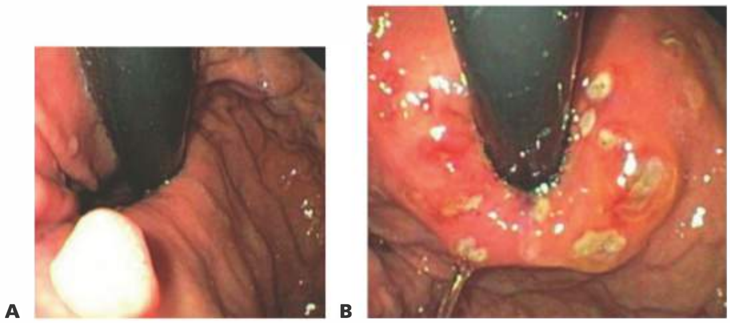


FIG 16 ● Retroflexed views of the GE junction immediately before **(A)** and after **(B)** use of the Stretta device.

LOWER ESOPHAGEAL SPHINCTER AUGMENTATION SURGERY

- The only commercially available laparoscopic LES augmentation device in the United States is the LINX Reflux Management System (Torax Medical, St. Paul, MN). The LINX system is designed to decrease reflux of gastric contents into the distal esophagus via placement of a flexible, expandable device consisting of multiple interlinked titanium beads with a magnetic core (**FIG 17**).
- When placed around the GE junction, it enhances the ability of the LES to resist opening and prevent reflux into the esophagus.
- With the device in place, once a patient swallows and esophageal peristalsis reaches the GE junction, the pressure of the peristalsis overcomes the magnetic field within the LINX device thereby allowing the device to open and food to enter into the stomach. The magnetic beads can also separate when intragastric pressure exceeds the magnetic strength of the beads, which allows the patient to belch or vomit if/when necessary.

Preoperative Planning

- General anesthesia is necessary.
- Preoperative prophylactic antibiotics are administered prior to incision to reduce the chance of infection.

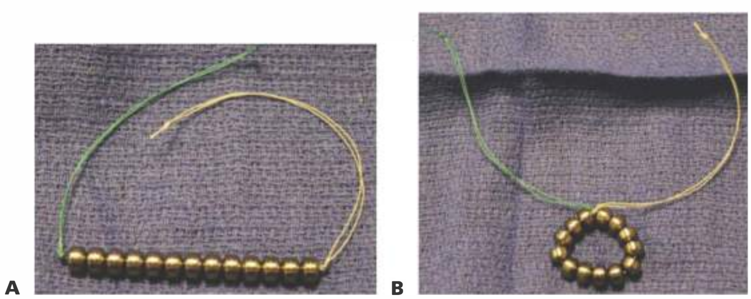


FIG 17 ● **A.** LINX device fully open with sutures at each end. **B.** Magnetic beads at each end are brought together. This is the configuration that the device is in when placed around the GE junction.

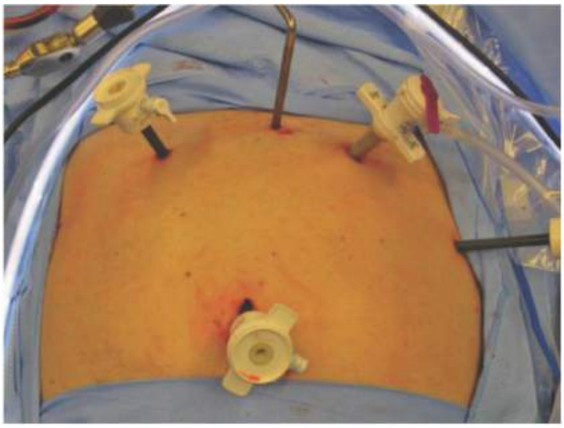


FIG 18 ● A 5-mm supraumbilical port, 8-mm left upper quadrant port, 5-mm left upper outer quadrant port, and 5-mm right upper quadrant port are placed. A bladed 5-mm subxiphoid port is temporarily placed to facilitate insertion of a liver retractor. The surgeon stands between the patient's legs and uses the 5-mm right upper quadrant port and 8-mm port. The assistant on the patient's left controls the camera and retracts the stomach inferiorly via the 5-mm right upper outer quadrant port.

Positioning

- The patient can be placed into either the supine or split-leg position on the operating room table.

Port Placement and Initial Dissection

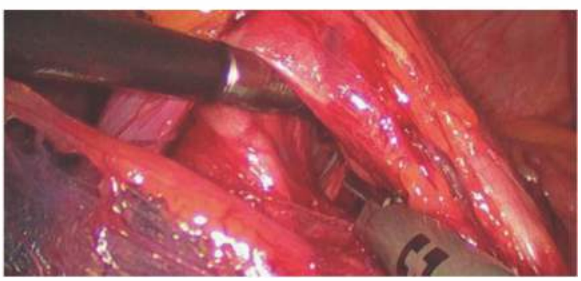
- Our technique involves initial placement of a Veress needle in the left upper quadrant. Four ports are subsequently placed including a 5-mm supraumbilical port, 8-mm left upper quadrant port, 5-mm left upper outer quadrant port, and 5-mm right upper quadrant port. A 5-mm port is temporarily placed in the subxiphoid position to facilitate placement of a liver retractor (**FIG 18**).
- A 5-mm camera is inserted through the supraumbilical port, which is operated by an assistant surgeon standing on the patient's left. The operating surgeon stands between the patient's legs and uses the 5-mm right upper quadrant port and the 8-mm port. The operating surgeon uses a blunt grasper (left hand) and an ultrasonic dissector (right hand) to enter the lesser sac via the pars flaccida. The left upper outer 5-mm port is used by the assistant surgeon to retract the stomach downward and laterally toward the spleen to facilitate dissection of the GE junction.

Dissection of Gastroesophageal Junction

- The medial border of the right crus of the diaphragm is identified to facilitate the dissection of the retroesophageal space (**FIG 19**). The posterior vagal trunk is identified and preserved. The medial border of the left crus is then identified from the patient's left to further open the retroesophageal space.
- The blunt grasper in the surgeon's left hand is then passed through the retroesophageal plane between the posterior esophageal wall and the posterior vagal trunk, which is preserved. The tip of the grasper exits the retroesophageal tunnel anterior to the left crus of the diaphragm and is maintained in that location.

Device Selection and Placement

- A Penrose is placed into the upper abdomen and pulled through the retroesophageal tunnel. This serves as a tract for smooth passage of the sizer.
- The sizing instrument is placed into the abdomen through the 5-mm port (surgeon's left hand) and advanced through the retroesophageal plane from the patient's right to left.
- The white portion of the sizing instrument is then tightened around the GE junction cephalad to the hepatic branches of the anterior vagal trunk. As the circumference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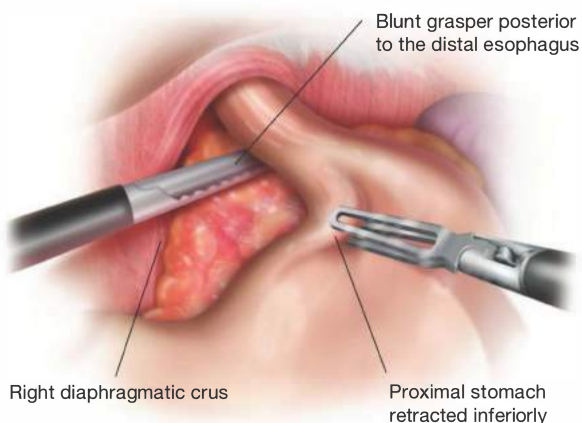

B

FIG 19 ● **A,B.** A blunt grasper in the surgeon's left hand retracts the medial border of the right crus laterally to open up the retroesophageal plane while the proximal stomach is retracted inferiorly and laterally. The vagus nerve has been mobilized away from the esophagus to open up the plane for the sizer to be introduced. (Photo courtesy of Dr. Kyle Perry, The Ohio State University Wexner Medical Center.)

of the sizer approaches that of the GE junction, the appropriate LINX device size will be indicated on the sizing device (**FIG 20**).

- The sizing instrument is removed and the LINX device is inserted through the same plane that the sizer was placed through. The LINX device is then wrapped around the GE junction anteriorly. The sutures at each end of the device are then secured with a Ti-Knot device or securing the magnetic clasp depending on the version of the device employed (**FIG 21**).
- The abdomen is desufflated, the ports are removed, and the skin incisions are sutured closed.

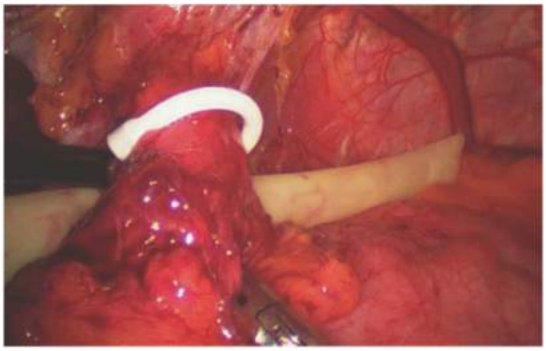

FIG 20 ● With the sizer gently wrapped around the GE junction anteriorly, the appropriate length of the LINX device is estimated and the LINX device is modified so that the length of the device matches this distance. (Photo courtesy of Dr. Kyle Perry, The Ohio State University Wexner Medical Center.)

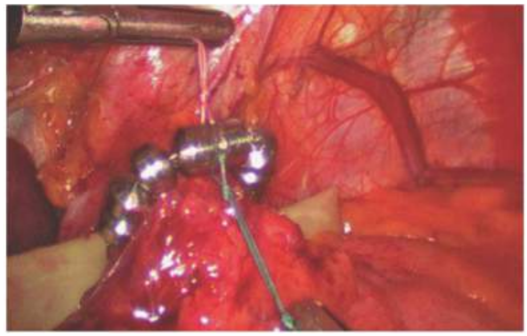

FIG 21 ● The LINX device is in place around the GE junction. The sutures at each are retracted superiorly and inferiorly to illustrate ideal positioning of the device. (Photo courtesy of Dr. Kyle Perry, The Ohio State University Wexner Medical Center.)

PEARLS AND PITFALLS

Pitfall	Pearl
Transoral incisionless fundoplication	
■ Cervical esophageal injury during placement of the device given the relatively large size of the device	■ Dilation of the esophagus with a large bougie (i.e., 56 Fr) and generous application of lubricant to the device will minimize the likelihood of esophageal injury. ■ Nasotracheal intubation will help clear the oropharynx for EsophyX device insertion.
■ Postoperative bleeding due to helix retractor placement or during fastener placement, particularly along the lesser curve of the stomach	■ Minimize the number of times that the helix retractor is deployed (once at the 12 o'clock position and once at the 6 o'clock position should be enough). ■ Minimize fastener placement along the lesser curvature. ■ Postprocedural EGD will identify early bleeding that may occur during these steps; if identified, endoclips can be placed.
■ Gastric or esophageal perforation related to fastener placement	■ Avoid placement of the fasteners through the diaphragmatic crura by ensuring that the fasteners are deployed below the point where the crura cross the esophageal wall. ■ Administer antiemetics aggressively to avoid significant postoperative retching which may pull on the fasteners.
Radiofrequency energy application	
■ Imprecise radiofrequency energy application due to patient movement during the procedure	■ Adequate amounts of anxiolytic and narcotic medications will help minimize patient movement; if necessary, general anesthesia can be administered.
■ Overdistention of the stomach from excess irrigation fluid	■ Monitor the suction return closely to prevent the stomach from filling up with irrigant; there should be essentially a 1:1 correlation between irrigation and suction fluid.
■ Uneven energy application via the four-needle electrodes due to asymmetry of the GE junction (i.e., if a small hiatal hernia is present)	■ More than two device rotations per level may be necessary to ensure that the radiofrequency energy is applied at numerous points throughout the circumference of the esophagus.

Lower esophageal augmentation surgery	
■ Esophageal injury while developing the retroesophageal plane.	■ Minimize the use of the ultrasonic dissector near the esophagus. ■ To minimize bleeding near the posterior vagal trunk, which may obscure the retroesophageal plane, carefully and bluntly dissect with a Maryland or blunt grasper.
■ Postoperative dysphagia due to excessive restriction from the device	■ Ensure that there is no tension on the sizer when measuring the circumference around the GE junction.
■ Device migration	■ When developing the retroesophageal plane, minimize the amount of dissection posterior to the GE junction. The dissection only needs to be wide enough to permit passage of the sizer.

POSTOPERATIVE CARE

- TIF—Patients are admitted postoperatively for overnight observation. A liquid diet is initiated following the procedure and advanced to a soft solid diet within the next several weeks. Antiemetics are administered liberally to minimize postoperative retching. Routine postoperative imaging is not obtained.
- Radiofrequency energy application—Patients are discharged home on the day of the procedure. They are kept on a liquid diet for the first several weeks and are subsequently advanced to a soft solid diet. Routine postoperative imaging is not obtained.
- LES augmentation surgery—Patients are admitted to the hospital overnight. During our early experience, as part of a clinical trial, all patients underwent a routine chest x-ray and barium esophagram to verify correct position of the device. Routine imaging is not currently obtained. The patient may resume a normal diet immediately after the procedure.

OUTCOMES

- TIF—With the earliest case series being published in 2008,[5] truly long-term data regarding TIF are lacking. In 2012, Trad and colleagues[6] published their data which involved 28 patients and a median follow-up of 14 months. Eighty-two percent of patients remained off their daily antireflux medications, whereas 68% were satisfied with the results of the procedure.[6] Heartburn and regurgitation symptoms were eliminated in 65% and 80% of patients, respectively.
- Radiofrequency energy application—In the earliest multicenter trial conducted in the United States (involving 47 patients), 87% of patients had discontinued their antireflux medications at 6 months while quality of life improved and esophageal exposure to acid (pH <4.0) decreased by over 50% (11.7% to 4.8% of the total time).[7] Four-year follow-up data from a study published in 2007 found that, along with sustained improvements in quality of life scores, 85% of patients remained off proton pump inhibitors or had decreased their use by half.[8]
- Lower esophageal augmentation surgery—In February 2013, the results of a nonrandomized multicenter trial were published in the *New England Journal of Medicine*.[9] Sixty-four percent of patients had either normalized or significantly reduced their esophageal acid exposure at 1 year. Ninety-three percent of patients had significantly reduced their antireflux medication regimen, whereas 92% experienced a substantial improvement in quality of life.

COMPLICATIONS

- TIF
  - Esophageal laceration/perforation
  - Postoperative bleeding
  - Gastric leak, mediastinal abscess
  - Early fundoplication failure
- Radiofrequency energy application
  - Bloating, dyspepsia
  - Esophageal ulceration/bleeding
  - Esophageal perforation
- LES augmentation surgery
  - Bloating, dysphagia
  - Device migration and/or erosion into the GI tract (to date, none have been reported or published in the literature)
  - Allergic reaction to the device (patients with titanium, stainless steel, nickel, or ferrous allergies)

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Chapter 27

Radiofrequency Ablation of Barrett's Esophagus

Shajan Peter C. Mel Wilcox Klaus Mönkemüller

DEFINITION

- Barrett's esophagus (BE) is an acquired condition due to a change in the normal esophageal squamous epithelium to columnar epithelium containing goblet cells. This metaplastic change can progress to low-grade dysplasia (LGD) and high-grade dysplasia (HGD), with the latter having a 5% to 10% risk of developing into esophageal adenocarcinoma.[1,2]
- Radiofrequency ablation (RFA) is a safe and effective endoscopic treatment modality for BE whereby squamous tissue replaces the ablated metaplastic or dysplastic epithelium. RFA uses a bipolar electrode array to generate thermal energy to result in tissue dissipation.[3]

PATIENT HISTORY AND PHYSICAL FINDINGS

- It might be difficult to distinguish symptoms of BE from gastroesophageal reflux disease (GERD) clinically, although increased duration, severity, and early age of onset for reflux symptoms as well as obesity predispose to BE occurrence.[4]
- Age older than 55 years, male gender, white ethnicity, or smokers are predisposing factors for BE development and progression to dysplasia. Genetic influences may play a role, although only a small proportion (7%) of patients with BE have a documented family history of BE or esophageal cancer.[5]
- Selection of patients for endoscopic treatment of BE requires a multidisciplinary approach consisting of the endoscopist, pathologist, and the surgeon.
- Confirmation of dysplasia (high or low grade) on biopsies or endoscopic mucosal resection (EMR) specimens is done by a dedicated gastrointestinal (GI) pathologist.[6]

IMAGING AND OTHER DIAGNOSTIC STUDIES

- Detailed endoscopic examination with high-definition white light of the BE segment is essential for management.
- The extent of the BE segment should be defined using the Prague C & M classification including the length of the circumferential segment (C) and the maximal extent of the BE segment (M)[7] (**FIG 1**).

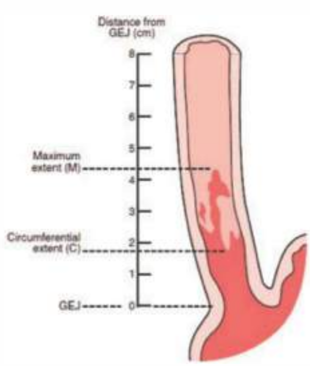


FIG 1 ● Prague C & M classification.

- Other imaging modalities that might help in delineating BE are narrow band imaging (NBI), chromoendoscopy, autofluorescence imaging, and confocal laser endoscopy. These adjuncts aid in directed biopsies.
- Any visible lesions in the Barrett's segment should be described using the Paris classification.[8]
- Targeted biopsies are obtained from visible abnormalities, followed by four-quadrant biopsies of every 1 to 2 cm of the BE segment (Seattle protocol) and these should be reviewed by a dedicated GI pathologist.[9] Nodular lesions are best staged by an EMR as described in Part 1, Chapter 28.

ENDOSCOPIC MANAGEMENT

Preoperative Planning

- Patients are given standard esophagogastroduodenoscopy (EGD) preprocedure preparation instructions with specific attention to factors that increase risk of sedation including morbidly obese patients; anatomic variants such as short neck, cervical osteophytes, cricopharyngeal hypertrophy; and prior history of surgery involving the GI tract, radiation, or documentation of previous strictures.
- No antibiotics are required and it is desirable to minimize or stop antiplatelet/anticoagulation prior to the procedure.
- Equipment lists for circumferential and focal ablation can be found in Tables 1 and 2.

Positioning

- The patient is placed in the left lateral decubitus position and prepared as for a routine upper endoscopy.

Table 1: Circumferential Ablation Equipment List
Endoscope and equipment
RFA energy generator console
HALO^{360} sizing balloon
HALO^{360} balloon ablation catheter
HALO cap
Gauze
1% N-acetylcysteine solution
Spray catheter
Savary spring-tipped guidewire

From Frantz DJ, Dellon ES, Shaheen NJ. Radiofrequency ablation of Barrett's esophagus. Techniques Gastrointest Endosc. *2010;12:100–107.*

Table 2: Focal Ablation Equipment List
Endoscope and equipment
RFA energy generator
HALO^{90} ablation device
Gauze
1% N-acetylcysteine solution
Spray catheter

From Frantz DJ, Dellon ES, Shaheen NJ. Radiofrequency ablation of Barrett's esophagus. Techniques Gastrointest Endosc. *2010;12:100–107.*

CIRCUMFERENTIAL ABLATION

Endoscopy with Inspection and Recording the Landmarks

- Measurements are taken to map the extent of the BE showing (1) top of intestinal metaplasia (TIM), (2) proximal contiguous area of BE (M), (3) proximal level at which the BE is circumferential, (4) and the top of the gastric folds (TGF) (**FIG 2**).
- Careful inspection should be made to rule out prior ulceration, strictures, previous scarring from EMR or residual nodularity as these may compromise any balloon circumferential ablation. Dilatations should be performed prior to ablation.
- Mucosa is washed with N-acetylcysteine to clear any excess mucus and prepare the tissue for further ablation.
- After adequate inspection and recording landmarks, a guidewire is passed into the gastric antrum and then the endoscope removed.

Sizing

- The sizing balloon is attached to the control unit and then calibrated externally also to rule out any leaks. It is then introduced over the guidewire into the body of the esophagus, placing it 3 cm proximal to the TIM measurement.
- Serial measurements are taken at 1-cm intervals, starting proximally and proceeding distally by inflating the device on the pedal provided. The displayed measurements on the console are then recorded by a technician or nurse. The smallest diameter treatment balloon suggested throughout the sizing is chosen as appropriate ablation catheter.

Selecting Appropriate Ablation Device

- After sizing, the catheter is then removed, keeping the guidewire in place.
- The smallest diameter treatment balloon suggested throughout the sizing is chosen as appropriate ablation catheter and attached to the generator.

First Ablation Pass

- The Barrx™ 360 RFA Balloon Catheter (Covidien, Mansfield, MA) (**FIG 3**), consisting of a 3-cm electrode array encircling a 4-cm long balloon, is then passed over the guidewire into the esophagus (**FIG 4A**). The endoscope is intubated alongside the catheter to visualize the proximal end of the balloon, which is then positioned 1 cm proximal to the TIM.
- The balloon is automatically inflated first and then energy delivered by using the foot pedals attached to the control unit. The uniform energy has a density of 12 J/cm^2 and power of 40 W/cm^2 ablating to a depth of 700 to 1,000 μm over 3 cm of array (**FIG 4B**).
- After a second of ablation, the balloon automatically deflates and the circumferential burn is visible.
- Depending on the length of the segment, an additional 3 cm of circumferential ablation is performed such that there is minimal overlap with the previously ablated segment (**FIG 4C**).

Cleaning Procedure

- The balloon catheter is then removed along with the endoscope, leaving the guidewire in place. Outside the patient, it is inflated and cleaned using damp gauze, removing adherent ablated tissue.
- The treated area is then cleaned of the coagulum using a HALO cap attached to the tip of the endoscope (**FIG 5**). After reintroduction of the endoscope, the coagulum is gently removed using the edge of the cap, debriding proximal to distal in a circumferential manner and thereafter cleaning with saline lavage. The endoscope is removed and then the cap discarded.

Second Ablation Pass

- The cleaned ablation catheter device is then introduced over the guidewire with the endoscope and a second set of ablation is performed as described previously, retreating the area and further coagulating any superficial blood vessels preventing bleeding.

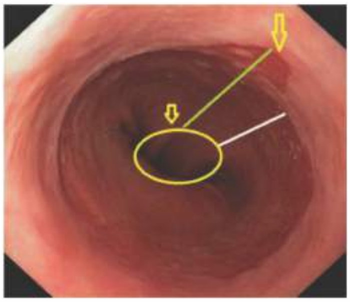


FIG 2 ● Endoscopic appearance of BE. *Yellow oval* indicates top of gastric folds, *green line* to *yellow arrows* indicates maximum length of BE, and *white line* denotes length of circumferential BE.

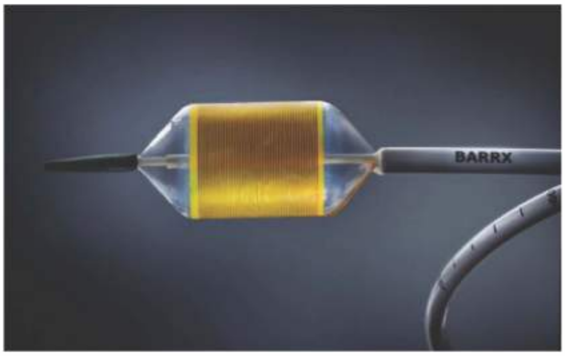


FIG 3 ● Barrx™ 360 RFA Balloon Catheter (© 2014 Covidien).

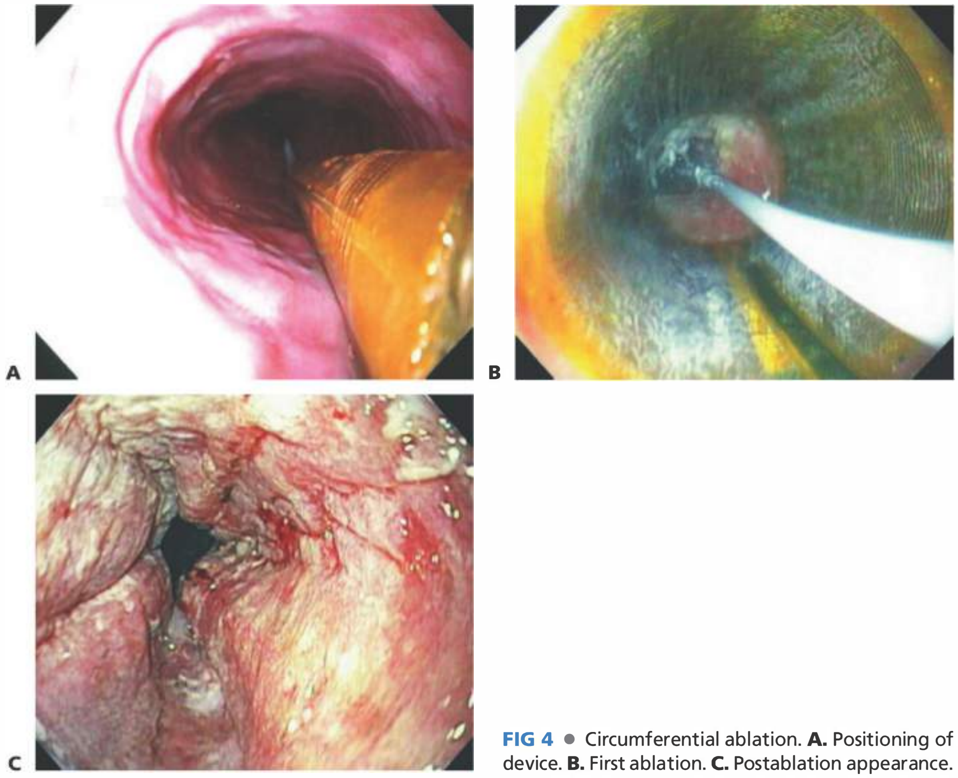


FIG 4 ● Circumferential ablation. **A.** Positioning of device. **B.** First ablation. **C.** Postablation appearance.

Focal Ablation

- The focal ablation is performed for treating shorter segments, tongues and islands of BE, and during follow-up after an initial circumferential RFA. It may also be of special use in treating areas adjacent to the squamous-columnar junction.

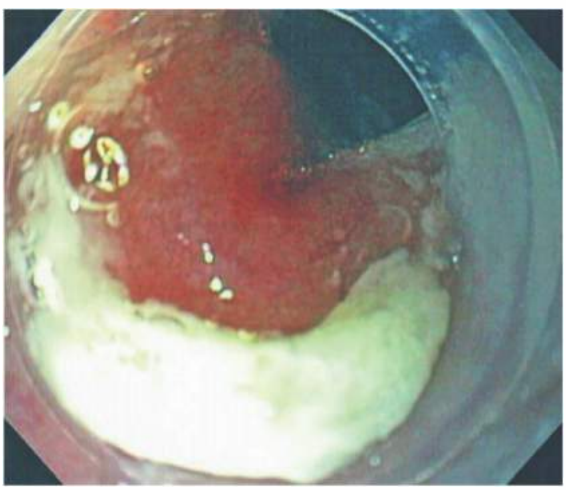
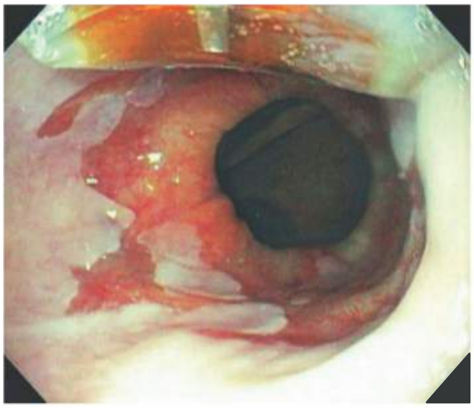


FIG 5 ● Cleaning using HALO cap.

- After careful endoscopic examination, the areas are recorded and endoscope removed while externally, the HALO^{90} device (array measuring 13 × 20 mm) is attached to the tip of the scope. It is positioned such that the back of the thumb-shaped array is located at 12 o'clock position on the endoscopic field of view and can be pivoted easily. It is reintroduced into esophagus after careful intubation.
- The esophagus is washed with N-acetylcysteine solution. The targeted area of BE is identified and the endoscope is angulated such that the ablation device is tightly opposed to the mucosa (FIG 6A).
- After maintaining optimal contact, the energy is delivered using the foot pedal using the similar energy settings previously described. Maintaining the same position, a second pulse of energy is given. The device is then moved to the next treatment area and previously mentioned steps repeated, treating all visualized BE (FIG 6B).
- The coagulum of desiccated mucosa is then removed using either a HALO cap as previously described or even the tip of the ablation device could be used to scrape the tissue. After gentle debridement, the device is then externally cleaned using damp gauze, reintroduced while mounted on the scope and a second round of two applications per area are performed in an identical manner such that eventually each targeted area receives a total of four energy ablations.

A 

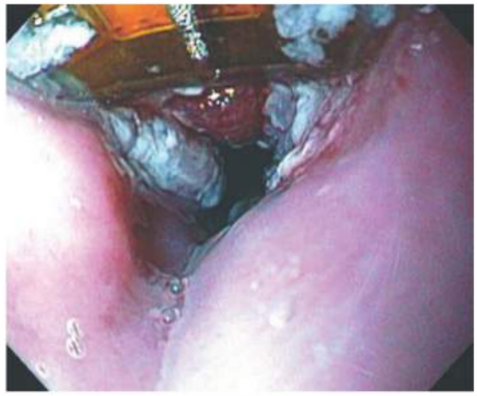
B 

FIG 6 ● Focal ablation. **A.** Positioning of device. **B.** Ablation.

FOLLOW-UP

- Endoscopic evaluation of the ablated area is performed 2 months following the procedure, and complete healing should have occurred by this time (**FIG 7**).

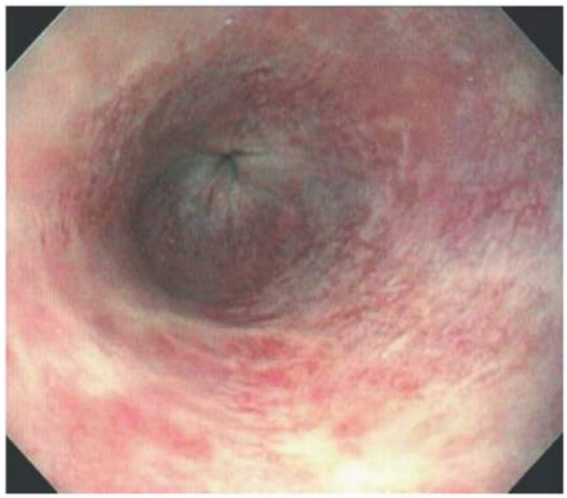


FIG 7 ● Follow-up showing healing.

PEARLS AND PITFALLS

Indications	■ Careful history, endoscopic findings, and pathologic review of records should be done prior to selection of patients for ablation.
Selection of ablation method	■ Long-segment circumferential areas should be targeted using the circumferential HALO[360] device. ■ Short segment and subsequent sessions or "touch up" of BE can be treated using the focal HALO[90] device.
Circumferential ablation	■ Endoscopic identification of landmarks and length on segment based on Prague classification ■ Sizing of device and selection of balloon ablating catheter ■ Careful positioning and endoscopic visualization of the catheter and performing the first ablation pass ■ Cleaning of device externally while performing debridement of tissue using the endoscope and cap ■ Performing the second ablation pass
Focal ablation	■ Endoscopic identification of landmarks ■ Attachment of device to endoscope such that it is in 12 o'clock endoscopic view ■ Optimal opposition to targeted mucosa and energy delivered using "dual technique" with continued ablation of all areas ■ Debridement of tissue, cleaning of device, and second pass of ablation for all areas
Follow-up	■ Immediate postprocedure instructions are given regarding food intake, pain management, and antireflux medications. ■ Follow-up after 2 months for repeat endoscopy, further ablation, or biopsies.

POSTOPERATIVE CARE

- After RFA treatment, patients may experience chest pain and dysphagia for 3 to 4 days thereafter.
- Postoperative care includes a pain management with viscous lidocaine or liquid acetaminophen with narcotic. A liquid diet is advised for 24 hours after treatment and then to slowly return to normal diet.
- A maintenance dose of proton pump inhibitor (PPI) such as esomeprazole 40 mg twice a day during the entire treatment period for adequate acid suppression is required to promote healing. In addition, sucralfate 1 g four times a day for 2 weeks is prescribed.
- Patients are usually discharged home on the same day as the procedure. On occasion, severe chest pain may require admission for observation and optimizing pain management.
- They are instructed to be followed up for 2 months after the initial ablation when they are reassessed for further treatment or biopsies if neo-squamous epithelium is seen. Approximately 3.5 treatment sessions may be necessary to clear all dysplastic BE and this will depend on the length of segment.

OUTCOMES

- RFA is effective for treatment of HGD and LGD.[3]
- In a randomized sham-controlled trial, complete eradication for HGD was noted in 81.0% compared to 19.0% in controls. Similarly, disease progression was lower in the ablation group (3.6% vs. 16.3%).[10] Patients with LGD achieved eradication in 90.5% of the ablation group as compared to 22.7% of control group at the end of 12 months. Durability of RFA demonstrated eradication of dysplasia in 98% and 91% of metaplasia at the end of 3 years since ablation therapy.[11]

COMPLICATIONS

- RFA has a low complication rate with low adverse events. Chest pain and dysphagia are commonly associated symptoms lasting for a period of 3 to 4 days posttreatment and resolves spontaneously to baseline.[12,13]
- Strictures can occur on follow-up and the rate varies between 0% and 8%, with longer segments and preceding EMR to be higher risk factors for developing them. They can, however, be managed by endoscopic dilatation.
- Bleeding is rare (<1%) and encountered especially in patients on antiplatelet or anticoagulation therapy.
- No perforations or RFA-related deaths have been reported after RFA. Fever is also a rare complication and can be managed using antipyretics.
- Buried intestinal metaplasia or glands has been of concern postablation and may not be visible endoscopically. It is less frequently reported after RFA (0.9%) and highlights the need for deep endoscopic biopsies, which need to be carefully reviewed by the pathologist.[14]

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Chapter 28 Endoscopic Mucosal Resection for Barrett Neoplasia

Shajan Peter C. Mel Wilcox Klaus Mönkemüller

DEFINITION

- Barrett esophagus (BE) is a strong risk factor for esophageal adenocarcinoma.[1]
- The annual risk of BE progression to adenocarcinoma ranges from 01.12% to 0.61%.[1,2]
- The traditional treatment of choice for "resectable" esophageal adenocarcinoma is esophagectomy.
- However, surgical resection is still associated with significant mortality and morbidity, even in high-volume centers and especially in elderly or poor surgical candidates.[3]
- Thus, during the last two decades, patients with early cancer or those with high-grade dysplasia have been successfully treated with endoscopic resection methods.[4,5]
- The most common method used is endoscopic mucosal resection (EMR) or "mucosectomy."[4,5]

DIFFERENTIAL DIAGNOSIS

- The differential diagnosis of mucosal neoplasia of the distal esophagus is narrow. The most common malignant neoplasia of the distal esophagus is adenocarcinoma, followed by squamous cell cancer.[4,5]
- Proximal stomach cancer such as cardiac or fundic adenocarcinoma extending into the esophagus may be difficult to differentiate from distal esophageal adenocarcinoma.
- Submucosal tumors such as gastrointestinal (GI) tumors, spindle cell tumors, lipoma, and leiomyoma are easily differentiated from mucosal lesions as these tumors generally have a normal overlying mucosa.

PATIENT HISTORY AND PHYSICAL FINDINGS

- Most patients with Barrett's neoplasia do not have any specific symptoms and BE is discovered incidentally during an upper GI endoscopy performed for the evaluation of gastroesophageal reflux symptoms, dyspepsia, or abdominal pain.[6]
- However, Barrett's neoplasia is more common in patients with the following characteristics: male, central obesity, Caucasian, age older than 50 years, tobacco use, and chronic gastroesophageal reflux disease (GERD).[6]
- Although reflux of acid is a common occurrence in BE, a high proportion of BE patients deny a history of reflux symptoms.[7]
- Therefore, any patient undergoing upper endoscopy should be carefully investigated for columnar-lined epithelium and intestinal metaplasia of the distal esophagus, with special attention to patients with the risk factors mentioned earlier.

IMAGING AND OTHER DIAGNOSTIC STUDIES

- Radiologic studies do not play a role in the evaluation of BE unless there is a stricture present (benign or malignant). In this instance, a barium esophagogram can be helpful to determine the length and characteristics of the stenosis.
- Although computed axial tomography is useful to evaluate for lung metastasis and mediastinal and perigastric lymph node involvement in esophageal adenocarcinoma, its role in patients with early Barrett neoplasia is negligible, as most of these patients have local disease, which does not extend beyond the submucosa of the esophagus.
- Patients with Barrett's cancer invading the submucosa (sm1) have a very low risk of lymph node metastasis and thus are ideal candidates for EMR.[4–6]
- In the past, endoscopic ultrasound (EUS) was used to determine the depth of GI layers involvement in early Barrett neoplasia.[8]
- However, the sensitivity and specificity of EUS for early Barrett neoplasia are low and the results can be misleading.[8]
- The mainstay of diagnosis of BE is with light endoscopy, ideally using high-definition endoscopes and equipment.[9]
- It is very important to measure the proximal distance of extension of cylindrical-type epithelium into the esophagus. The extent of BE segment should be defined using the Prague C & M classification including the length of the circumferential segment (C) and the maximal extent of the BE segment (M).[10]
- The use of various staining agents and dyes (chromoendoscopy) such as methylene blue (**FIG 1**) and indigo carmine or agents such as acetic acid (**FIG 2**) enhances the mucosal pit pattern analysis (see the following text) and thus facilitates the detection high-grade dysplasia and carcinoma.[9]

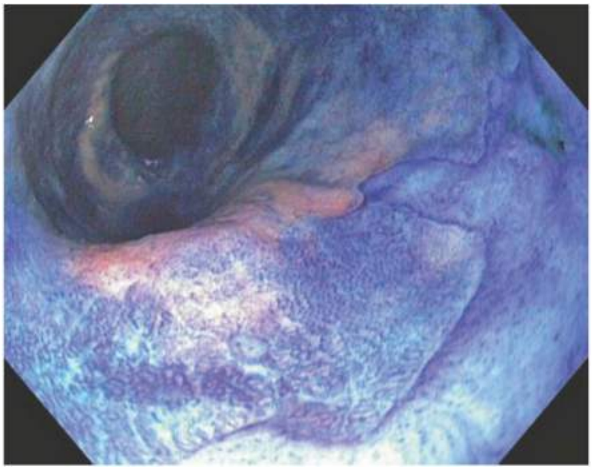

FIG 1 ● Chromoendoscopy with methylene blue allows for a better definition of the pit pattern and the detection of areas of dysplasia and carcinoma. The absence of colorant points to a suspicious area of dysplastic cells. This image shows a pit pattern type IIIS.

FIG 2 ● Acetic acid is another useful adjunct to define the mucosal pit pattern. Careful analysis of the pit pattern of Barrett's epithelium is mandatory to define its type and discover areas of dysplastic cells. This sample shows a type II pit pattern.

- Other imaging modalities that might help in delineating BE are narrow band imaging (NBI) (**FIG 3**), autofluorescence imaging, and confocal laser endoscopy.
- Magnification endoscopy is also important to characterize the mucosal surface and pit pattern (**FIG 4**).
- The most widespread classification used to categorize the pit pattern in BE is the Endo classification (adapted from S. E. Kudo).[11]
- This classification categorizes the opening of the pits into round (I), stellar or asteroid (II) (see **FIG 2**), tubular elongated (IIIL), tubular short or round (IIIS) (see **FIG 1**), gyrus or sulcus branched (IV) (see **FIG 4**), and irregular or amorphous (V) (**FIG 5**).
- Types I, II, and III pit patterns are "benign," whereas pit pattern types IV and V are more commonly present in advanced neoplasia or carcinoma.
- Chromoendoscopy is performed to aid in obtaining directed (i.e., targeted) biopsies prior to mucosectomy to define the precise extent of neoplastic involvement.
- Targeted biopsies are obtained from visible abnormalities, followed by four-quadrant biopsies of every 1 to 2 cm of the BE segment (Seattle protocol; see Part 1, Chapter 27) and these should be reviewed by a dedicated GI pathologist.

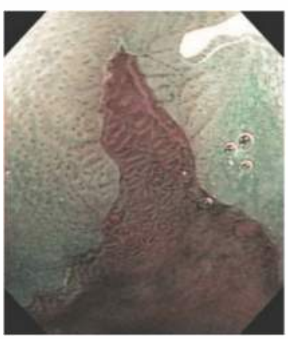

FIG 3 ● NBI is one of the many "virtual" chromoendoscopy techniques to evaluate the mucosal and submucosal surface. This sample shows a pit pattern type IIIL.

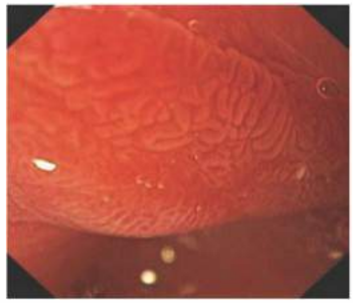

FIG 4 ● Magnification endoscopy permits the close examination of the mucosa. The pit pattern in this case is mixed (IIIL and IV).

ENDOSCOPIC MANAGEMENT

- The two most important indications for EMR of Barrett's neoplasia are diagnostic and therapeutic.[5,6,12]
- EMR can be generally attempted if the lesions are smaller than 20 mm in diameter.
- Endoscopic submucosal dissection (ESD) should be reserved for larger lesions.
- However, ESD is a technique that has been mainly used for early squamous cell cancer of the esophagus. The results of ESD for Barrett neoplasia are still suboptimal.

Preoperative Planning

- All patients should undergo a thorough history and physical examination and be classified based on the American Society of Anesthesiologists (ASA) score.
- Interventions in patients with ASA score greater than or equal to 4 are not deemed beneficial, as the risk of harm outweighs the potential benefits.
- Obtaining routine laboratory data such as white blood cell and platelet count, bleeding studies (partial thromboplastin time [PTT]/international normalized ratio [INR]), and creatinine and electrolytes is mainly indicated in multimorbid patients or those taking medications that specifically affect any organ or system (e.g., anticoagulant, diuretics).
- Management of anticoagulants preoperatively should be based on the guidelines established by the American Society for Gastrointestinal Endoscopy.[13]

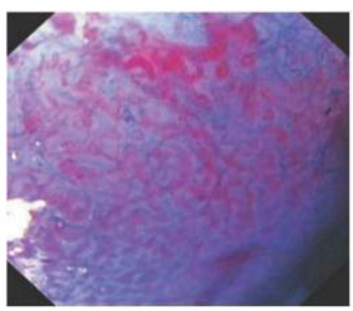

FIG 5 ● The abnormal and amorphous pit pattern (type V) with the presence of tortuous or irregular vessels is suggestive of dysplasia and malignancy.

- In patients with high-risk cardiovascular conditions on warfarin, it is important to bridge this period with the use of low-molecular or fractionated heparins.[13]
- Prophylactic antibiotics are not recommended before EMR.[14]
- The standard of care is the administration of conscious sedation.[4,5,12,15]
- Exceptions include patients who ingest narcotics or benzodiazepines, multimorbid patients, or heavy alcohol drinkers. For these groups of patients, we prefer monitored anesthesia care (MAC), use of nurse-assisted propofol sedation (NAPS), or general anesthesia (GA).
- We want to emphasize that a carefully performed EMR in expert hands should take less than 15 minutes.
- When performing an EMR, the bulk of time is usually in recognizing and characterizing the lesion. The resection per se is a focused procedure that should be targeted, efficient and efficacious.

Positioning

- The patient is placed in the left lateral decubitus position and prepared as for a routine upper endoscopy.

ENDOSCOPIC MUCOSAL RESECTION TECHNIQUES

- Several EMR techniques have been described for removal of focal and diffuse lesions in BE.[4,5,12,15]
- Table 1 lists the essential equipment needed for EMR.

Table 1: Endoscopic Mucosal Resection Equipment List

Endoscope with high-definition white light capabilities
Spray catheter (or biliary cannula) to apply dye for chromoendoscopy
Indigo carmine or methylene blue solution for chromoendoscopy
Duette® EMR kit or esophageal varices banding device
Snares (hexagonal and oval)
Injection needle
Roth Net to retrieve resected specimen
Cork or Styrofoam plates and pins to pin down the specimen
Electrosurgical unit

EMR, endoscopic mucosal resection.

SNARE TECHNIQUE

- This is the most "simple" technique to remove a lesion.[4,5,15]
  - It entails using an oval or hexagonal electrocautery snare.
- However, simple refers mainly to the commonly used instruments to perform an EMR, as it requires high-level skills and experience to be able to grasp the target lesion and resect it entirely by just using a snare.
- It is important to always remove all the air before snaring the lesion. This allows for ensnaring more tissue.
- The assistant holding the snare should carefully close it while the endoscopist aspirates the air and advances the snare catheter toward the lesion.
- The electrocautery used for performing EMR should be predominantly cut or blended.
- Coagulation currents tend to produce deep injury and are associated with high risk of perforation.

SUBMUCOSAL INJECTION AND SNARE

- A modification of the snare technique is the use of a submucosal cushion below the tissue to be removed.[4,5,12]
- This "safety" cushion may theoretically decrease the risks of perforation.
- By iatrogenically swelling up the mucosa with the injection of substances, it will be harder for the pathologist to determine the depth of tumor invasion (if present).
- We also caution against the use of epinephrine in the solution used to create the submucosal cushion as the venous irrigation from the distal esophagus returns to the right heart without first-pass metabolism through the liver via the azygous vein, thus increasing the chance of systemic effects and side effects, including cardiac ischemia.

USE OF A TRANSPARENT CAP ("SUCK-AND-CUT" OR INOUE TECHNIQUE)

- A transparent cap is attached to the tip of the scope.
- The cap is placed perpendicularly against the mucosa, preferentially in the greater curvature of the stomach. A snare is advanced, opened, and placed around the inner ring of the cap (**FIG 6**).
- Once the snare is partially opened, completely inside the inner part of the cap, the scope is pulled back into the esophagus and directed toward the lesion of interest.
- The lesion is then aspirated inside of the cap and the snare is closed snuggly around the base of the lesion (**FIG 7**).
- Once the lesion has been caught with the snare, electrosurgical currents are applied and the lesion is resected (**FIG 8**).

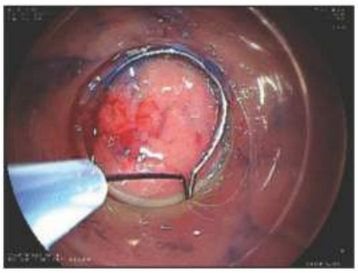

FIG 6 ● A snare is advanced, opened, and placed around the inner ring of the cap.

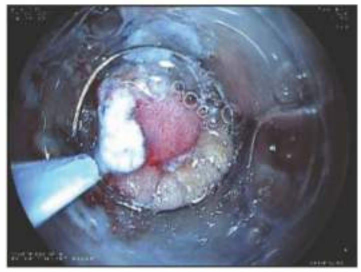

FIG 7 ● Once the lesion has been sucked inside the cap and caught with the snare, electrosurgical currents are applied and the lesion is resected.

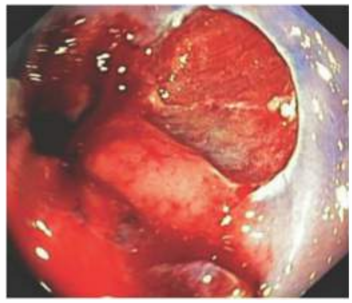

FIG 8 ● Successful EMR. The resected site shows the muscularis propria demonstrating an effective resection of mucosa and submucosa. The aim of any EMR should be an in toto and R0 resection.

USE OF CAP WITH LIGATURE DEVICE ("SUCK-LIGATE-AND-CUT" TECHNIQUE)

- With this method, both the mucosa and submucosa are aspirated or "sucked" into a transparent cap loaded with elastic ligature bands or rings (**FIG 9**).
- This device is essentially the same as the one to perform esophageal variceal ligation.
- Whereas some experts use a "multiband" ligator (MBL), using a single-band ligation device is also possible.
- After placing the bands, the scope is retrieved, the cap is removed, and the scope is reinserted to perform the EMR.
- By aspirating ("sucking") the tissue into the cap and releasing the ring on its base, a pseudopolyp is created (**FIG 10**).
- The main advantage of the Duette®-MBL (Cook Medical, Winston Salem, NC) is that a 5-Fr polypectomy snare can be passed through both the ligator handle and channel of the scope, thus permitting ligation and subsequent resection using the snare without removal of the endoscope (**FIG 11**).

FIG 9 ● The mucosa and submucosa are sucked into a transparent cap loaded with elastic ligature bands or rings.

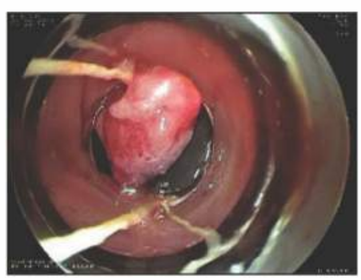

FIG 10 ● By aspirating (sucking) the tissue into the cap and releasing the ring on its base, a pseudopolyp is created.

FIG 11 ● The main advantage of the Duette®-MBL (Cook, Winston Salem, NC) is that a 5-Fr polypectomy snare can be passed through both the ligator handle and channel of the scope, thus permitting ligation and subsequent resection using the snare without removal of the endoscope.

- The "pseudopolyp" is then snared off.
- An advantage of using an MBL method is the creation of one or multiple pseudopolyps.
- The MBL methods is a great option for (1) removing lesions located in various sites, (2) piecemeal EMR of a larger lesion, and/or (3) to perform hemi- or full circumferential resection of the distal esophageal mucosa.[15]
- Resected specimens are collected using the snare Roth Net (US Endoscopy, Mentor, OH) or aspirated into the inside of the cap of the scope and retrieved out of the esophagus or stomach.
- The piece(s) should be fixed onto a piece of cork or Styrofoam before being immersed in 4% formalin solution and sent for histopathologic assessment.

PEARLS AND PITFALLS

Patient evaluation	■ Careful history, endoscopic findings, and pathologic review of records should be done prior to selection of patients for EMR.
Indication	■ EMR is only indicated for lesions less than 20 mm.
Endoscopy	■ Endoscopic identification of landmarks and length on segment should be based on the Prague classification. ■ Knowledge of chromoendoscopy and advanced endoscopic methods is essential for a successful EMR. ■ The chromoendoscopy devices should be ready before the procedure gets started. ■ Careful description and documentation of the exact location of the lesion is mandatory. ■ Use a diagram to document findings. ■ Endoscopic photodocumentation is mandatory.
EMR method/technique	■ EMR should be only performed by endoscopists with advanced endoscopic training. ■ Become well-versed in one EMR technique. ■ Remove the air before ensnaring the lesion. ■ Be ready for potential complications (bleeding, perforation) and know how to treat them. ■ Each resected specimen should be pinned down into cork or Styrofoam and placed into distinctly labeled formalin containers. ■ Always have an additional large hexagonal and small oval snare readily available.
Follow-up	■ All patients undergoing EMR should be put on long-term proton pump inhibitors. ■ All EMR cases should be presented at the pathology conference. ■ Follow-up endoscopy is mandatory to ensure complete resection and evaluate for synchronous or metachronous lesions or recurrence. ■ All patients undergoing EMR should be kept in a registry to ensure quality care.

POSTOPERATIVE CARE

- A liquid diet is administered for 24 hours after treatment and then advanced to regular diet.
- All patients undergoing EMR should be on long-term proton pump inhibitors.
- The dosage is doubled after EMR and kept at this level for 4 weeks.
- Patients are usually discharged home on the same day of the procedure.
- Follow-up endoscopy is based on the type and histology of lesion resected.
- Long-term follow-up is based on the recommendations of the American College of Gastroenterology and American Society for Gastrointestinal Endoscopy.

OUTCOMES

- EMR is efficacious method to treat BE with high-grade dysplasia and early cancer as long as the lesions are less than 20 mm.[4,5,12,15]
- In expert hands, complete remissions of more than 95% can be achieved.[4,5,12,15]
- A favorable outcome is dependent on the following "low-risk" criteria: invasion not beyond sm1, absence of infiltration into lymph vessels and/or veins, histologic grade G1/2, and macroscopic type I/II.
- Recurrence or metachronous neoplasia are seen in up to 20% to 30% of patients.
- Repeat endoscopic treatment can be performed in almost all patients presenting with metachronous or recurrent disease.

- Ablative therapy using radiofrequency ablation of the residual or recurrent Barrett segment is possible, feasible, and effective.

COMPLICATIONS

- EMR has low complication rates in expert hands.
- *Early* complications include perforation (<0.5%) and bleeding (5% to 14%).
- Moderate or severe post-EMR bleeding can be easily controlled by diluted epinephrine injection (1:10,000) and/or metal clip application.
- Esophageal stenosis is more common in patients undergoing resection of more than 50% of the distal esophageal circumference

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Chapter **29**

Esophagectomy: Transhiatal and Reconstruction

Robert E. Glasgow

DEFINITION

- Transhiatal esophagectomy (THE) or esophagectomy without thoracotomy is defined as removal of the esophagus and upper stomach using an incision in the left anterior neck for purposes of dissection of the upper third of the esophagus via the thoracic inlet, and an upper midline abdominal incision for purposes of dissection of the stomach and lower two-thirds of the esophagus and creation of a conduit for esophageal reconstruction (stomach, colon).
- Although THE is usually applied for purposes of treating esophageal and gastroesophageal (GE) junction carcinoma, THE may also be used for treatment of benign esophageal conditions including end-stage achalasia and medically/endoscopically recalcitrant esophageal stricture from caustic injection or end-stage reflux disease and acute perforation.
- The remainder of this discussion will focus on the use of THE in the treatment of malignant disease. Most aspects of the diagnostic workup and operative techniques also apply to the evaluation and treatment of benign conditions for which THE is being considered.

DIFFERENTIAL DIAGNOSIS

- THE is most commonly used in treatment of esophageal cancer. In particular, adenocarcinomas of lower third of the esophagus and Siewert types I and II GE junction adenocarcinoma (**FIG 1**; Table 1) are optimally suited for this approach.
- Squamous cell carcinomas (SCCs) of the lower third of the esophagus may also be approached via THE, whereas tumors of the middle and upper third of the esophagus usually require transthoracic esophagectomy (TTE) to allow for direct visualization of the dissection of the involved esophagus.

PATIENT HISTORY AND PHYSICAL FINDINGS

- All patients should undergo a comprehensive medical history with emphasis not only on clinical history pertinent to the primary indication for consideration of THE but also the pertinent comorbid conditions that would influence treatment planning. Included in this history is a comprehensive past surgical history. Prior fundoplication will make dissection of the esophageal hiatus more difficult. Patients with a prior history of gastric resection, for example, may not be candidates for use of the stomach as a conduit for reconstruction because of inadequate length or blood supply. Finally, if the colon is to be considered for use for reconstruction, the influence of prior colectomy on anatomy and blood supply should be very carefully considered.

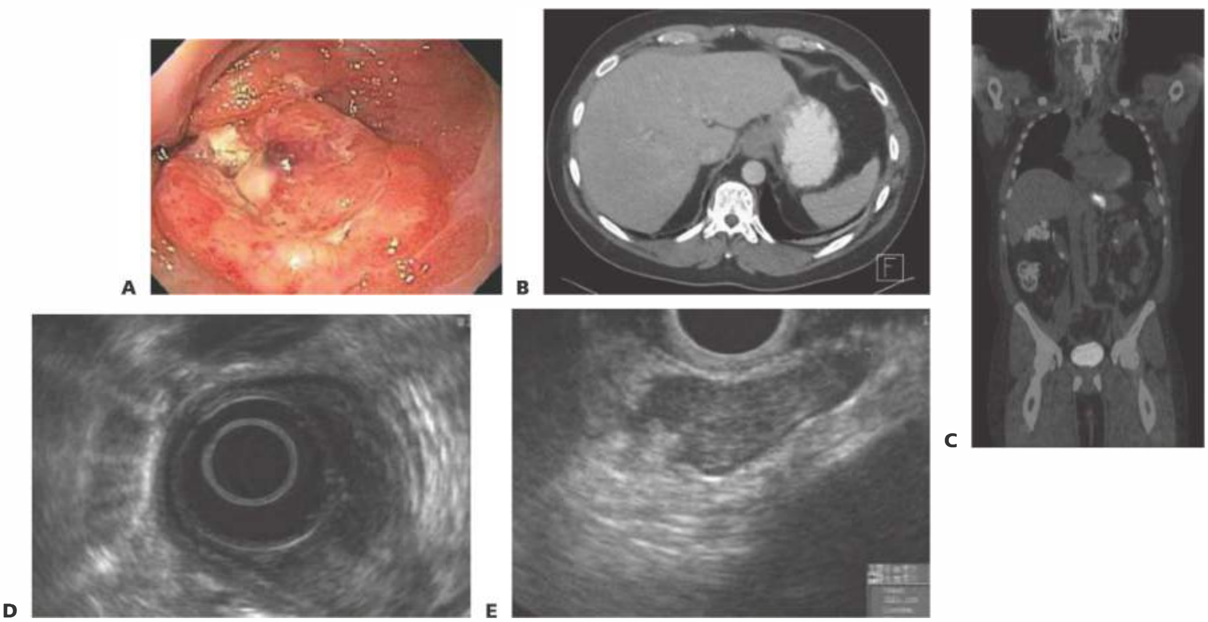


FIG 1 ● Imaging and diagnostic evaluation of a patient with a localized T3, N1, M0 Siewert type 2 GE junction adenocarcinoma undergoing consideration for THE. **A.** Upper endoscopy showing ulcerated mass in the lower third of the esophagus. **B.** CT showing an enlarged mass at the lower third of the esophagus. **C.** PET-CT. **D.** Endoscopic ultrasound showing mucosal-based mass invading into the adventitia of the esophagus. **E.** Endoscopic ultrasound showing enlarged lymph node fine needle aspiration (FNA) biopsy confirming adenocarcinoma.

Table 1: Siewert Classification for Gastroesophageal Junction Adenocarcinoma

Type I: Adenocarcinoma of the lower esophagus with the center located within 1 cm above and 5 cm above the anatomic EGJ.
Type II: True carcinoma of the cardia with the tumor center within 1 cm above and 2 cm below the EGJ.
Type III: Subcardial carcinoma with the tumor center between 2 and 5 cm below EGJ, which infiltrates the EGJ and lower esophagus from below.

EGJ, esophagogastric junction.
From Rüdiger Siewert J, Feith M, Werner M, et al. Adenocarcinoma of the esophagogastric junction: results of surgical therapy based on anatomical/topographic classification in 1,002 consecutive patients. Ann Surg. *2000;232(3):353–361.*

- Whether it be for benign or malignant disease, the principal symptom at the time of presentation for a patient who would undergo THE is dysphagia. Often, these patients have significant nutritional impairment, most notably, weight loss.
- In patients with adenocarcinoma of the esophagus and GE junction, a history of GE reflux disease should be elicited as well as a careful history of prior endoscopic and radiographic evaluations. In patients with SCC, a prior and current history of tobacco and alcohol use should be elicited.
- A comprehensive physical examination should be performed with special attention to the cervical and supraclavicular areas for enlarged lymph nodes, chest exam for possible effusions, and abdominal exam for palpable masses and periumbilical lymph nodes (Sister Mary Joseph nodule).

IMAGING AND OTHER DIAGNOSTIC STUDIES

Upper Endoscopy with Biopsy

- All patients presenting with dysphagia should undergo upper gastrointestinal endoscopy and biopsy with the goal of making a diagnosis and localizing the site of obstruction (**FIG 1**).
  - Multiple biopsies of suspicious areas (nodules, ulceration, stricture, possible Barrett's) should be obtained.
  - Endoscopic mucosal resection (EMR) of focal nodules should be performed to provide accurate T staging and to evaluate degree of differentiation and vascular and/or lymphatic invasion.
  - For cancer, the location of the tumor as measured from the incisors and GE junction and extent of tumor length, circumferential involvement, and degree of obstruction should be documented.

Computed Tomography of Chest and Abdomen

- Once a diagnosis of cancer is made, a computed tomography (CT) of the chest and abdomen with oral and intravenous contrast is done.
- Tumor location, locoregional involvement or invasion, regional and extraregional lymph node involvement, and metastatic disease should be evaluated and recorded.
- If metastasis is suspected, biopsy of concerning lesions should be undertaken to confirm stage and direct palliative treatment.

Positron Emission Tomography–Computed Tomography

- In patients whom a standard CT of the chest and abdomen is unremarkable, a positron emission tomography–computed tomography (PET-CT) should be performed again to confirm primary tumor location and extent, evaluate regional and extraregional nodal involvement, and exclude occult metastases.

Endoscopic Ultrasound

- In patients without metastatic disease (stage 4), an endoscopic ultrasound is done to document depth of invasion of the tumor (T stage) and evaluate mediastinal and perigastric/celiac lymph node involvement (N stage). Biopsy of suspicious lymph nodes is indicated.
- All patients should then be assigned a pretreatment TNM stage to guide treatment planning discussions, preferably under the direction of a multidisciplinary treatment planning conference attended by surgical, medical, and radiation oncology.[1] The National Comprehensive Cancer Network (NCCN) defines optimal treatment planning algorithms.[2]
- In considering options for reconstruction, the two most common conduits are the stomach and colon. Although variations in stomach blood supply are very rare, variations in colonic blood supply are common enough to justify preoperative evaluation of arterial anatomy and collateral circulation by visceral angiography in planning choice of conduit.
  - For purposes of using the stomach as a conduit for esophageal reconstruction, an intact right gastric and, more importantly, right gastroepiploic artery is imperative (**FIG 2**).
  - For purposes of the colon as a conduit for esophageal reconstruction following a THE, an adequate collateral blood supply via an intact marginal artery is required (**FIG 3**). Obviously, a colonoscopy to exclude and/or treat colonic pathology must be done prior to use of the colon.

SURGICAL MANAGEMENT

- As THE is a technically complex operation with a high degree of associated morbidity and mortality, this operation should be done by surgical teams experienced in the perioperative management of these patients.[3–5] This includes experienced operating room personnel and anesthesiologists.

Preoperative Planning

- Patients should undergo preoperative evaluation by the surgical and anesthesia team for purposes of mitigating perioperative risks in the area of cardiac, pulmonary, and renal comorbidities.
- A discussion should be done with the patient as to how pain will be measured and managed following surgery. Regional anesthetics such as an epidural catheter are very

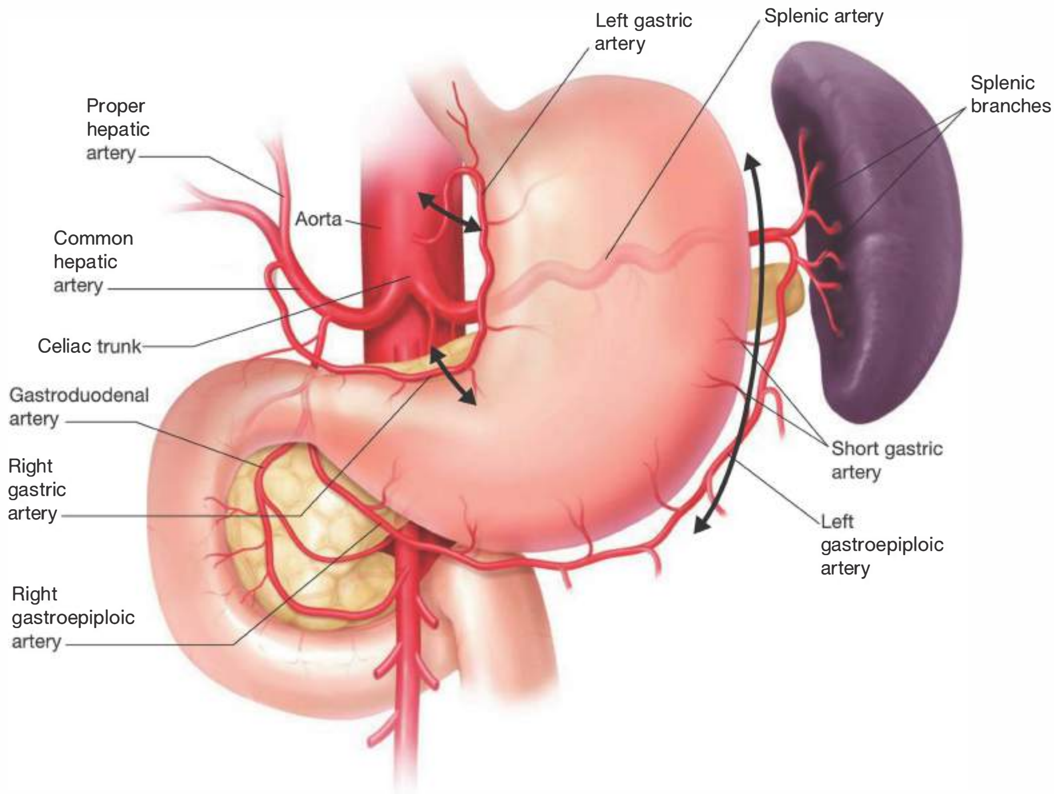


FIG 2 ● Stomach blood supply for purposes of using the stomach as a conduit for reconstruction following THE. *Arrows* show lines of division including the short gastric arteries, left gastroepiploic artery, left gastric artery, and ligation of the right gastric artery at the incisura angularis at the point of origin of the gastric conduit staple line.

helpful in alleviating pain, thereby allowing the patient to be more engaged in early mobilization and physical therapy.

- Perioperative antibiotics should be administered within 60 minutes of skin incision and redosed in a timely manner during the operation. Cefazolin, dosed to weight specifications and redosed every 4 hours, is recommended. Cefoxitin can also be used and redosed every 3 hours. For patients with a beta-lactam allergy, clindamycin or vancomycin and aminoglycoside or aztreonam or fluoroquinolone are used. All prophylactic antibiotics are not necessary beyond surgery completion.[6]
- Perioperative monitoring with an arterial line is helpful especially during blunt mediastinal esophagus dissection where transient hypotension is common because of decreased venous return and compression on the heart. Rarely is a central line indicated.
- Appropriate deep venous thrombosis prophylaxis is required. Intermittent sequential compression devices should be placed prior to induction of anesthesia and continued after surgery. Chemical prophylaxis should be instituted postoperatively once clinically indicated.
- Urinary catheters are placed following induction of anesthesia and discontinued within 24 hours of surgery.

Positioning

- Patients undergoing THE are positioned supine on the operating room table (**FIG 4**).
- Both arms are tucked and pressure points padded to prevent injury during the course of the operation.
- A towel or medium gel roll is placed behind the shoulders to allow for mild extension of the neck. This is of particular importance in obese, short-necked patients.
- The head is rotated 30 degrees to the right to open exposure to the left neck.

Placement of Surgical Incisions

- A midline laparotomy from the xiphoid process to the umbilicus is made (**FIG 4**).
- After verifying the patient to be a candidate for resection and verifying that THE can proceed, a 5-cm incision is made overlying the anterior border of the left sternocleidomastoid muscle with the inferior extent at the head of the clavicle. Contraindications to THE include difficult mediastinal blunt dissection of the esophagus because of tumor or treatment effect, excessive mediastinal bleeding with blunt dissection, and inadequate conduit length for reconstruction.

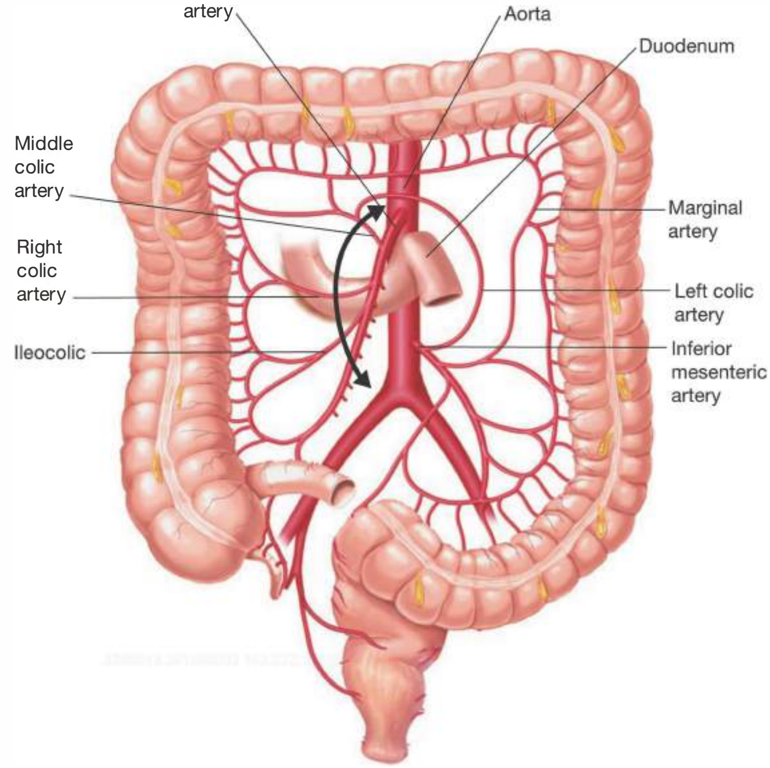


FIG 3 ● Colon blood supply for purposes of using the colon as a conduit for reconstruction following THE.

FIG 4 ● Supine position with location of surgical incisions for THE.

TRANSHIATAL ESOPHAGECTOMY

Abdominal Exploration to Exclude Metastatic Disease

- Upon entering the abdomen, visceral and parietal peritoneal surfaces are palpated to exclude occult peritoneal carcinomatosis. This should include inspection of the lesser sac by opening thru the gastrocolic omentum.
- The liver is palpated for suspicious nodules and biopsy performed. Intraoperative ultrasound can be a useful adjunct in this step. If indeterminate lesions are noted on preoperative imaging, ultrasound-guided biopsy is indicated.
- Metastatic disease is an absolute contraindication to proceeding with surgical resection.

Exploration of the Esophageal Hiatus to Determine Local Resectability

- Prior to proceeding with dissection of the stomach, the esophageal hiatus is explored to make sure the distal esophagus and GE junction can be dissected free of the esophageal hiatus and surrounding abdominal and mediastinal structures. If so, and in the absence of metastatic disease, resection can proceed.

- This dissection and subsequent dissections are facilitated by use of an electrosurgical device such as an ultrasonic or bipolar scalpel.
- The pars flaccida is opened, including division of an accessory or replaced left hepatic artery, if necessary.
- The peritoneum and phrenoesophageal membrane overlying the junction of the right crus of the diaphragm and esophagus is incised allowing the esophagus to be dissected off the right crus.
- The phrenoesophageal membrane just cephalad to the GE fat pad is divided as is the peritoneal reflection overlying the angle of His.
- The esophagus is dissected off the left crus of the diaphragm and esophagus encircled with a 1-in Penrose drain (**FIG 5**).
- The esophagus and GE junction are then dissected free of the crural confluence of the esophageal hiatus, and esophagus with associated periesophageal fatty tissue and lymph nodes dissected free of the esophageal hiatus and underlying aorta.
- If the esophagus and GE junction are free of surrounding structures, resection can proceed. If adherent to or invading the pleura, pericardium, or diaphragm (T4a), resection of these structures can be performed. If adherent to the aorta, vertebral body, or trachea (T4b), resection should be aborted.

Mobilization of the Stomach and Duodenum

- Once it is determined that resection can proceed, the stomach and duodenum are mobilized. Most often, the stomach is used as the conduit for reconstruction following THE. Therefore, mobilization of the stomach for purposes of proceeding with the esophagectomy and for purposes of the creation of the gastric conduit occur simultaneously.
- The right gastroepiploic artery and vein are identified along the greater curvature of the stomach. An adequate pulse in this vessel is imperative if the stomach is to be used for the reconstruction (**FIG 6**). These vessels terminate at the bare area roughly one-half the distance along the greater curvature between the pylorus and GE junction. It is imperative to preserve these vessels as they are the blood supply to and from the conduit.

FIG 5 ● Dissection of the GE junction and encirclement with a Penrose drain to facilitate manipulation.

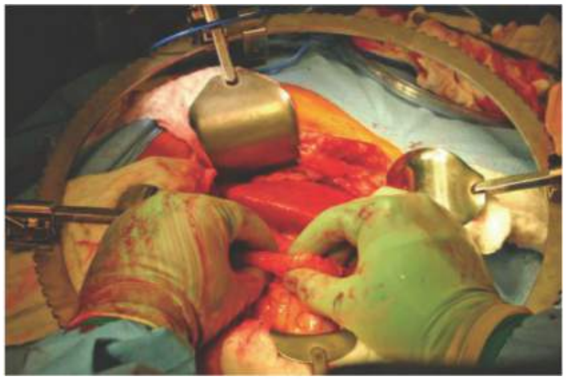
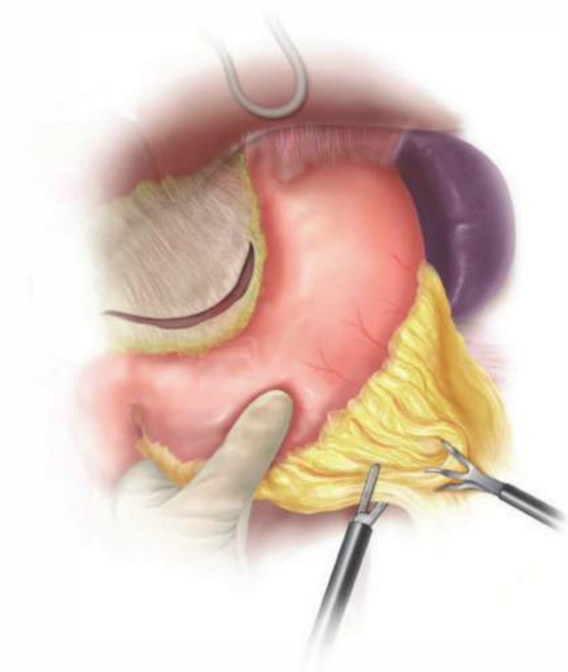


FIG 6 ● Palpation of the right gastroepiploic pedicle along the greater curvature of the stomach to ensure an adequate pulse to permit use of the stomach as a conduit for reconstruction.

- Once these vessels are identified, the gastrocolic ligament is entered several centimeters from the bare area entering the lesser sac.
- Using an electrosurgery device, the gastrosplenic ligament and short gastric vessels are divided proceeding along the greater curvature toward the esophageal hiatus. Placing a surgical clip on the distal ends of larger vessels, including the left gastroepiploic artery, can ensure ongoing hemostasis of these vessels. The posterior leaflet of the gastrosplenic ligament is likewise divided as are the congenital adhesions of the stomach to the anterior surface of the pancreas. This frees the greater curvature.
- Division of the gastrocolic ligament then proceeds distally, paying careful attention to stay at least a few centimeters away from the right gastroepiploic vessels (**FIG 7**). Careful attention should be paid to not placing traction or trauma to these vessels while freeing the stomach from the colon. This is especially true as one frees the stomach from the anterior surface of the pancreas and approaches the origin of these vessels from under the duodenal bulb. Traction of the vein, in particular, can traumatize these vessels resulting in impaired venous outflow and conduit venous congestion.
- After freeing the stomach from the colon, a Kocher maneuver is performed to permit mobilization of the duodenum. An adequate Kocher maneuver permits mobilization of the pylorus to reach the esophageal hiatus (**FIG 8**).
- At this point, the remainder of the gastrohepatic ligament is divided and left gastric pedicle is identified.
- The lymph nodes along the left gastric pedicle and celiac axis and surrounding aorta are dissected free of the origin of the left gastric artery and included in the surgical specimen. The left gastric artery and vein are then divided with either a vascular load of a surgical stapler or suture ligated.



A

B

FIG 7 ● Mobilization of the greater curvature of the stomach by dividing the gastrosplenic **(A)** and gastrocolic ligament **(B)**, being careful to not injure the gastroepiploic pedicle.

- The stomach is now free of its upper attachments and vasculature. If a colon conduit is preferred, preparation of the colon should proceed. If a gastric conduit is preferred, the gastric conduit is created to avoid trauma to the conduit during retraction of the stomach necessary for the inferior mediastinal dissection. This also allows verification of the adequacy of the blood supply to the apex of the conduit and length of the conduit prior to proceeding with the transhiatal dissection. This will be discussed in the following text. For this discussion, the mediastinal dissection will be described.
- With a Penrose drain around the GE junction for caudal retraction of the stomach and lower esophagus with associated lymphatic tissue is dissected under direct visualization from the lower mediastinum. This dissection is facilitated by a medium handheld malleable retractor and the use of an electrosurgical device. Approximately 5 to 10 cm of mediastinal esophagus can be dissected under direct visualization by this technique. Mobility of the mediastinal esophagus to assure feasibility and safety of a transhiatal blunt dissection is verified.
- After the limits of direct visualization are reached, blunt mediastinal dissection can proceed. To assure proper tactile orientation of the esophagus during blunt dissection, a 44-Fr bougie dilator or equivalent is placed in the esophagus.
- The hand is then first advanced posterior to the esophagus, between the esophagus and aorta. The surgeon's fingers are then advanced up this plane with pressure on the bougie containing esophagus to assure proper tissue plane dissection (FIG 9).
- The same dissection is then performed anterior to the esophagus.
- If vagal nerve sparing is planned, the vagus nerves are elevated off the esophagus by hooking the nerves with the index finger and bluntly dissecting them down and off the esophagus where they are then dissected free from the GE junction and stomach. As this operation is most often performed for malignancy, division of the vagal nerves is required to assure proper oncologic dissection. The nerves are then divided at the level of the hiatus with the electrosurgery device.
- This completes the abdominal stomach and esophagus mobilization.

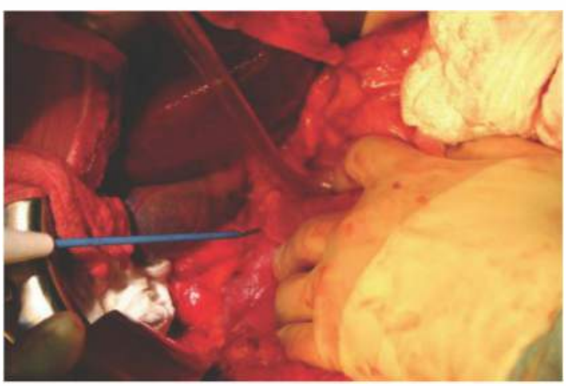
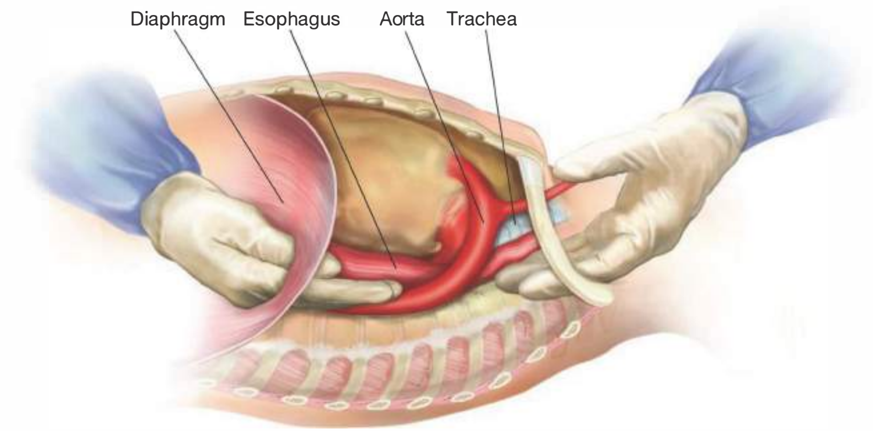


FIG 8 ● Kocher maneuver to ensure adequate mobility of the pylorus. This is assured if the pylorus can freely reach to the hiatus without tension.



A

B

FIG 9 ● **A,B.** Mediastinal mobilization of the esophagus with a hand placed thru the esophageal hiatus from the abdominal incision and finger placed thru the cervical incision.

Cervical and Upper Mediastinal Esophageal Mobilization

- The cervical esophagus is approached thru a 5-cm incision anterior to the left sternocleidomastoid muscle. The skin, subcutaneous tissues, and platysma are divided with electrocautery (**FIG 10**).
- The thin fascial layer surrounding the anterior border of the sternocleidomastoid muscle is incised with cautery.
- The dissection is carried medial and deep to the sternocleidomastoid muscle. The omohyoid muscle is identified and divided with cautery. The inferior thyroid artery and middle thyroid vein, if identified, are ligated with fine silk or absorbable suture.
- Dissection is carried medial to the carotid sheath with gentle lateral traction on the sternocleidomastoid and carotid sheath and medial traction on the trachea and thyroid. The recurrent laryngeal nerve (RLN)

A

B

FIG 10 ● Cervical skin incision and dissection. **A.** Location of cervical skin incision. **B.** Dissection thru platysma.

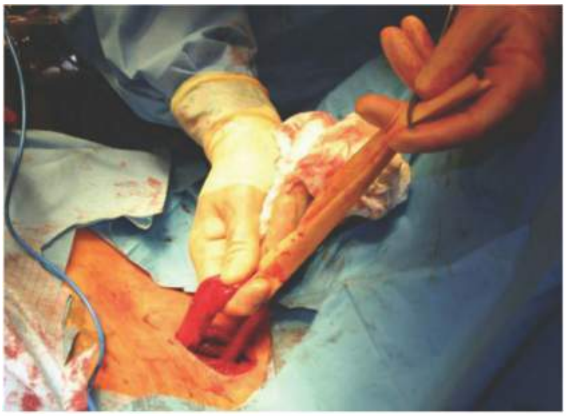


FIG 11 ● Dissection of the cervical esophagus is facilitated by placement of a Penrose drain around the esophagus after sharply dissecting the esophagus free of other vital cervical structures, including the RLN.

is identified and preserved adherent to the tracheoesophageal groove. Dissection is carried down to the prevertebral fascia allowing the surgeon to then pass the index finger between the prevertebral fascia and esophagus.

- The cervical esophagus is then sharply dissected from trachea, being careful to not dissect free nor injure the RLN. Once free of the trachea, a blunt right-angle clamp placed between the trachea and esophagus, rotated and advanced to the prevertebral fascia facilitates placement of a Penrose drain around the esophagus (**FIG 11**).
- Upward traction is placed on the cervical esophagus and blunt mediastinal dissection of the upper and middle third of the esophagus can ensue (**FIG 9**). The surgeon maintains contact between the volar aspect of the first two fingers and the esophagus at all times to the proper tissue plane of dissection. Again, a small-caliber bougie dilator placed in the esophagus facilitates tactile feedback of the esophagus.
- With anterior and upward traction of the cervical esophagus and caudal retraction on the stomach, a hand is inserted thru the hiatus posterior to the esophagus and is met by fingers inserted thru the neck incision down the prevertebral plane. Loose areolar attachments are divided until fingers meet.
- The same dissection is then performed anterior to the esophagus. When performing this dissection, the surgeon must maintain constant pressure on the esophagus to avoid injury to the membranous trachea. Both the anterior and posterior planes can usually be dissected relatively easily.
- Having freed the esophagus from its anterior and posterior attachments, the lateral attachments are then divided. This is often done with a combination of direct downward pressure on these attachments with the index finger from above or by placing the inferior index finger above the attachment pulling down along the insertion of the attachment into the esophagus.
- Alternatively, the bougie can be removed from the esophagus and the lateral attachments divided under direct visualization as the esophagus is retracted anteriorly out the cervical incision. Usually, some sort of bimanual dissection in the posterior mediastinum is required.
- At any point where this dissection proves difficult because of difficult adhesions; fused tissue planes especially in the vicinity of the membranous trachea, carina, and azygous vein; lack of mobility of the esophagus; or excessive bleeding, the blunt dissection should be abandoned and dissection under direct visualization performed via an incision in the right chest.

Removal of the Esophagus

- After complete mobilization of the esophagus, the cervical esophagus is delivered into the next for several centimeters and divided leaving approximately 20 cm of length to the esophagus. The remaining esophagus can subsequently be divided further at the time of anastomosis.
- A 1-in Penrose is affixed to the distal esophagus and the stomach and esophagus drawn down thru the hiatus dragging the Penrose thru the esophageal bed into the abdomen. This will allow the reconstruction conduit to be attached to the Penrose and delivered cephalad up into the cervical incision for subsequent anastomosis to the cervical esophagus (**FIG 12**).

FIG 12 ● Removal of the esophagectomy specimen thru the abdominal incision after attaching a Penrose drain to the cut distal end of the esophagus to guide advancement of the reconstruction conduit back up thru the esophageal bed in the posterior mediastinum.

RECONSTRUCTION: GASTRIC CONDUIT

Creation of Gastric Conduit

- After mobilization of the stomach, the gastric conduit is created. This is best done prior to completion of the mediastinal dissection so as to protect the conduit from trauma due to manipulation of stomach during dissection.
- The goals of creating the gastric conduit are as follows:
  - Create a gastric tube based on the greater curvature blood supply.
  - Create a gastric tube of sufficient length to reach into the cervical incision.
  - Divide the proximal stomach at a point assuring negative surgical margin, usually 5 cm distal to the GE junction along the greater curvature.
  - Resect the lesser curvature of the stomach to include the lesser curvature lymphatic drainage along the distribution of the left gastric artery.
- Six centimeters from the pylorus along the lesser curvature, roughly corresponding to the incisura angularis, the lesser curvature neurovascular pedicle is suture ligated. Careful attention is directed at preserving the integrity of the right gastric artery.
- Using a surgical stapling device, the stomach is divided from this point along the lesser curvature parallel to the greater curvature creating a 5-cm wide gastric tube (**FIG 13**). The division of the stomach is completed 5 cm from the GE junction along the greater curvature (**FIG 14**). For this step, a "thick" load of the stapling device is recommended.
- Length of the conduit is inspected by delivering the conduit over the patient's torso (**FIG 15**). The apex should reach to the sternal notch to be of sufficient length to reach into the cervical incision once brought thru the esophageal bed.
- The conduit should be inspected for viability. If the viability is in question, removal of some of the apex of the stomach may result in insufficient length forcing conversion to a transthoracic approach where gastric conduit length is less of a concern.

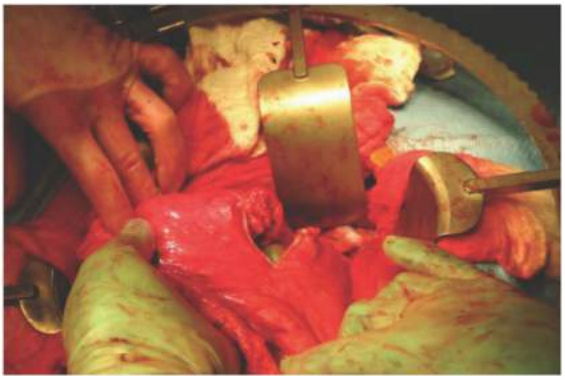
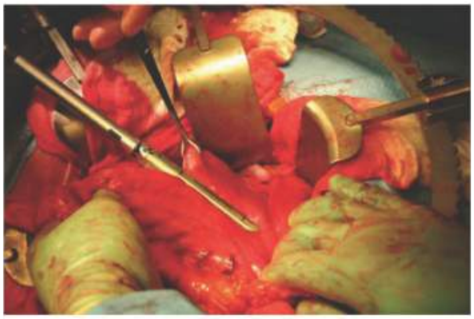


FIG 13 ● The gastric conduit is begun by ligating the lesser curvature neurovascular pedicle then starting the conduit staple line at the incisura angularis.



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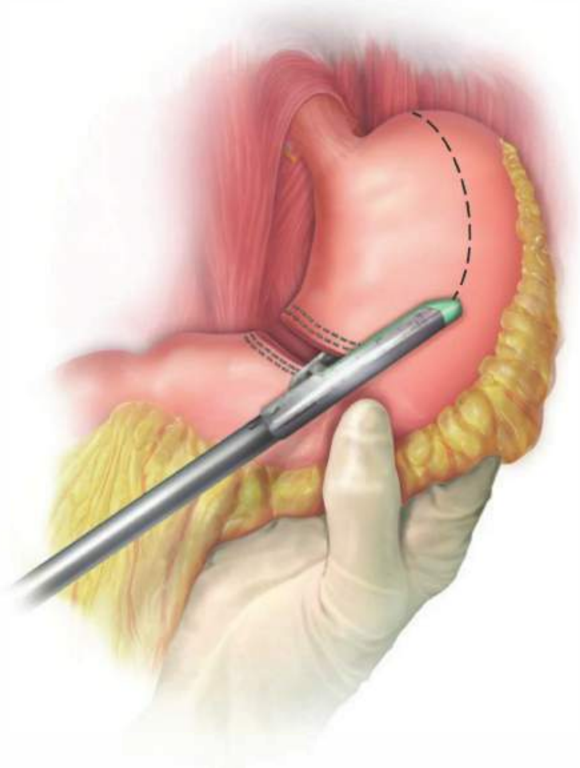


B

FIG 14 ● **A,B.** The staple line proceeds cephalad toward the hiatus giving rise to a 5-cm wide gastric conduit while removing the lesser curvature of the stomach and straightening the natural curvature of the stomach to optimize conduit length. The gastric staple line terminates 5 cm from the GE junction along the greater curvature of the stomach.

Gastric Drainage Procedure

- As the vagus nerves will be divided, a gastric drainage is usually necessary either in the form of a pyloromyotomy or pyloroplasty. With tubularization of gastric conduit, some have omitted this step as unnecessary.[7] In these patients, delayed gastric emptying can be managed postoperatively by endoscopic balloon dilation or botulinum toxin injection into the pylorus.

FIG 15 ● The completed gastric conduit.

- For pyloromyotomy, an incision measuring 1.5 cm along the stomach extending 1 cm along the anterior surface of the duodenum across the pylorus is made using the needle tip cautery. With a fine mosquito clamp, the pyloric muscle fibers are divided. An omental patch can be used to patch the exposed submucosa using a Graham patch technique.
- For pyloroplasty, a 4-cm full-thickness longitudinal incision is made beginning 2 cm proximal to the pylorus on the anterior stomach. This full-thickness incision is then closed transversely with interrupted full-thickness 3-0 silk suture (**FIG 16**).

Esophagogastrostomy

- The apex of the gastric conduit is then sutured to the end of the Penrose drain. The Penrose is then drawn up and out the cervical incision delivering the stomach into the neck. Typically, the stomach reaches with excess length permitting trimming of further stomach off the apex of the conduit. Similarly, the esophagus can be further trimmed and both additional specimens marked and sent for final proximal and distal margin analysis.
- The cervical anastomosis can be accomplished either by a hand-sewn or stapled approach.[8,9]
- For hand-sewn, two-layer anastomosis is performed with an outer layer of interrupted 3-0 silk suture in a seromuscular fashion and inner layer of running full-thickness monofilament absorbable suture. Others have described a single-layer anastomosis using monofilament absorbable running suture.
- For a stapled anastomosis, a stay suture of 2-0 silk is placed at the 6 o'clock position of the cervical esophagus. A 2-cm long longitudinal gastrotomy is made on the anterior surface of the gastric conduit close to the greater curvature. The 2-0 silk is then placed at the apex of this gastrostomy and tied to serve as stay suture holding orientation of cervical esophagus and gastric conduit for application of the stapler. A 45-mm stapler is advanced with one arm in the esophagus and the other in the stomach. The stapler is directed toward the right ear with the anastomosis placed along the greater curvature of the stomach. The remaining common enterotomy is closed in two layers with an inner layer of running full-thickness, 3-0 monofilament suture and an outer later of interrupted 3-0 silk suture in a seromuscular fashion (**FIG 17**).

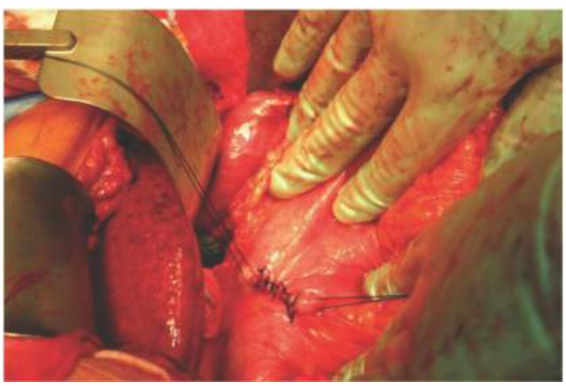
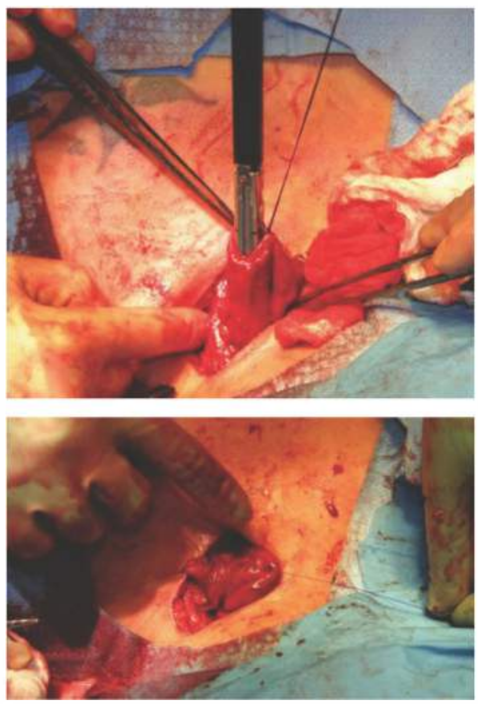


FIG 16 ● A Heineke-Mikulicz pyloroplasty is made by making a 4-cm longitudinal incision centered at the pylorus. This full-thickness incision is closed transversely with interrupted 3-0 silk sutures using a full-thickness bite.



A

B

FIG 17 ● **A.** Linear stapled esophagogastrostomy using a 45-mm line stapler in a side-to-side fashion. **B.** Suture closure of the anterior portion of the anastomosis or common enterotomy of the esophagogastrostomy.

- After completion of the anastomosis, careful caudal traction of the stomach at the hiatus is applied as the anastomosis is delivered back into the neck behind the trachea and excess redundancy of the conduit in the chest is straightened out.
- Either a nasojejunal feeding tube is placed or surgical jejunostomy tube placed for postoperative nutrition.
- The gastric conduit is anchored to the arch of the hiatus with interrupted 3-0 silk suture to prevent herniation.
- The soft closed suction drain is placed thru the thoracic inlet and delivered out onto the chest wall. The neck wound is closed by approximating the platysma muscle with interrupted suture and closing the skin with a running subcuticular suture of 3-0 monofilament absorbable suture. The abdominal wound is closed per routine.

RECONSTRUCTION: COLON CONDUIT

Mobilization of the Colon

- When performing a colon interposition for reconstruction following THE, the stomach is preserved other than the portion removed to assure adequate distal margins. This would include preservation of the left gastric artery. To facilitate use of the colon, however, complete gastric mobilization as discussed earlier is necessary as the preferred route for the colon is retrogastric to decrease tension on the conduit and blood supply.
- Complete colonic mobilization is required including mobilization of both the splenic and hepatic flexures. This often entails extension of the surgical incision below the umbilicus.
- Once mobilization is complete, verification of adequacy of blood supply for the subsequent conduit is needed even in the setting of preoperative angiography. This can be accomplished by serial ligation of the ileocolic artery, then right colic artery, and, if necessary, middle colic arteries with Bulldog clamps (**FIG 3**).
  - Angiographic arterial anatomy requirements for a successful left colic–based colon interposition reconstruction include a patent inferior mesenteric artery, patent ascending branch of the left colic artery, intact marginal artery anastomosis between the left colic (inferior mesenteric) and middle colic (superior mesenteric) arteries, single middle colic trunk prior to bifurcation into a right and left branch, and separate origin of the right colic artery.[10]
- To reach to the neck, a conduit based on the left colic artery branch of the inferior mesenteric artery and, if possible, middle colic arteries is needed. This entails delivering the colon in an isoperistaltic fashion to the neck with the cecum or proximal right colon serving as the proximal end of the colon conduit (**FIG 18**)
- If the blood supply is adequate for a left colic vascular based conduit, the ileocolic artery is ligated as low in the mesentery as possible, as is the right colic artery. The mesentery of the ascending colon is likewise divided to the level of the middle colic arteries.
- The terminal ileum is divided with a surgical stapler.
- The cecum is rotated up to the neck to verify adequate conduit length. If not, the middle colic branches can be divided as well (**FIG 19**).

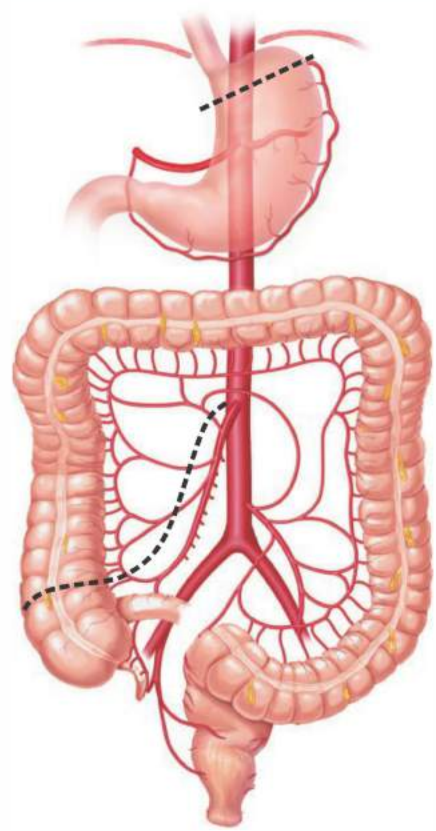


FIG 18 ● Creation of the colon conduit based on the left colic artery.

Delivery of Colon

- Once the colon is mobilized, the colon is delivered thru the hiatus in a fashion similar to the gastric conduit as discussed earlier. To decrease demands on conduit length, it is optimal to deliver the colon to the hiatus behind the stomach in a retrogastric position. Alternatively, the colon can be delivered thru a retrosternal pathway if the posterior mediastinum is no longer a viable option. The disadvantage of this route is increased demand on conduit and blood supply length.
- As there is typically adequate length to the colon conduit, the proximal end of the colon can be amputated back,

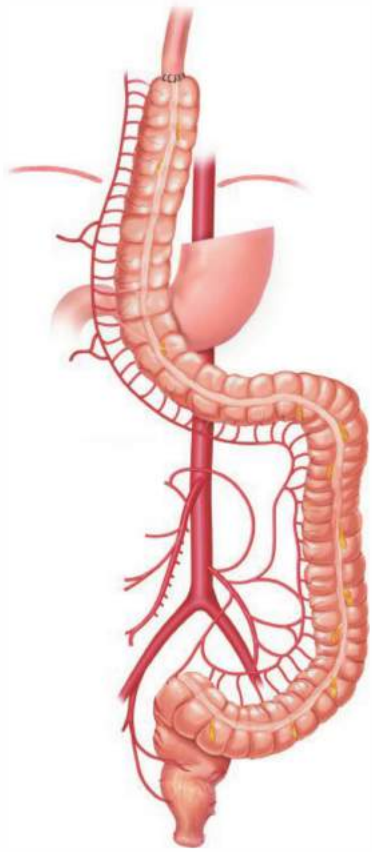


FIG 19 ● Delivery of the colon thru the mediastinum by rotating the cecum up thru the esophageal bed and out the cervical incision.

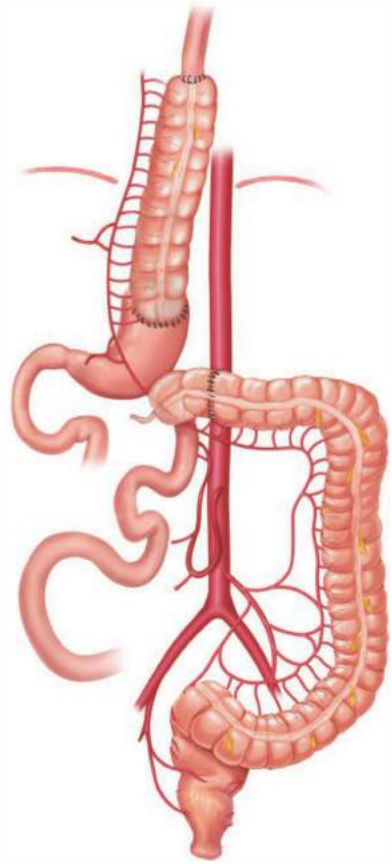


FIG 20 ● The completed reconstruction with both esophageal to colon and colon to stomach anastomoses.

usually removing the cecum. This has the advantage of decreasing the size differential between the cervical esophagus and colon as the colon narrows in luminal diameter and becomes thicker and more muscular. Also, as one moves distally on the colon, the reliance on mesenteric arcades for blood supply decreases.

Anastomoses

- The esophagus-to-colon anastomosis is accomplished in a similar fashion as described in the section on the use of the stomach as a conduit for reconstruction. This can be stapled using a linear stapler or hand sewn in either a one- or two-layer technique. Although circular staplers can be used, conduit length is often inadequate, making this awkward (FIG 20).
- The cervical anastomosis is drawn back in the neck by careful caudal traction on the colon at the hiatus.
- The colon is then divided at a point along the posterior stomach to permit a subsequent colon-to-stomach anastomosis. This is optimally done using a linear stapler joining the colon and stomach in a side-to-side fashion and closing the common enterotomy with an additional stapler load or hand-sewn closure.
- In manipulating the colon for this anastomosis, it is imperative to not disturb the mesentery of the colon out of concern for disrupting the mesenteric vessels.
- Enteric continuity is restored by completing the small bowel-to-colon anastomosis using surgical staplers in a standard fashion.
- A jejunostomy feeding tube is placed for nutritional support as is a cervical closed suction drain.
- A gastric drainage procedure is done if vagotomy was performed during the course of esophageal resection.

PEARLS AND PITFALLS

Indications	■ THE should only be performed for curative intent when treating malignancy. ■ NCCN guidelines should be followed as to preoperative evaluation, staging, and treatment algorithms.
Approach	■ THE should only be considered for patients with appropriate pathology (middle, lower third of the esophagus, and GE junction tumors). ■ In patients with unfavorable prior surgical history (prior gastric surgery rendering the gastric conduit inadequate) or locally advanced tumors that require a direct visualization of mediastinal dissection, a THE is contraindicated in favor of a transthoracic approach.
Gastric mobilization	■ Avoid any traction or direct trauma to the right gastroepiploic and right gastric artery pedicles so as to avoid disrupting these vessels or causing venous injury with resultant thrombosis as this will lead to graft failure. ■ Use of an electrosurgical device greatly improves efficiency and effectiveness of gastric mobilization.
Esophageal dissection	■ If excessive adhesions are encountered secondary to tumor extension or treatment effect or excessive bleeding is encountered with blunt dissection of the esophagus, a TTE should be performed. ■ A small-caliber bougie dilator (44 Fr) in the esophagus facilitates tactile localization of the esophagus during blunt dissection.
Reconstruction	■ Graft failure and anastomotic leak result from ischemia, which is a consequence of inadequate blood supply, venous congestion, tension on the anastomosis, or hypoperfusion in the early postoperative period. These factors should be avoided. ■ Proper orientation of the conduit with prevention of twisting is made easier by drawing parallel lines on the Penrose drain and making sure the drain does not twist as it is pulled out thru the neck delivering the conduit to the cervical incision.
Anastomosis	■ Proper orientation of the cervical anastomotic staple lines should be maintained to maximize perfusion of the gastric wall. This is accomplished by keeping the esophagogastrostomy staple line as far away from the conduit lesser curvature staple line. ■ When placing the anastomosis back in the neck, it should be straightened by reducing redundancy of the conduit by caudal traction on the conduit at the hiatus. Avoid placing tension on the anastomosis.

POSTOPERATIVE CARE

- Patients recover in the intensive care unit until acute cardiac, respiratory, and volume status issues are resolved.
  - As hypoxia and hypotension can lead to hypoperfusion of the reconstruction with anastomotic leak or, in the worst scenario, conduit necrosis, this should be avoided and quickly remedied if clinically encountered.
  - As respiratory failure and pneumonia are the most common complications encountered, aggressive pulmonary care is required. Early ambulation is mandatory.
  - Fluid overload can lead to hypoxia, pulmonary edema, and dysrhythmia (most often atrial fibrillation).
- Enteric nutrition is begun slowly on postoperative day 1.
- Patients should be carefully followed for signs of postoperative complications (see the following text) and evaluation and mitigation strategies employed at the first sign of such issues.
- If the patient is medically stable to consider oral intake, a water-soluble contrast study followed by barium is done on the fourth postoperative day to make sure there is no significant anastomotic leak and the conduit empties adequately into the small intestine.
- If ok, a liquid diet is started and continued for 2 weeks at which time the patient is transitioned to a soft diet for an additional 2 weeks prior to resuming a normal diet. The rationale for this approach is to avoid food impaction during the critical period of anastomotic healing. The surgical drain is removed after a negative study and no evidence of oral fluids in the drain within 48 hours of oral liquid intake.
- The feeding tube is discontinued when the patient is able to take adequate oral intake, usually within the first to second week following surgery.
- Patients should be counseled as to how to optimize their fluid and nutritional intake during this period of transition to regular diet and manage dumping symptoms with dietary and lifestyle modification.
- Patients should be advised as to the early signs of anastomotic stricture and need for esophageal dilation.

OUTCOMES

- THE is a very morbid, high-risk procedure with very high associated operative morbidity and mortality (see the following text).
- Regarding functional outcome, the best data available are reviews from patients who underwent this procedure for benign indications and early stage cancer given the longer survival in these patients compared to patients with cancer.[11,12]
  - Symptoms of physical impairment, including GE reflux, dumping, and dysphagia, are very common after surgery but show gradual improvement toward baseline over the first year, not quite reaching baseline. Long-term physical impairment is less common after THE compared to TTE.
  - Overall health-related quality of life (ability to work, social interaction, daily activities, emotional function, perception of health, energy level, and mental health) decreases after surgery but returns to baseline national norms within 1 year of surgery.

- Regarding cancer-specific outcome, long-term survival is a function of the underlying biology and stage of the tumor rather than surgical approach.[13,14]

COMPLICATIONS

- Perioperative complications occur in 40% to 50% of patients and fall into specific categories depending on the point of time in which they appear following surgery. Reported overall 30-day mortality for THE ranges from 1% in select single center reports to 10% in nonselective administrative database reports.[13,15,16]
- Early postoperative period (0 to 2 days)
  - Technical complications
    - Bleeding
    - RLN injury with resultant hoarseness (unilateral) and airway obstruction (bilateral)
    - Pleural violation with pneumothorax or pleural effusion
    - Conduit necrosis requiring removal of conduit and cervical esophagostomy
  - Medical complications
    - Respiratory complications (respiratory failure, pneumonia)
    - Cardiac complications (dysrhythmia, myocardial infarction, heart failure)
    - Urinary tract complications (renal failure or insufficiency)
- Intermediate postoperative period (2 to 14 days)
  - Technical complications
    - Anastomotic leak manifest as cervical wound infection and drainage or drainage of oral secretions via closed suction drain.
    - Conduit necrosis requiring removal of conduit and cervical esophagostomy
    - Thoracic duct injury with chyle leak, usually manifest by pleural effusion at onset of enteric or oral nutrition.
  - Medical complications
    - Respiratory complications (respiratory failure, pneumonia)
    - Cardiac complications (dysrhythmia, myocardial infarction, heart failure)
    - Urinary tract complications (renal failure/insufficiency, urinary tract infection)
    - Infectious complications, (line infection, organ space infection, wound infection)
- Late postoperative period (after 14 days)
  - Technical complications
    - Anastomotic stricture
    - Delayed gastric emptying
    - Dumping syndrome
  - Medical complications
    - Malnutrition
    - Cancer recurrence

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Chapter 30

Ivor Lewis Esophagectomy

Robert E. Merritt

DEFINITION

- An Ivor Lewis esophagectomy is defined as a resection of the esophageal tumor using a laparotomy incision and a right thoracotomy. The esophagogastric anastomosis is performed in the right thoracic cavity. This surgical approach is appropriate for patients with resectable tumors in the middle and distal third of the esophagus as well as the gastroesophageal junction.

PATIENT HISTORY AND PHYSICAL FINDINGS

- Patients who present with esophageal carcinoma should undergo a complete history and physical examination.
- Patients often complain of dysphagia to solid food and liquids. This symptom is related to esophageal obstruction from a bulky tumor.
- Barrett's intestinal metaplasia or gastroesophageal reflux disease (GERD) may precede the diagnosis of esophageal cancer.
- Significant weight loss is a common symptom of patients with esophageal cancer. The weight loss may be secondary to poor oral intake related to dysphagia or cancer cachexia.
- The cervical lymph nodes and supraclavicular lymph nodes should be thoroughly examined during physical examination. The cervical and supraclavicular lymph nodes are a common site for metastatic spread from esophageal carcinoma.

IMAGING AND OTHER DIAGNOSTIC STUDIES

- An esophagogastroduodenoscopy (EGD) should be performed on every patient with esophageal carcinoma (**FIG 1**). Upper endoscopy allows access to the tumor for diagnosis and determination of the histologic subtype (adenocarcinoma vs. squamous cell carcinoma). The location of the tumor is also important to determine whether an Ivor Lewis esophagectomy would be feasible. Esophageal tumors in the proximal third of the esophagus would require a transhiatal or three-field esophagectomy with a cervical esophagogastrostomy anastomosis.
- Endoscopic ultrasound (EUS) is a critical staging technique for esophageal cancer (**FIG 2**). The EUS determines the depth of invasion of the tumor into the esophageal wall (T stage). Esophageal tumors that penetrate through the esophageal wall are considered locally advanced and have a high propensity to metastasize to locoregional lymph nodes. Periesophageal lymph nodes that are enlarged can be visualized with EUS and fine needle aspiration biopsy can be performed to determine locoregional lymph node involvement. Patients with biopsy-proven lymph node involvement will typically be referred for preoperative chemotherapy or combined chemoradiation.

FIG 1 ● An upper endoscopy demonstrating a large distal esophageal carcinoma. An endoscopic biopsy was consistent with a moderately differentiated adenocarcinoma.

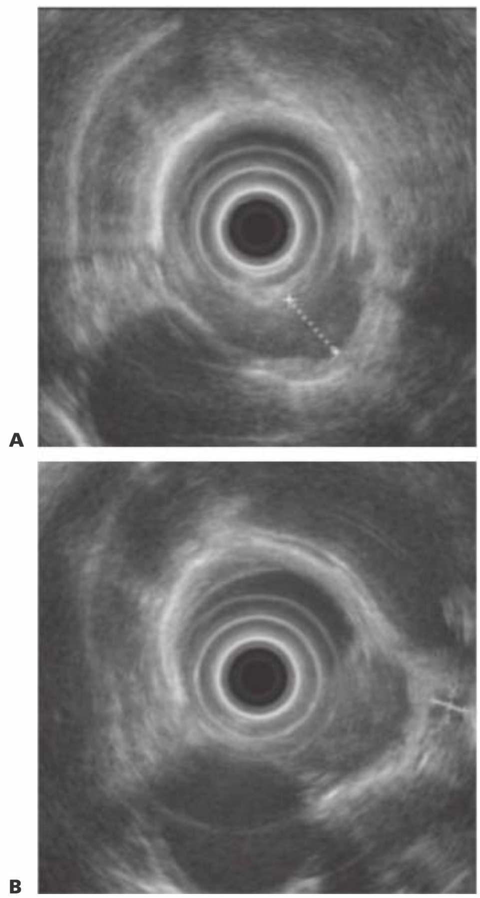

FIG 2 ● **A.** An EUS image demonstrating a T3 esophageal carcinoma with extension into the adventitia. **B.** Demonstration of a peritumoral lymph node.

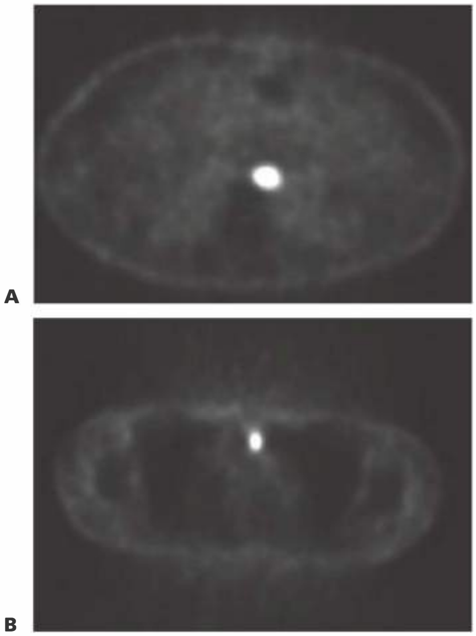

FIG 3 ● **A.** The first PET image demonstrates a hypermetabolic esophageal carcinoma located in the distal third of the esophagus. **B.** The second PET image demonstrates a hypermetabolic cervical lymph node that represents distant metastatic disease.

- All patients who are being considered for esophagectomy should undergo a computed tomography (CT) scan of the chest, abdomen, and pelvis to evaluate the primary tumor in the esophagus and the locoregional lymph nodes. The liver, celiac lymph nodes, bone, and adrenal glands are common sites for metastatic disease secondary to esophageal carcinoma. Positron emission tomography (PET) is an essential staging technique for esophageal carcinoma (**FIG 3**). PET scans can detect occult metastatic disease that was not identified on standard CT scans in about 10% to 15% of cases. This detection of occult metastatic disease will prevent patients with stage IV esophageal carcinoma from undergoing an unnecessary esophageal resection.

SURGICAL MANAGEMENT

Preoperative Planning

- Any patient who is being evaluated for an Ivor Lewis esophagectomy should undergo a complete and thorough cardiopulmonary evaluation prior to the operation. Cardiac disease and respiratory compromise should be identified in the preoperative period to properly access perioperative risk of complications and mortality.
- Pulmonary function tests should be obtained to measure the forced expiratory volume in 1 second (FEV_1) and diffusion capacity. Patients with a history of chronic obstructive pulmonary disease (COPD) will have diminished values for FEV_1 and diffusing capacity of lung for carbon monoxide (DLCO); therefore, they will be at increased risk for perioperative respiratory complications.
- A transthoracic echocardiogram is obtained to assess the left ventricular ejection fraction left ventricular wall motion. A treadmill stress test should be obtained when the echocardiogram findings are abnormal.
- Prior to surgical resection, a patient's nutritional status should be optimized. A preoperative feeding access for enteral nutrition may be necessary in cases of severe malnutrition. A prealbumin level can be measured to further assess the patient's nutritional status.
- Perioperative antibiotics should be given within 30 minutes of the first incision. Compression boots are placed on the lower extremities and subcutaneous unfractionated heparin is given to minimize the risk of postoperative deep venous thrombosis (DVT).
- An arterial line and central venous catheter should be placed for intraoperative hemodynamic monitoring.
- An epidural catheter should be placed for postoperative pain management. Epidural infusion of local anesthetic minimizes postthoracotomy pain and allows patients to participate in pulmonary toilet exercises.

Positioning

- The Ivor Lewis esophagectomy technique uses two incisions. Patients are positioned in the supine position first for the midline laparotomy incision (**FIG 4**). The second portion of the operation is performed through a right posterior lateral thoracotomy (**FIG 5**). Patients are positioned in the left lateral decubitus position. A beanbag is used to help hold patients into position. The operating room bed is flexed to open the rib spaces.

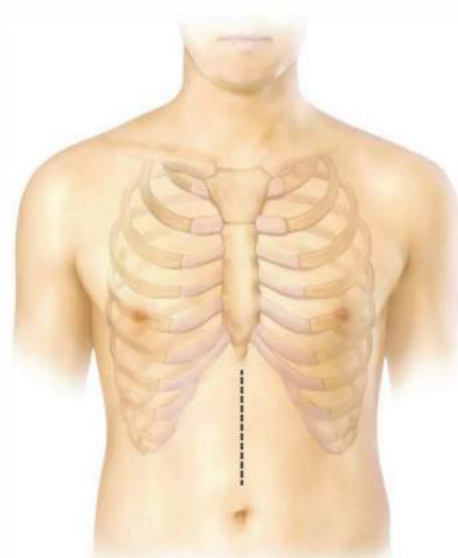

FIG 4 ● A midline laparotomy incision is located between the xiphoid and the umbilicus.

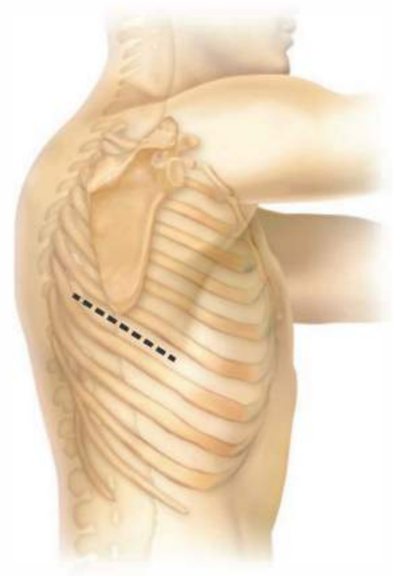

FIG 5 ● A standard posterior lateral thoracotomy incision provides excellent exposure of the intrathoracic esophagus.

MOBILIZATION OF THE GASTRIC CONDUIT

- The patient is positioned supine on the operating table. A double lumen endotracheal tube is placed for single lung isolation. An arterial line, central venous catheter, and epidural catheter are placed by the anesthesia team. Compression boots and subcutaneous heparin are given for DVT prophylaxis.
- A midline laparotomy incision is performed from the xiphoid down to the umbilicus. A full inspection of the abdominal cavity is performed to rule out tumor dissemination on peritoneal surfaces or liver metastasis. A Bookwalter retractor is used to provide exposure. The triangular ligament of the left lobe of the liver is divided and the left lateral segment is retracted cephalad to expose the esophageal hiatus.
- The dissection of the gastric conduit begins by entering the lesser sac along the great curvature of the stomach. The right gastroepiploic artery should be identified and preserved. The greater omentum is divided along the greater curvature of the stomach with an ultrasonic dissector by divided branches of the right gastroepiploic arcade and carefully preserving the gastroepiploic trunk (**FIG 6**).
- The gastrocolic omentum is divided toward the duodenum. The stomach is retracted upward and any adhesions between the stomach and pancreas should be carefully divided (**FIG 7**). The duodenum is then mobilized with the Kocher maneuver.

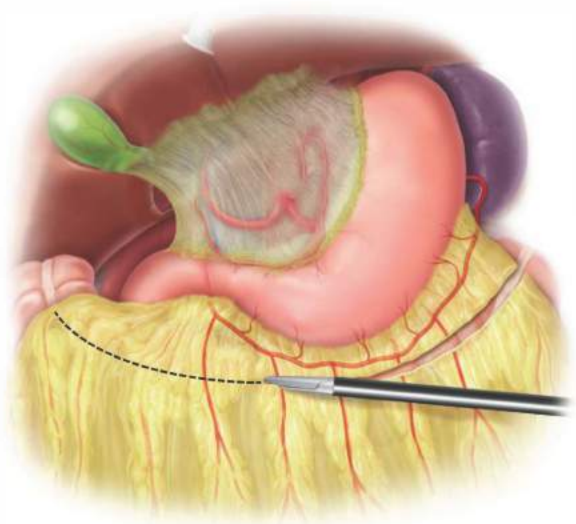

FIG 6 ● The division of the gastrocolic ligament along the great curvature of the stomach. The right gastroepiploic artery is preserved.

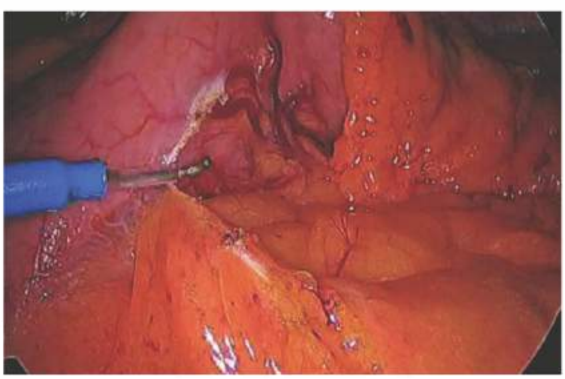

FIG 7 ● Mobilization of stomach.

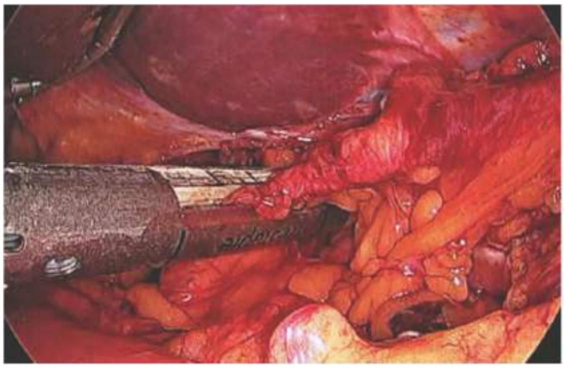

FIG 8 ● Division of left gastric artery.

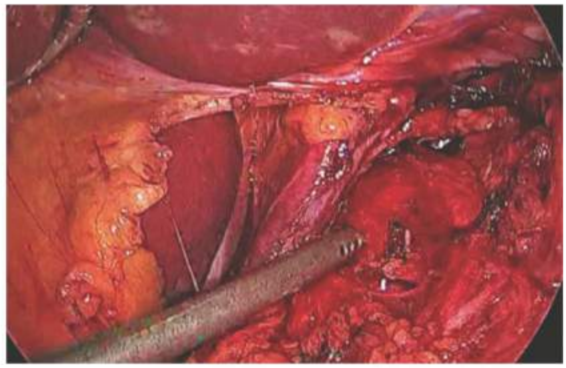

FIG 9 ● Dissection of the hiatus.

- The short gastric vessels are ligated using the ultrasonic dissector. The short gastric vessels should be ligated close to the spleen to avoid thermal injury to the stomach.
- The lesser omentum is then divided toward the esophageal hiatus. A replaced left hepatic artery should be identified and preserved if present. The right gastric artery can be preserved in most cases when the anastomosis is performed in the right thorax.
- The left gastric pedicle is identified along the lesser curvature of the stomach. The left gastric pedicle is divided at the origin from the celiac axis using an Endo GIA linear stapler. The surrounding adipose tissue and lymph nodes should be swept upward prior to ligation of the left gastric pedicle (FIG 8).
- The crura of the diaphragm are identified and the distal esophagus should be visualized. The phrenoesophageal membrane is then divided to facilitate mobilization of the esophagus around the esophageal hiatus (FIG 9). The right crus of the diaphragm are divided if necessary to permit four fingers to fit into the opened esophageal hiatus. This prevents compression of the esophageal conduit and possible ischemia.

FORMATION OF THE GASTRIC CONDUIT

- The Endo GIA linear stapler is used to divide the stomach along the lesser curvature. The staple line is started along the lesser curvature just proximal to the right gastric artery (FIG 10). The staple line should end between the cardia and the fundus. The staple line is oversewn with multiple interrupted 3-0 silk sutures to cover the staple line with serosa. The gastric tube should be 5 to 6 cm in width.
- The gastric tube is secured to the remnant of the gastric cardia with two interrupted 0-silk sutures. This will allow the gastric conduit to be pulled into the chest along with the esophagogastric specimen.

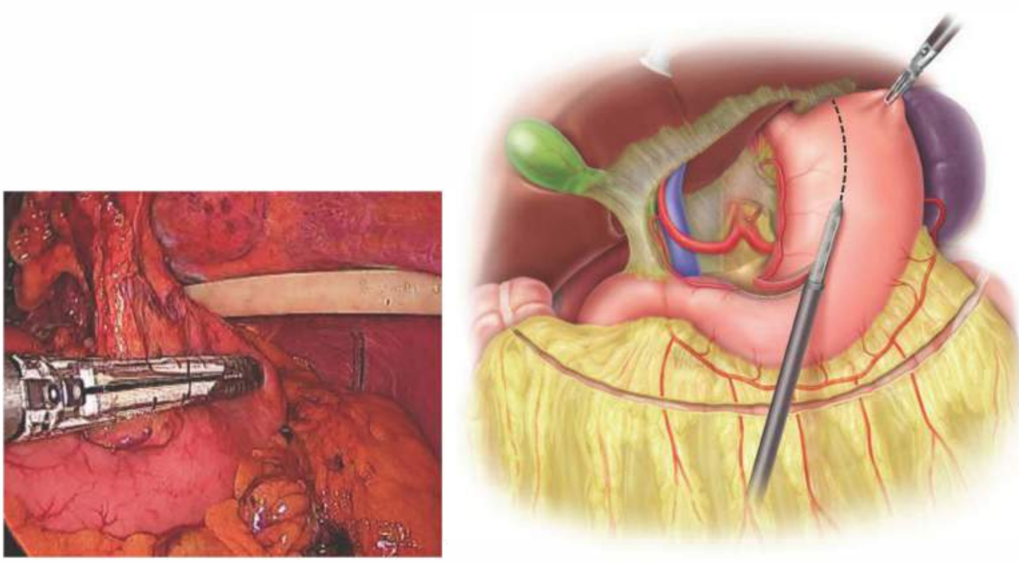

FIG 10 ● **Left and Right:** The formation of the gastric conduit using a linear endoscopic stapler. The gastric conduit should be 5 to 6 cm in diameter.

HEINEKE-MIKULICZ PYLOROPLASTY

- The pylorus muscle is identified with direct palpation at the border of the antrum of the stomach and the first portion of the duodenum. The pylorus muscle is incised longitudinally using the cautery and ultrasonic dissector. The incision is carried through the mucosal layer. The incision is then closed transversely with interrupted 4-0 Vicryl sutures and second layer of 3-0 silk sutures.

JEJUNOSTOMY FEEDING TUBE

- The ligament of Treitz is identified at the root of colon mesentery. The jejunostomy tube is placed in the proximal jejunum about 30 to 40 cm from the ligament of Treitz. A purse-string suture is placed on the serosa of the jejunum using a 4-0 chromic suture. A small enterotomy is created within the purse string. A 10-Fr jejunostomy tube is placed through the abdominal wall and into the jejunum. The purse-string suture is tied and the jejunostomy site is covered with multiple 3-0 silk sutures to imbricate the serosa.
- The jejunostomy insertion site is then secured to the abdominal wall with four interrupted 2-0 silk sutures. The jejunostomy tube site on the abdominal wall should not be twisted to avoid postoperative bowel obstruction or ischemia.

THORACIC MOBILIZATION OF THE ESOPHAGUS

- A right posterior lateral thoracotomy is performed and the right chest is entered through the 5th intercostal space. The serratus anterior muscle is preserved.
- The right lung is isolated with a double lumen chest tube and the right lung is retracted anteriorly.
- The inferior pulmonary ligament is incised with cautery and the level 9 lymph nodes are harvested. The mediastinal pleura along the anterior esophagus is incised with the cautery. The distal esophagus is dissected from the pericardium and the aorta posteriorly (**FIG 11**). The esophagus is then encircled with a 1-in Penrose drain.
- The esophagus is mobilized from the esophageal hiatus to the azygous vein (**FIG 12**). The ultrasonic dissector or LigaSure device can be used to divide small vessels and lymphatics. The thoracic duct should be suture ligated if the structure is injured during the esophageal dissection. The thoracic duct enters the right thorax through the aortic hiatus and is usually located between the azygous vein and the aorta. The thoracic duct crosses over to the left side at T4-T5 and passes behind the aortic arch. The thoracic duct passes posteriorly to the left carotid sheath and drains into the junction of the left jugular and subclavian vein.
- The azygous vein is routinely dissected and divided with an Endo GIA linear stapler. The esophagogastric anastomosis is usually performed at the level of the azygous vein. In cases where the esophageal tumor is located in midesopahgus, the esophageal dissection may have to be carried more proximally toward the thoracic inlet.

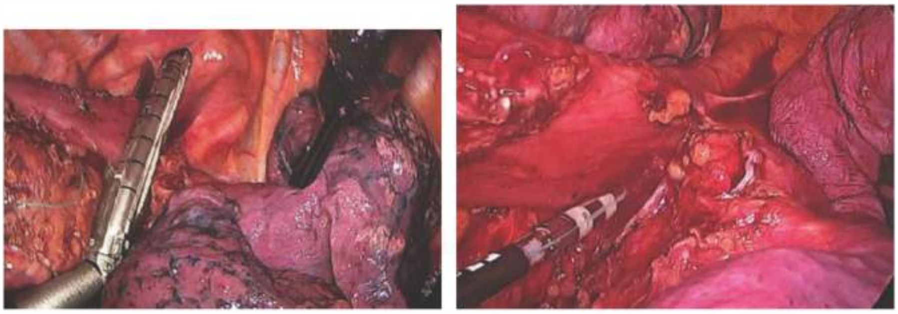

FIG 11 ● Dissection **(left)** and mobilization **(right)** of the esophagus.

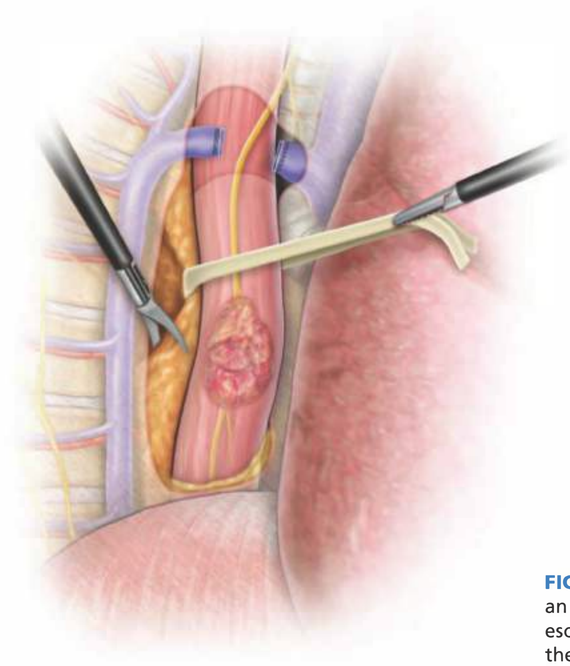

FIG 12 ● The mobilization of the intrathoracic esophagus using an ultrasonic dissector. The azygous vein is routinely divided. The esophagogastric anastomosis is usually performed at the level of the azygous vein.

ESOPHAGOGASTRIC ANASTOMOSIS

- The gastric conduit is pulled into the right chest and the sutures attaching to the esophagogastrectomy specimen are divided (**FIG 13**). The esophagus is divided 2 cm above the azygous vein with an Endo GIA linear stapler (**FIG 14**). The proximal esophageal margin and distal gastric margin are evaluated with frozen section.
- The 2-0 Prolene purse-string suture is placed through the mucosa and muscular layers of the esophagus. A 25-mm or 28-mm anvil is placed in the esophageal lumen and the purse-string suture is tied around the shaft of the anvil. A second purse-string suture is placed as well.
- A gastrotomy is performed along the proximal lesser curvature of the gastric conduit. An end-to-end anastomosis (EEA) circular stapler is inserted through the gastrotomy and the pin is deployed proximally along the great curvature. The anvil and EEA stapler are connected and the stapler is deployed (**FIGS 15** and **16**).
- The esophagogastric anastomosis should be inspected and checked for completeness (**FIG 17**). The "doughnuts" should be complete to ensure esophageal and gastric mucosal apposition. A nasogastric tube is then passed under direct vision.
- The gastrotomy site is resected with one to two applications of the Endo GIA stapler (**FIG 18**). The staple line is oversewn with interrupted 3-0 silk sutures.
- The anastomosis is reinforced with 3-0 silk sutures placed between the muscular layer of the esophagus and the serosa of the gastric conduit.
- A pleural flap is harvested and used to wrap the esophagogastric anastomosis. Omentum or intercostal muscle flaps could be used as alternatives for coverage of the esophagogastric anastomosis.

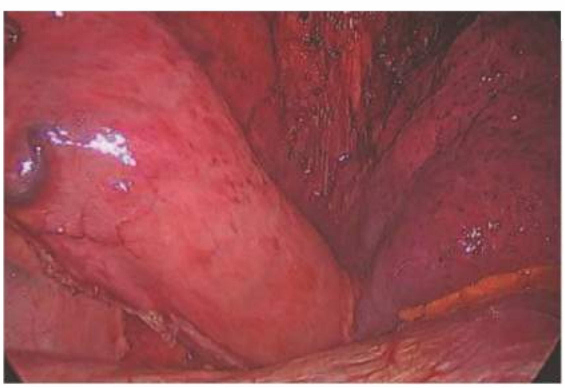

FIG 13 ● Conduit through hiatus.

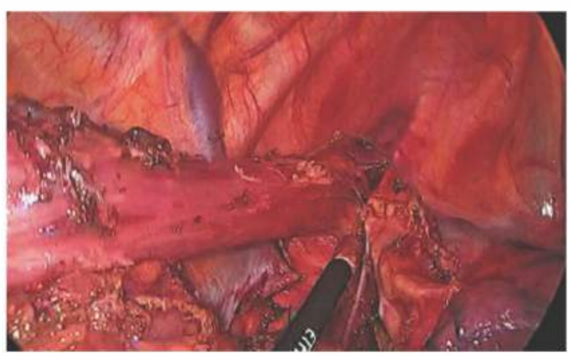

FIG 14 ● Proximal esophagus.

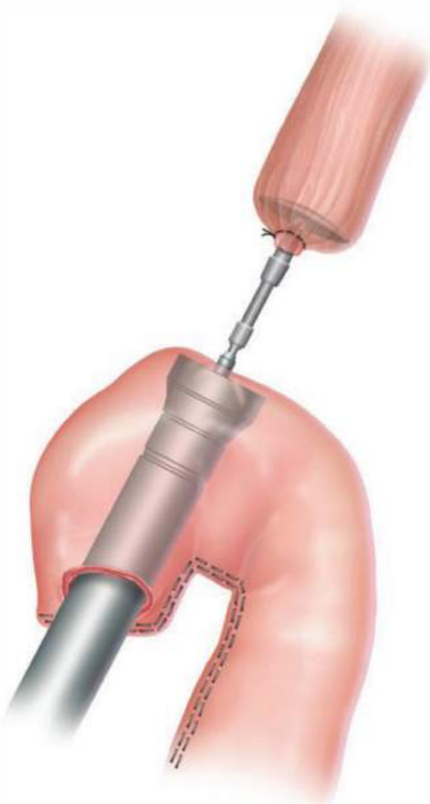

FIG 15 ● The formation of the esophagogastric anastomosis using a circular EEA stapler.

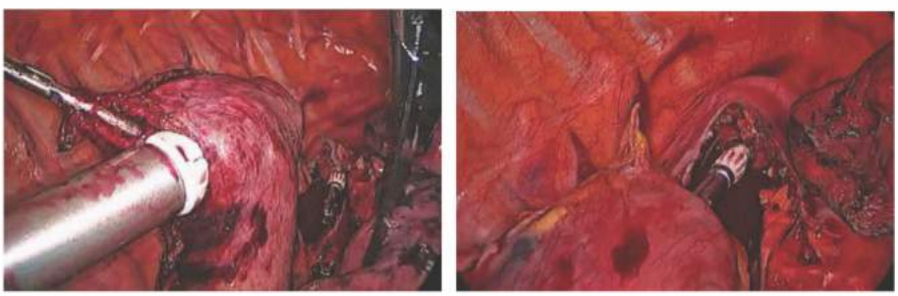

FIG 16 ● EEA in conduit **(left)** with anvil in esophagus **(right)**.

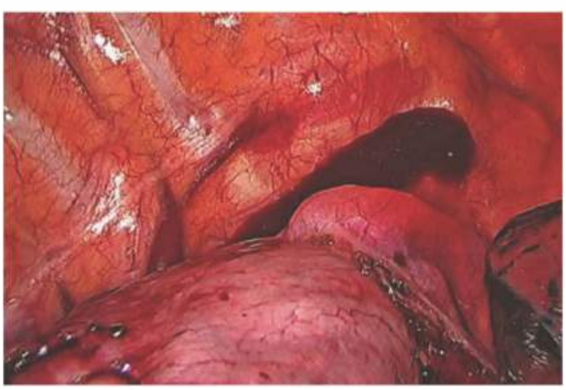

FIG 17 ● Anastomosis.

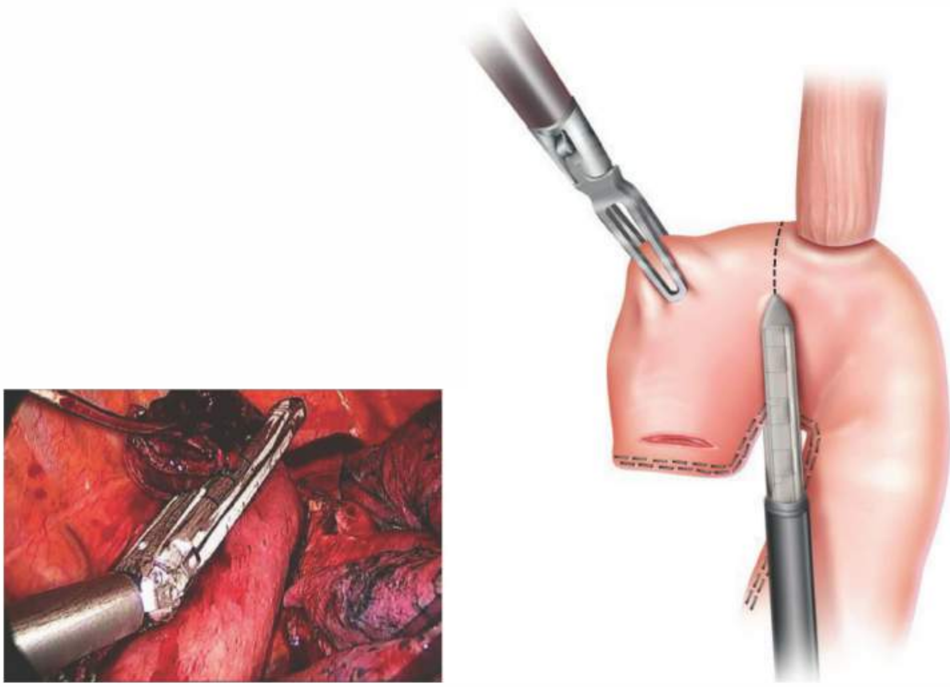

FIG 18 ● The completion of the esophagogastric anastomosis with resection of the gastrotomy site (**left**) with a linear endoscopic stapler (**right**).

PEARLS AND PITFALLS

Preoperative evaluation	▪ Preoperative staging should include a PET/CT scan and EUS. Patients with transmural tumors and nodal disease benefit from preoperative chemotherapy and radiation. ▪ Patients with a history of previous gastric surgery may require the use of a colonic or jejunal conduit. ▪ Patients should undergo pulmonary function tests and echocardiography to assess perioperative risk.
Mobilization of the stomach	▪ The right gastroepiploic artery and vein must not be injured. The primary blood supply to gastric conduit is derived from this vascular arcade. ▪ The gastric conduit should be 4 to 5 cm in diameter. ▪ The gastric conduit tip could be ischemic and should be resected if there is necrosis detected.
Esophagogastric anastomosis	▪ The anastomosis should be covered with a vascularized pedicle, such as omentum, pleura, or intercostal muscle. An anastomotic leak within the thorax could result in life-threatening mediastinitis. ▪ A two-layer anastomosis should be performed regardless of the technique.
Postoperative care	▪ Postoperative barium esophagram should be obtained 5 to 7 days after the procedure to evaluate the integrity of the esophagogastric anastomosis. Contained leaks can be managed with bowel rest and antibiotics. Large leaks typically require operative repair.

POSTOPERATIVE CARE

- Patients should be extubated in the operating room if possible. A chest radiograph is obtained in the recovery room or intensive care unit (ICU). An epidural catheter is used to administer local anesthesia for optimal pain control and pulmonary toilet.
- The nasogastric tube is placed on low continuous suction to avoid gastric stasis and aspiration.
- Fluid balance should be closely monitored to avoid volume overload and respiratory complications.
- Enteral nutrition can be initiated on postoperative day 3 to minimize perioperative malnutrition.

- A barium swallow study is obtained on postoperative days 5 to 7 to assess the anastomosis for a leak. A liquid diet can be initiated if the barium study is negative for a leak. The diet is slowly advanced to a soft mechanical diet.
- Patients are typically discharged when they are tolerating a soft diet and are able to ambulate without difficulty.

OUTCOMES

- In modern surgical series for Ivor Lewis Esophagectomy, the perioperative mortality rates range from 1.4% to 4.4%. The anastomotic leak rates range from 0% to 3.5%. The overall morbidity rates range from 26.6% to 45%.
- The overall 5-year survival rate for patients undergoing Ivor Lewis esophagectomy ranges from the 25.2% to 33.3%. Patients with positive nodal disease have a worse prognosis compared to patients with negative nodal disease.

COMPLICATIONS

- Pneumonia
- Anastomotic leak
- Thoracic duct injury and chyle leak
- Delayed gastric emptying
- Reflux
- Aspiration pneumonitis
- Pulmonary embolism
- Acute myocardial infarction

SUGGESTED READINGS

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5. Griffin SM, Shaw IH, Dresener SM. Early complications after Ivor Lewis subtotal esophagectomy with two-field lymphadenectomy: risk factors and management. *J Am Coll Surg*. 2002;194:285–297.
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Chapter 31

Minimally Invasive Esophagectomy

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DEFINITION

- The incidence of esophageal cancer, especially adenocarcinoma, has increased dramatically over the past decades. This phenomenon is secondary to the increasing incidence of obesity contributing to rising rates of reflux and Barrett's esophagus in the United States.

PATIENT HISTORY AND PHYSICAL FINDINGS

- Patients with esophageal malignancy present with progressive dysphagia and weight loss. The incidence is higher in men and in smokers. Patients often have a long-standing history of gastroesophageal reflux symptoms. The physical examination is usually unremarkable.

IMAGING AND OTHER DIAGNOSTIC STUDIES

- All patients with dysphagia should be evaluated with an upper endoscopy and biopsy of suspicious lesions. Patients with biopsy-proven carcinoma are staged to determine treatment. The staging process includes computed tomography (CT) of the chest and abdomen, an integrated positron emission tomography (PET)/CT, and endoscopic ultrasound. Patients with T3 or N1 disease are treated with neoadjuvant chemoradiation and restaged prior to resection.

SURGICAL MANAGEMENT

Preoperative Planning

- If the patient is unable to maintain adequate nourishment during neoadjuvant therapy or is malnourished and too weak for resection, we place a jejunostomy tube (J-tube), preferably with a laparoscopic approach. This allows for staging and the ability to rule out metastatic disease. A percutaneous endoscopic gastrostomy tube should be avoided in any patient that is being considered for esophageal resection. Additionally, having the J-tube placed up front minimizes the abdominal portion of the esophageal resection procedure.

Positioning for the Abdominal Portion

- The patient is positioned in the supine position with both arms tucked and a Foley catheter in place. We do not routinely use an arterial line or a central line. A nasogastric tube (NGT) is routinely placed. If one is placed, care must be taken to pull it far back into the esophagus as well as to remove all esophageal temperature probes or other devices prior to stapling the stomach. If body habitus or other concerns prevent arm tucking, it is not a necessity.

TECHNIQUES

PORT PLACEMENT

- A Veress needle entry technique is used to place a 5-mm trocar approximately 15 cm inferior to the xiphoid and 3 cm to the left of the midline. The abdomen is then inspected for evidence of distant disease and any suspicious areas are biopsied and sent for frozen section. Four additional trocars are placed: (1) 12-mm trocar is placed 7 cm inferior to the right costal margin and 3 cm from the midline, (2) 5-mm trocar is placed 6 cm superior to the 12-mm trocar and usually to the right of the falciform ligament, (3) 5-mm trocar just off midline to the right and inferior to the base of the xiphoid to retract the left lateral segment of the liver. A 5-mm locking grasper positioned underneath the left lateral segment of the liver and the diaphragm is grasped anterior and to the right of the esophageal hiatus taking care to avoid the phrenic vein, and (4) 5-mm trocar 2 cm below the left costal margin in the anterior axillary line (**FIG 1**).
- The patient is positioned in moderate reverse Trendelenburg position. The surgeon stands on the patient's right side and uses the two right-sided ports. The assistant stands on the patient's left and uses the left subcostal port and camera port.

FIG 1 ● Abdominal port placement for gastric mobilization.

CRURAL DISSECTION AND ESOPHAGEAL MOBILIZATION

- The gastrohepatic ligament is divided using an ultrasonic dissector. The right crus of the diaphragm can then be identified at the esophageal hiatus. The phrenoesophageal ligament is divided anteriorly, taking care to follow the stomach toward the angle of His, lateral and inferior to the left esophageal crus. The crura are dissected circumferentially and the esophagus is isolated.
- Once the retroesophageal window is completed, a Penrose drain is placed around the gastroesophageal junction. The two tails are sutured together with a single 2-0 Vicryl stitch to use as a handle to assist in the crural dissection and for intrathoracic pull-up and manipulation during the second portion of the procedure (**FIG 2**). Dissection of the lower 5 to 7 cm of the esophagus is then performed while the assistant places the Penrose on traction. This can mostly be performed with blunt dissection. If the left pleural space is entered, we place a chest tube at the completion of the abdominal portion of the operation. Radiation changes can make this part of the dissection more difficult.

FIG 2 ● Placement of a Penrose around the gastroesophageal junction. It is important to suture the Penrose so that it can be used to help deliver the conduit into the chest.

GREATER CURVATURE DISSECTION

- On the distal aspect of the greater curvature of the stomach approximately 5 cm proximal to the pylorus, the greater curvature is grasped and elevated anteriorly by the surgeon's left hand and the assistant places the transverse colon on downward traction. The surgeon divides the gastrocolic ligament well inferior to the projected course of the right gastroepiploic vessels. Because the right gastroepiploic vessels will serve as the primary blood supply for the gastric conduit, great care is taken to avoid injuring these vessels during greater curvature dissection (**FIG 3**).
- The lesser sac is entered at least 1 to 2 cm inferior to the right gastroepiploic vessels projected course. Once the lesser sac is entered, the posterior stomach wall is grasped and elevated anteriorly and to the patient's right side with the surgeon's left hand to open the dissection tension plane. This maneuver positions the gastroepiploic vessels anteriorly and helps protect them from injury due to inadvertent grasping (**FIG 4**).
- Dissection is then carried proximally, taking care to stay superior to the transverse colon as it courses toward the splenic flexure. This is accomplished by lifting the posterior stomach wall anteriorly and toward the patient's right side with the surgeon's left hand while the assistant retracts the greater omentum inferiorly and to the patient's left. The proximal aspect of the greater curvature is mobilized by dividing all short gastric vessels until the left crus of the diaphragm is reached. If there is excess omentum impeding the view, we will place a "fat stay" using a 2-0 Vicryl suture on an MH needle. The suture is placed through the fat, the needle is removed, and the assistant grasps both ends of the suture and extracts them through the left-sided trocar. The trocar is then removed and reinserted so that the suture comes through the track but not the trocar. Tension is placed on the suture until the fat is retracted; then, the suture is secured with a hemostat at the level of the skin.
- We leave some omentum along the superior aspect of the greater curvature of the stomach to be used to buttress the intrathoracic anastomosis.

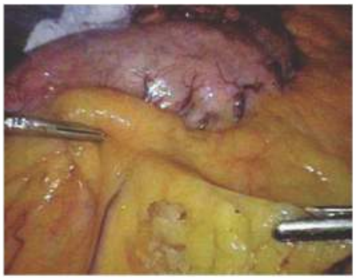


FIG 3 ● Identification of the right gastroepiploic vessels adjacent to the greater curvature and entering the lesser sac.

FIG 4 ● Grasp the posterior wall of the stomach inferiorly through the lesser sac, rolling the gastroepiploic vessels onto the anterior stomach wall. This assists in protecting the right gastroepiploic artery as the dissection is carried proximally along the greater curvature of the stomach.

LESSER SAC AND LEFT GASTRIC PEDICLE DISSECTION

- The posterior attachments to the stomach are divided, exposing the origin of the left gastric vessels along the lesser curvature. In exposing the left gastric artery, the adjacent fat and lymph nodes should be elevated anteriorly to allow for resection with the specimen.
- The left gastric vessels are then identified on the medial aspect of the lesser curvature. Once these vessels are skeletonized, a white vascular (2.5 mm) staple load is fired across the left gastric artery at its origin from the celiac axis (FIG 5).

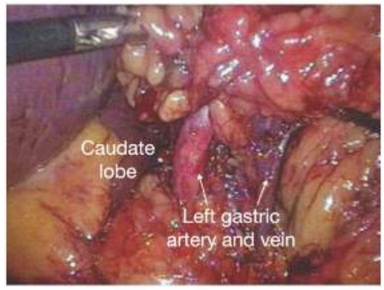


FIG 5 ● Exposure of the left gastric pedicle along the lesser curve.

THE PYLORUS

- The gastrocolic ligament is divided beyond the pylorus with care of staying away from the origin of the right gastroepiploic vessels.
- A Kocher maneuver is performed to further mobilize the pylorus. One good assessment of mobility of the stomach is whether the pylorus can be placed adjacent to the right crus.
- We do not perform a pyloromyotomy or pyloroplasty and instead inject botulinum toxin into the anterior wall of the pylorus.
- Botulinum toxin (100 units) is diluted into 5 mL of saline and drawn into a syringe. A 20-gauge spinal needle is inserted into the anterior aspect of the pylorus (FIG 6). The total volume of botulinum toxin is divided into at least three to four separate injection sites along the anterior pylorus.

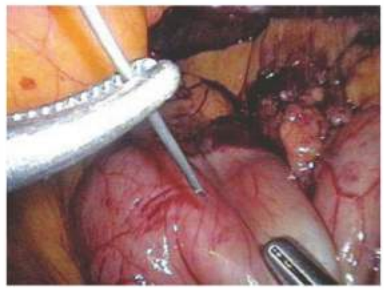


FIG 6 ● Percutaneous injection of 100 units of botulinum toxin into the anterior wall of the pylorus.

CREATION OF THE GASTRIC CONDUIT

- The lesser curvature is cleared of omentum at approximately the level of the incisura to allow for an avascular landing zone for the first staple load on the stomach (FIG 7).
- The conduit is created with sequential applications of a 60-mm stapler using green (4.8 mm) loads aiming toward the angle of His. The goal is to create a conduit that is 6 to 8 cm in width. Once divided, staple-line integrity and hemostasis are verified.
- The conduit is then sutured to the proximal stomach remnant using two interrupted 2-0 Vicryl stitches of alternate color to facilitate orientation following the thoracic pull-up (FIG 8). The tails are left at least 5 cm long to assist in intrathoracic location/manipulation and the first stitch is always placed at the superior apex of the conduit to diminish pull-up tension.
- The surgeon then places the Penrose drain and proximal stomach into the posterior mediastinum. We do not routinely enlarge the hiatus unless there appears to be constriction of the conduit.
- A laparoscopic J-tube is placed if not already present per standard laparoscopic technique to optimize postoperative nutrition.

FIG 7 ● Lesser curvature dissection in preparation for creation of the gastric conduit.

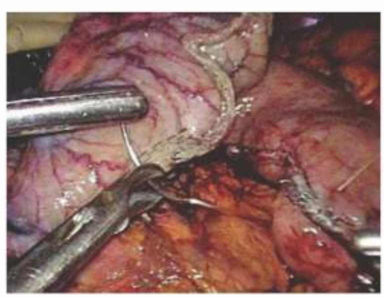


FIG 8 ● Suturing gastric conduit to the proximal stomach to allow for the conduit to be delivered into the posterior mediastinum during the thoracic portion of the operation.

POSITIONING AND PORT PLACEMENT FOR THE ROBOTIC THORACIC PORTION

- After the abdomen portion is completed, the single lumen endotracheal tube is exchanged for a double lumen tube.
- The patient is placed in a left lateral decubitus position and then rolled even more anteriorly. This allows all of the benefits of prone positioning without the anesthesia delays. The patient's body needs to be turned so that the robot can approach the patient from over his or her back and right shoulder.
- The first port placed is the camera port, which is 9 cm from the right axillary port. We use a 5-mm port here initially, with a 5-mm thoracoscope to assist in placing the other ports. Carbon dioxide (CO_2) is insufflated into the chest at a pressure of 12 cm H_2O.
- Port placement is shown in **FIG 9**. It is important to note that the three anterior ports comprise robotic arm 1; the camera port and robotic arm 2 are in a line that runs slightly posterior, headed toward the patient's right hip. If the line is in the anterior axillary line, you will be too close to the diaphragm for robotic arm 2. After the camera port is placed, the robotic arm 3 is placed as posterior and inferior as possible and a seeker needle is inserted first to ensure its safe trocar placement. Robotic arms 1 and 2 are the 8-mm ports through which most of the dissection takes place; robotic arm 3 is a 5-mm port and used primarily for retraction of structures during the dissection.
- The access port for the assistant is positioned last. This port should be triangulated behind robotic arm 2 and the camera port so that the robotic arms will not interfere with the assistant. Care should be taken to avoid the internal mammary artery and the diaphragm when this access port is placed. The insufflation tubing is switched to the access port so that it does not interfere with the movement of the robotic arms.
- **FIG 10** demonstrates the anatomic structures of the right hemithorax as seen from the camera port during the robotic portion of the Ivor-Lewis esophagectomy.

FIG 9 ● Port placement for robotic thoracic phase of esophagectomy. *C*, camera port; *1*, robotic arm 1; *2*, robotic arm 2; *3*, robotic arm 3; *A*, assistant port.

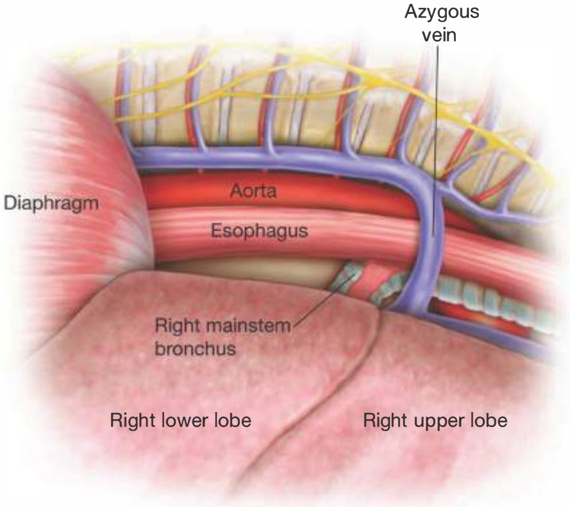


FIG 10 ● Structures of right hemithorax as seen from camera port during robotic Ivor-Lewis esophagectomy.

ESOPHAGEAL DISSECTION AND NODE RETRIEVAL

- Robotic arm 3 holds the lung anteriorly. Robotic arm 2 has a Cadiere forceps and lifts the mediastinal pleura. Robotic arm 1 has a thoracic dissector that incises the mediastinal pleura along the lung (**FIG 11**). The inferior pulmonary ligament is generally divided and lymph node within the ligament resected.
- The mediastinal pleura along the right mainstem bronchus is opened and divided all the way up to the azygous vein and all the way down to the diaphragm. The subcarinal lymph nodes are located posterior and inferior to the right mainstem bronchus and resected. Care should be taken to achieve proper hemostasis of this area, as the subcarinal nodes tend to be well vascularized.

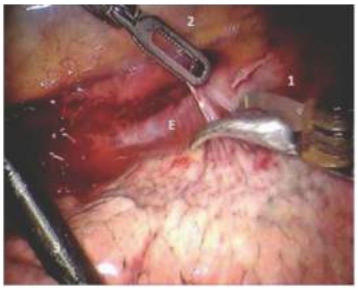


FIG 11 ● Incision of mediastinal pleura overlying esophagus. *E*, esophagus; *1*, robotic arm 1; *2*, robotic arm 2.

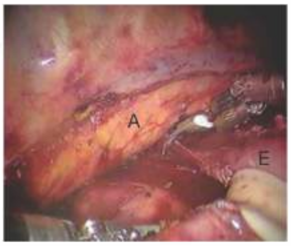


FIG 12 ● The esophagus *(E)* is dissected off the aorta *(A)*. We perform an en bloc dissection from the pericardium to the aorta. Robotic arm 3 is used to grasp the Penrose drain that was placed around the esophagus in the abdomen. It is pulled anteriorly to assist with the esophageal dissection off of the pericardium and aorta.

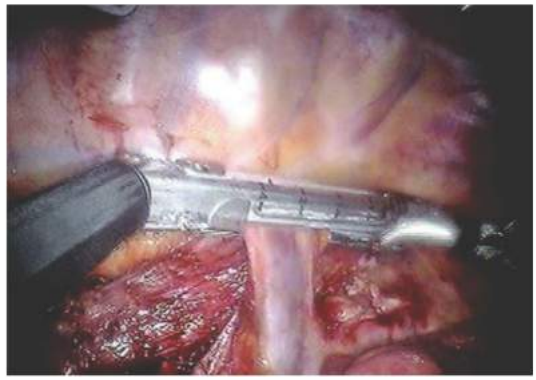


FIG 14 ● The azygous vein is stapled as posteriorly as possible.

- The posterior pleura along the hemiazygous vein going up to the azygous vein is opened. The bipolar thoracic dissector can be used to take the small arteries off the aorta that run to the esophagus. Clips are not necessary for these arteries (**FIG 12**).
- The lymph node dissection is carried out well above the azygous vein and to the posterior paraesophageal tissue (**FIG 13**).
- The azygous vein is dissected off the trachea. It is very important to staple the azygous vein posteriorly (**FIG 14**). This avoids a long azygous stump from getting in the way of performing an anastomosis.
- The esophagus should be completely mobilized from the thoracic inlet to the diaphragmatic hiatus. Performing this part of the operation robotically allows for a thorough harvest of the periesophageal tissue, including lymph nodes. The paraesophageal lymph nodes are dissected carefully off the left and right mainstem bronchi and aorta. Use of the bipolar device and careful dissection during this phase helps avoid thermal injury to the airway, which may present as an esophagobronchial fistula and can be catastrophic for the patient. The subcarinal nodes should be included in the specimen. After completion of the dissection, the pericardium should be visible to the level of the inferior pulmonary veins bilaterally (**FIG 15**).

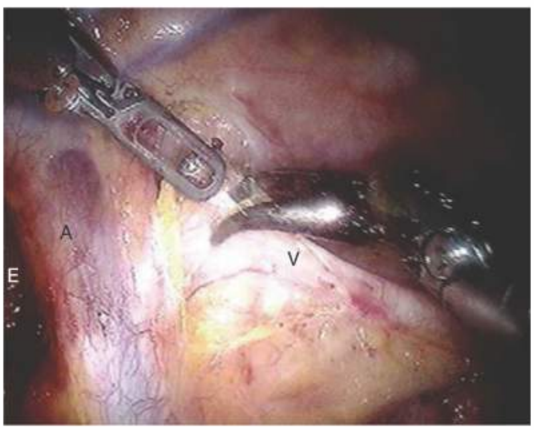


FIG 13 ● Dissection of paraesophageal tissue above the azygous vein *(A)*, vagus nerve *(V)*, and esophagus *(E)*.

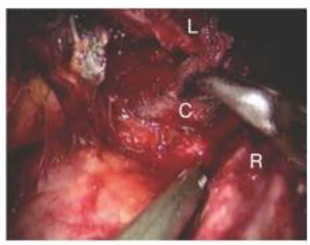


FIG 15 ● The entire left mainstem bronchus *(L)* is identified. We use the bipolar thoracic dissector to minimize thermal injury to the airway. *C*, subcarinal space; *R*, right mainstem bronchus.

DIVISION OF THE PROXIMAL ESOPHAGUS AND MOBILIZATION OF GASTRIC CONDUIT

- The Penrose drain encircling the conduit that was placed during the laparoscopic stage of the procedure is located in the inferior mediastinum and will be used to bring the conduit into the chest.
- The thoracic dissector in robotic arm 1 (right arm) is exchanged for the bipolar scissors. With traction applied to pull it distally, the proximal esophagus is divided just above the azygous vein to ensure the best possible margin away from cancer and/or Barrett's esophagus; it is beveled so that the posterior aspect of the esophagus is longer. Cautery is applied to cut and coagulate simultaneously (**FIG 16**).
- The scissors in robotic arm 1 are switched back to the Cadiere forceps, and the assistant helps pull the resected esophagus and gastric conduit gently into the chest with

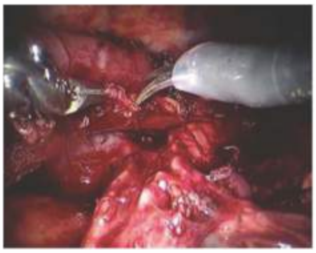


FIG 16 ● The esophagus is mobilized and ready to be cut. The esophagus is pulled downward and it is cut at the level of the carina just about above the azygous vein. Frozen section analysis is performed to ensure the proximal margin that is free of Barrett's metaplasia and cancer. Robotic hot shears are used to cut and coagulate the esophagus as it is cut.

FIG 17 ● The assistant uses a blunt Scanlon clamp, which is less traumatic than the robotic instruments. The clamp is placed through the nonrobotic access port and grasps the gastric conduit and carefully transports it into the right hemithorax.

an atraumatic clamp (rather than using the robotic arm, which because of its strength can damage the conduit) (**FIG 17**). Prior to dividing the sutures attaching the esophagus to the conduit, silk sutures are placed anteriorly and posteriorly, tacking the conduit to the pleura. This helps reduce the amount of tension on the anastomosis and maintain orientation of the conduit. Care should be taken to avoid twisting the conduit; the staples from conduit creation (i.e., the former lesser curve) should be oriented toward the lung. The esophageal specimen is then detached from the conduit (**FIG 18**).

FIG 18 ● The sutures attaching the conduit to the specimen are cut so that the specimen can be placed in a pouch and removed.

CREATION OF THE ESOPHAGOGASTROSTOMY

- A double-layered esophagogastrostomy is created. In general, we have found that the best instruments to use for robotic suturing are a long atraumatic forceps in robotic arm 2 and a suture-cut needle driver in robotic arm 1.
- First, interrupted 3-0 silk sutures are placed along the "back wall" of the anastomosis for the seromuscular layer (**FIGS 19** and **20**). Then, a transverse gastrotomy approximately 2 to 3 cm in diameter on the posterior surface of the stomach approximately 5 mm away from the row of silk sutures is created with electrocautery (**FIG 21**).

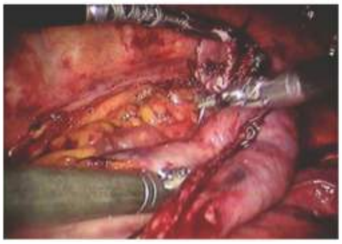


FIG 20 ● The spot where the first suture is placed on the conduit side should be located near the greater curve as far away from the staple line. The conduit is held in place by the bedside assistant to take all tension off of the first suture.

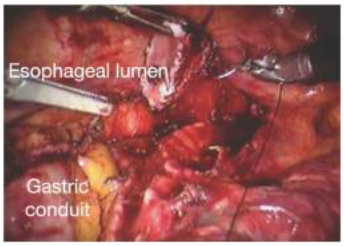


FIG 19 ● A two-layered completely hand-sewn chest anastomosis is performed. The first suture of the back row is placed furthest away from the surgeon. It is a 3-0 silk suture on an RB-1 needle and it is placed as shown to start on the esophagus. This sets up the anastomosis. The conduit is held by the assistant to keep it in place.

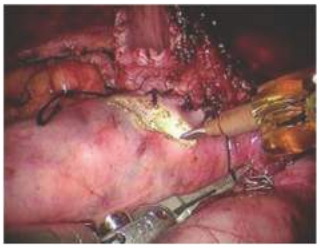
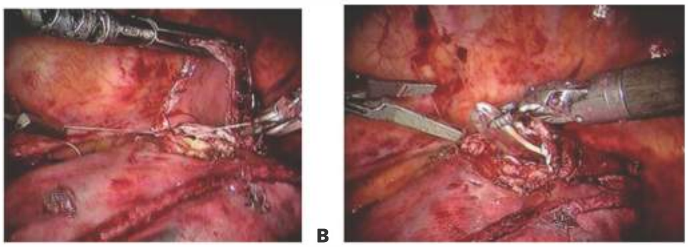


FIG 21 ● Once the posterior row of interrupted sutures are finished, the gastrotomy is performed. The location is carefully chosen approximately 5 mm from the interrupted back row of silk sutures and as far away from the staple line as possible. Note that the gastrostomy is performed on the posterior aspect of the stomach.



A B

FIG 22 ● **A.** The posterior inner layer of interrupted 3-0 Vicryl sutures is placed. **B.** The NGT is then slid through the anastomosis prior to placing the anterior inner layer of sutures. All the holes on the NGT are positioned into the gastric conduit to prevent evacuating the CO_2 insufflation and so no sutures go through the NGT inadvertently. An outer layer of interrupted silk sutures is placed after the inner layer is completed.

The gastrotomy should be located as far away from the staple line as possible, toward the greater curve of the stomach. Interrupted 3-0 Vicryl suture is used to create the full-thickness layer of the anastomosis around the circumference of the cut end of esophagus/gastrotomy. Typically, a suture is placed at each "corner" of the anastomosis and sutured in a running fashion to create the back wall (**FIG 22**).

- A running 3-0 Vicryl full-thickness suture is then placed in the "front wall," starting at the corner farthest away from the surgeon, to complete the anastomosis. The NGT is fed under direct vision into the conduit prior to completion of this layer. All the holes of the NGT are positioned in the gastric conduit to prevent evacuating the CO_2 insufflation. An additional row of interrupted 3-0 silk sutures is then placed to complete the double-layered anastomosis anteriorly.
- A tongue of omentum coming off the gastroepiploic artery is brought up from beneath the gastric conduit and tacked over the anterior side of the anastomosis with silk sutures (**FIG 23**). If possible, the omentum can be positioned between the anastomosis and the airway (left mainstem bronchus/trachea) to prevent fistula formation. The conduit is sutured to the right hemidiaphragm near the hiatus to prevent herniation of abdominal contents into the chest (**FIG 24**).

FIG 23 ● The omentum is then tacked down to buttress the anterior aspect of the anastomosis. We also leave a large pad of omentum between the conduit and underlying right and left mainstem bronchus to help prevent fistula formation.

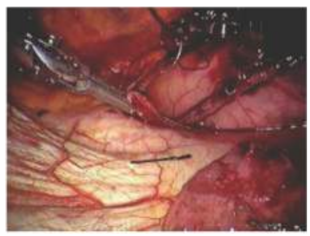


FIG 24 ● A tacking 3-0 silk suture between the gastric conduit and the right hemidiaphragm is placed to help prevent herniation of abdominal contents into the chest.

REMOVAL OF THE SPECIMEN/ CONCLUSION OF SURGERY

- The specimen is removed with a large bag via the assistant port, and frozen section examination is performed to confirm that the proximal and distal margins are clear of tumor and/or Barrett's mucosa. A chest tube is placed directly posteriorly and toward the apex through the incision for robotic arm 2. The ports are removed with the CO_2 insufflation turned off to ensure the absence of bleeding. The robot is undocked and moved away from the patient. The lung is reexpanded and the incisions are closed. We frequently remove the NGT prior to extubation.

PEARLS AND PITFALLS

Nutritional evaluation	■ Assess nutritional status preoperatively and have a low threshold for pretreatment J-tube placement to improve nutritional status prior to esophagectomy.
Aberrant arterial anatomy	■ Clip accessory or replaced left hepatic artery in the gastrohepatic ligament and assess liver viability prior to transection.
Excessive intraabdominal fat	■ Carefully locate the right gastroepiploic vessels prior to dividing the gastrocolic ligament. ■ Liberal use of fat stays to retract omentum to expose the short gastric vessels.

Avoid use of monopolar cautery around the airway	■ Balance risks of airway injury with benefit of taking all peribronchial nodes. ■ Devascularization injury to the airway can result in delayed esophagobronchial fistula and associated mortality.
Bedside fiberoptic endoscopic examination of swallowing (FEES) prior to initiating oral intake	■ Aspiration is common following esophagectomy. Perform FEES prior to contrast study evaluating the anastomosis. ■ Some advocate for delayed oral intake for 4–6 weeks following esophagectomy.
Delayed gastric emptying	■ Emptying of the gastric conduit is poor even with the use of concomitant emptying procedures. ■ Patients must be counseled to keep their head of bed elevated and not eat close to bedtime.

POSTOPERATIVE CARE

- The postoperative care of patients who undergo esophagectomy is based on a team approach. Most literature shows improved outcomes in high-volume centers. This is secondary to a more experienced team not only in the operating room (OR) but also on the floor. Low-molecular-weight heparin is administered prior to surgery and on every postoperative day (POD). Our postoperative care algorithm is as follows for each POD:
  - POD 1
    - The patient receives about 100 to 125 mL per hour of lactated Ringer's solution.
    - The J-tube is placed to gravity.
    - Patient begins ambulating three to four times a day.
  - POD 2
    - Trophic tube feeds are started though the J-tube at 10 mL per hour.
    - The intravenous fluid given is decreased based on urinary output, and changed to 5% dextrose in half normal saline.
    - Ambulate four to six times a day.
  - POD 3
    - The chest tube is usually removed.
    - The patient continues to ambulate four times a day.
    - J-tube feedings are advanced as tolerated.
  - POD 4
    - The patient receives a bedside fiberoptic endoscopic examination of swallowing (FEES).
    - If the vocal cords are normal on FEES, the patient is sent to radiology for an upper gastrointestinal (UGI) swallow. This test evaluates two important components:
      - The anastomosis
      - The time for emptying of the gastric conduit
  - POD 5
    - If the swallow is negative, the patient is advanced to 30 mL per hour of thickened liquids by mouth.
  - POD 6 or POD 7
    - The patient is usually discharged home.

OUTCOMES

- We presented the world's largest series of consecutive robotic Ivor-Lewis esophagectomy procedures in January 2013; we have now completed over 70 robotic esophageal resections. From our experience, we have learned that the keys to preventing complications in this operation are contingent on the following:
  - Performing a mucosa-to-mucosa anastomosis without tension
  - A well-perfused conduit
  - Adequate functional status of the patient at the time of surgery

COMPLICATIONS

- Despite adherence to these technical concepts during surgery, postoperative complications can commonly occur. The most frequent complications include the following:
  - Anastomotic leak: When it is subtle, it can be managed conservatively by keeping the patient NPO and observation for a week. If it is large, an esophageal stent should be placed endoscopically for 8 to 12 weeks. Video-assisted thoracic surgery (VATS) decortication and drainage of effusion should be performed if there is any evidence of new or infected pleural material.
  - Pulmonary complications are common after any thoracic surgery and include atelectasis and pneumonia, including aspiration pneumonia in particular.
  - Chylothorax: This is a complication that can require reoperation. We generally choose to manage this with percutaneous embolization of the thoracic duct for high-output fistulas. If the output is greater than 400 mL per day, it should be immediately treated.
  - Atrial fibrillation: The incidence of atrial fibrillation after an esophagectomy is reported to be about 20% and correlates to the extent of the mediastinal node dissection performed during the operation. As such, patients should be on telemetry in the postoperative period.

Chapter 32

Treatment of Esophageal Perforation: Cervical, Thoracic, and Abdominal

Nathalie Boutet   Moishe Liberman

DEFINITION

- Esophageal perforation is defined as a tear in both the mucosa and muscularis propria layers of the esophagus.

DIFFERENTIAL DIAGNOSIS

- The presentation of esophageal perforations is variable and thus the differential diagnosis can be quite extensive. In cases without obvious etiology, cardiac and pulmonary pathologies will often have been ruled out before the diagnosis of esophageal perforation is made. Myocardial infarction, aortic dissection, pneumonia, pneumothorax, gastroesophageal reflux, and esophageal spasm are among the pathologies that can present with symptoms similar to esophageal perforation.

PATIENT HISTORY AND PHYSICAL FINDINGS

- History may include recent events of forceful vomiting, blunt abdominal trauma, ingestion of caustic substances or foreign bodies, or recent upper gastrointestinal (GI) endoscopy.
- Patients may report a history of dysphagia of rapid onset accompanied by neck, chest, or abdominal pain. Dysphonia and a febrile state may also be reported.
- A thorough review of esophageal function should be obtained as symptoms of achalasia or dysphagia may impact on the choice of treatment.
- Evaluation of comorbid conditions such as heart disease and pulmonary function should be performed. A history of prior surgical and radiation therapy should be sought.
- Physical exam may reveal the presence of subcutaneous emphysema in the neck or chest. Reduced air entry may signal the presence of an associated pleural effusion or pneumothorax.

IMAGING AND OTHER DIAGNOSTIC STUDIES

- Evaluation of other diagnoses found in the differential will often lead to basic imaging studies being performed in these patients, such as a chest x-ray. One can expect to find air in the subcutaneous tissues of the neck, chest wall and mediastinum (**FIG 1**), and in the prevertebral space on the lateral views. Associated plain film findings may include pleural effusion, pneumothorax, hydropneumothorax, pneumoperitoneum, or pneumoretroperitoneum.
- Cervical and thoracic computed tomography (CT) scans with oral contrast can be performed to diagnose esophageal perforations. An extraluminal leak of contrast medium can be seen in the prevertebral or pleural spaces (**FIG 2**). CT scan also allows for the evaluation of other potential causes of clinical presentation. CT scan is the investigation of choice when diagnosis is uncertain. Pneumomediastinum, pneumoperitoneum, and air in the subcutaneous tissues of the neck will often be seen in cases of esophageal perforation (**FIG 3A,B**). CT also allows for the evaluation of the neck, mediastinum, abdominal cavity, and pleural spaces, which can aid in operative incision planning and/or drainage planning in nonoperative cases.[1]

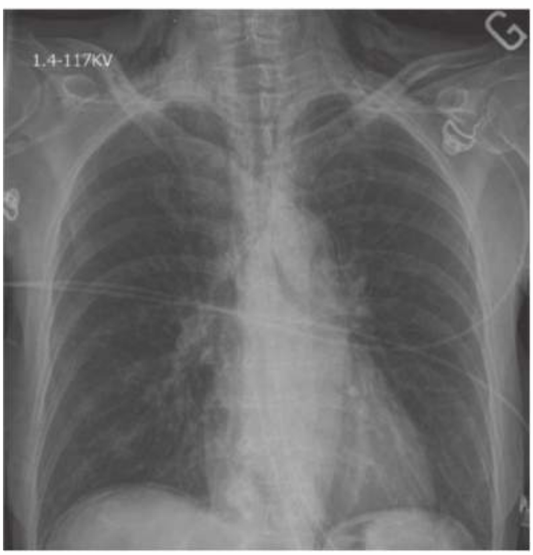


FIG 1 • Chest x-ray showing subcutaneous emphysema and pneumoperitoneum.

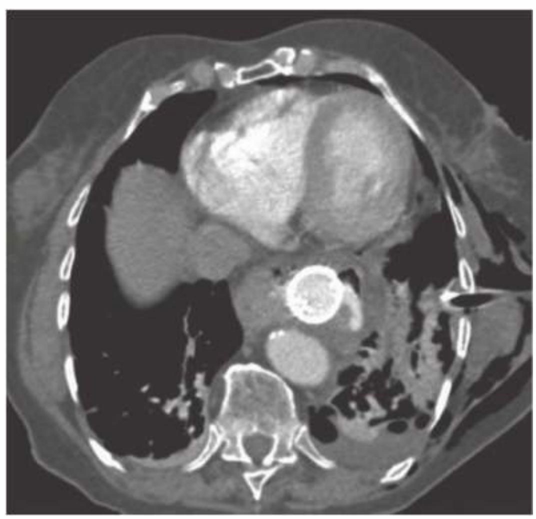


FIG 2 • CT scan with extraluminal leak of water-soluble oral contrast in the mediastinum. Subcutaneous emphysema is also present.

A B

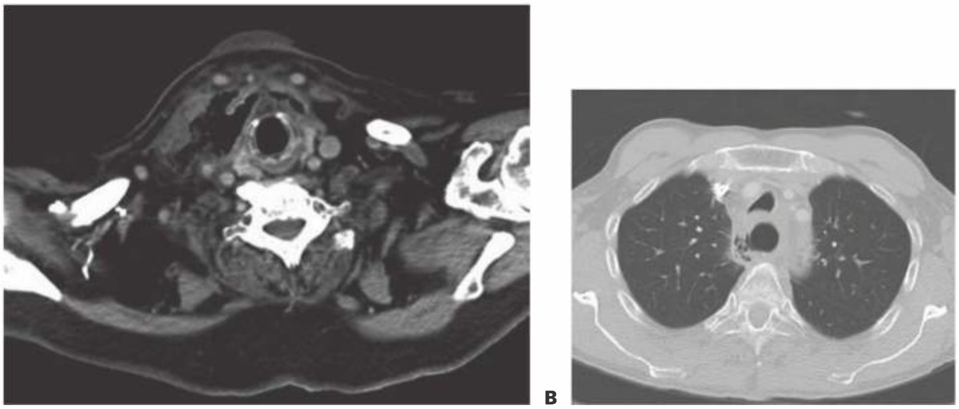


FIG 3 ● **A.** CT scan showing subcutaneous emphysema in the neck following cervical esophageal perforation. **B.** CT scan showing pneumomediastinum.

- Gastrografin studies can also be performed and should be immediately followed by a barium swallow in the event of negative findings, as barium studies are more sensitive than Gastrografin. Water-soluble contrast should be avoided when tracheoesophageal fistula is considered in the differential. With CT scan and endoscopy, oral esophagograms are not usually necessary in the modern day diagnosis of esophageal perforation.
- Diagnosis can also be made using endoscopy (**FIG 4**). Endoscopy should always be performed under general anesthesia in the operating room at the time of esophageal repair, exclusion, stenting, clipping, or decision regarding conservative management. It should always be performed by an experienced upper GI endoscopist and is very important in not only assessing the site of the perforation but also in evaluating for distal obstruction, quality of the esophagus, size of the hole, associated upper GI pathology, and mucosal quality/necrosis. It is primordial that insufflation be kept to a minimum in order to avoid increasing the extent of the perforation.

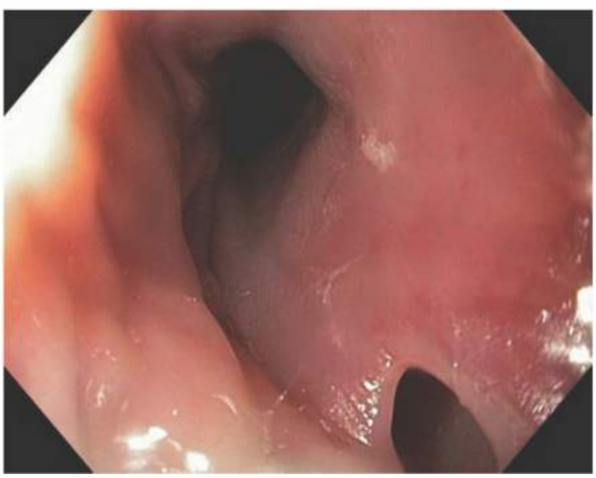


FIG 4 ● Esophagogastroscopy showing an esophageal perforation in the **bottom right** corner. The esophageal lumen is seen in the **upper left** corner. Note the clear margins of the perforation and the absence of mucosal necrosis.

SURGICAL MANAGEMENT

Preoperative Planning

- Appropriate resuscitation is mandatory prior to surgical treatment. Diagnosis should be confirmed either by CT scan, water-soluble contrast/barium swallow, or endoscopy. This is critical as approaches to cervical, thoracic, and abdominal esophageal perforations are drastically different. Broad-spectrum intravenous antibiotics should have been started as soon as the diagnosis is made.
- We recommend on-table endoscopy under general anesthesia in all cases in order to precisely delineate the location, size, and extent of the hole and assess the quality of the esophagus (including evaluation of possible downstream obstruction). Additionally, endoscopy can be used as a treatment option (stenting, clipping) or as an adjunctive procedure during repair (perforation cannulation, percutaneous endoscopic gastrostomy, percutaneous endoscopic jejunostomy). In cases requiring thoracotomy, laparotomy, or cervical exploration, a flexible soft-tipped guidewire is typically placed through the perforation using endoscopy in order to make it simple and expedient to find the site of perforation during surgical exploration and minimize dissection (**FIGS 5** and **6**).

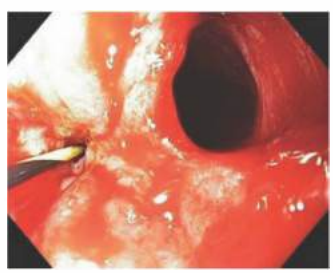


FIG 5 ● Esophagogastroscopy showing insertion of a guidewire into the esophageal lumen with a large perforation seen on the right.

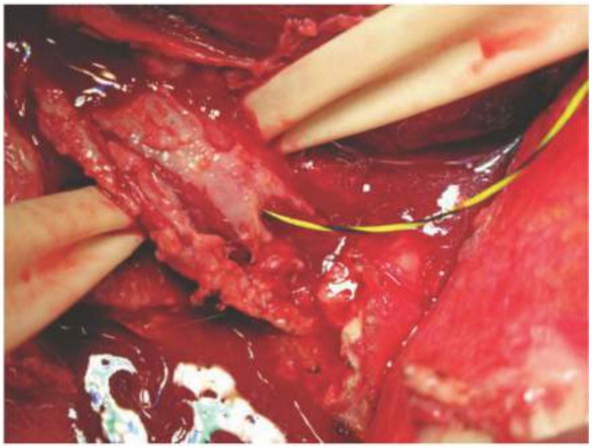


FIG 6 • Dissected esophagus with guidewire through site of esophageal perforation.

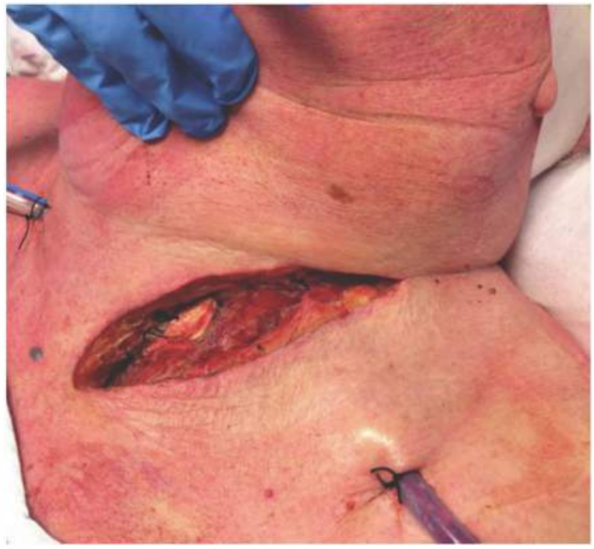


FIG 7 • Slight hyperextension of the neck allows easy access for neck dissection. Incision along the medial border of the sternocleidomastoid muscle.

Positioning

- Cervical perforation
  - The patient is placed in dorsal position with a bolster under the scapulae to obtain a slight hyperextension of the neck. The endotracheal tube is secured to the right corner of the mouth and the head is slightly turned to the right side (**FIG 7**).
- Upper two-thirds thoracic perforation
  - The patient is placed in left lateral decubitus with a double lumen endotracheal tube in place. The flexion point of the operating table should be located at the level of the 5th thoracic vertebra. An axillary roll is placed under the thoracic cage, two fingerbreadths below the left axilla to protect the brachial plexus. The table is flexed in order to open the intercostal spaces on the right side. The right arm is positioned anterosuperiorly to the head. Once positioning is adequate, the position of the double lumen endotracheal tube is confirmed with bronchoscopy and the right lung is isolated from ventilation.
- Lower one-third thoracic perforation
  - The patient is placed in right lateral decubitus with a double lumen endotracheal tube in place. All specifics of positioning are the same as for the left lateral decubitus position previously described.
- Abdominal perforation
  - The patient is placed in dorsal position with both arms abducted.

TECHNIQUES

CERVICAL PERFORATION REPAIR AND DRAINAGE

Skin Incision

- The medial border of the left sternocleidomastoid muscle is identified. An incision is performed along the border of the muscle (**FIG 7**). The platysma is incised in the orientation of the skin incision.

Dissection

- The sternocleidomastoid muscle is dissected and retracted laterally, exposing the vessels of the neck. The carotid sheath is left intact and retracted laterally. If necessary, the middle thyroid vein is ligated and the larynx and trachea are retracted to the right. Care is taken to not damage the left recurrent laryngeal nerve, which lies in the tracheoesophageal groove. The prevertebral plane is entered, moving the esophagus anteriorly (**FIG 8A,B**). The entire space is dissected as far caudally as the carina.

Repair

- In most instances, the site of the perforation is not identified nor should any extensive amount of time be spent searching for it. If the perforation is visualized and easily accessible, it can be repaired. The first step of the repair is the lengthening of the opening in the muscularis propria as this is often smaller than the orifice in the

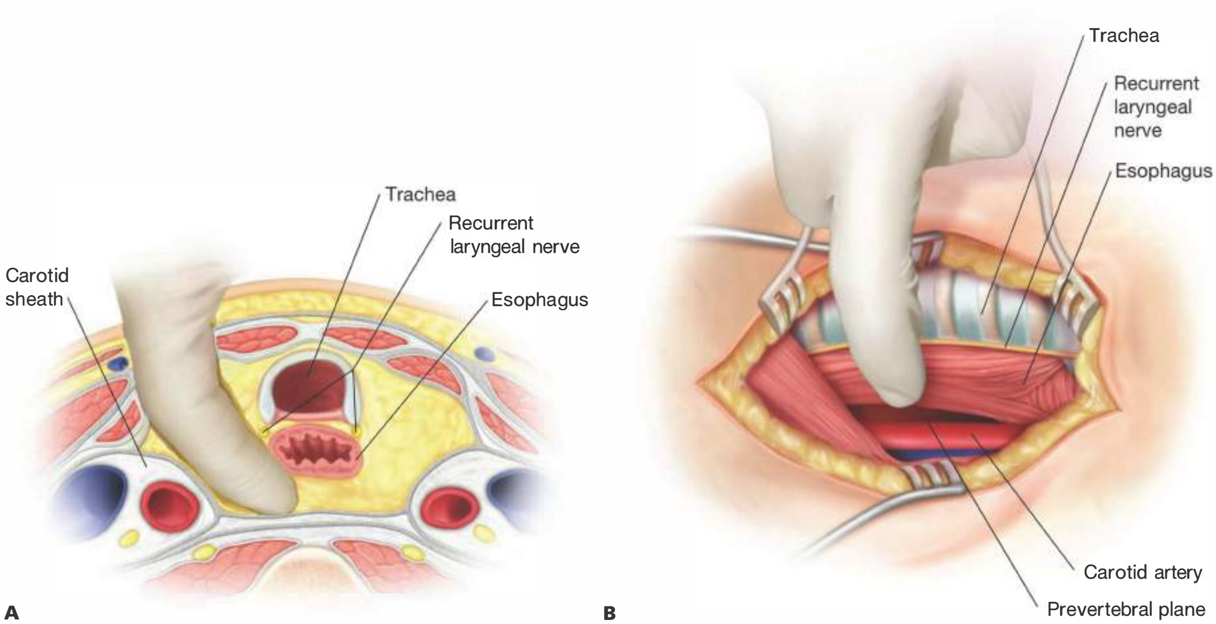


FIG 8 ● **A.** Transverse section showing the prevertebral space. Dissection is carried medially to the carotid sheath. The recurrent laryngeal nerve is protected within the tracheoesophageal groove. **B.** Lateral view of the dissected prevertebral space with trachea, esophagus, and recurrent laryngeal nerve retracted anteriorly.

mucosa (**FIG 9**). Once the entire length of the perforation is exposed, the repair is performed with single interrupted absorbable sutures on the mucosal plane and nonabsorbable sutures on the muscular plane (**FIG 10**). In most cases, the inflammation at the site of perforation will prevent easy identification of both mucosal and muscular planes. In such instances, it is appropriate to proceed with a single layer repair using single interrupted absorbable sutures. A rubber bougie should be placed in the esophagus orally to assure that the repair does not result in esophageal obliteration or significant stenosis.

Sternocleidomastoid Flap

- Leaks from primary repairs of esophageal perforations are common and it is preferable to protect the repair with a vascularized flap. For perforations of the cervical esophagus, the sternal head of the sternocleidomastoid muscle is detached using electrocautery and rotated to

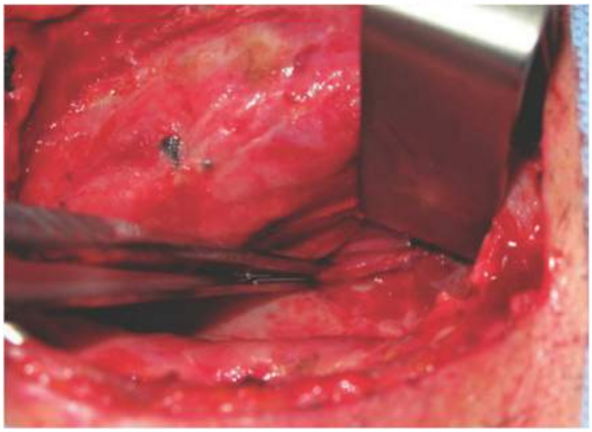


FIG 9 ● Esophageal perforation at the tips of the forceps. The esophageal lumen is seen with normal mucosa.

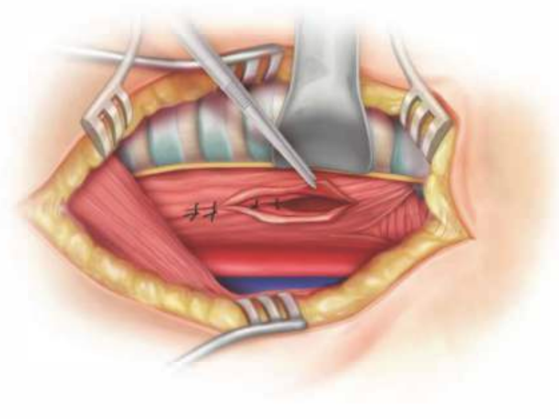


FIG 10 ● Repair of esophageal perforation in two planes of single interrupted sutures (mucosa and muscularis propria).

cover the site of the perforation. The muscle is fixed with multiple interrupted sutures around the repair. The muscle should be tightly opposed to the repair site and cover it entirely (**FIG 11**). In the case of concomitant tracheal injury, the flap should be placed in between the repaired esophagus and the trachea to avoid the formation of a tracheoesophageal fistula.

Drainage

- Regardless of whether the site of perforation was identified and/or repaired, the prevertebral space is irrigated abundantly and drains are left in place. Drains are brought out through separate skin stab wounds.

Closure

- The platysma is reapproximated in the superior portion of the incision with absorbable sutures. The skin incision is closed with staples.

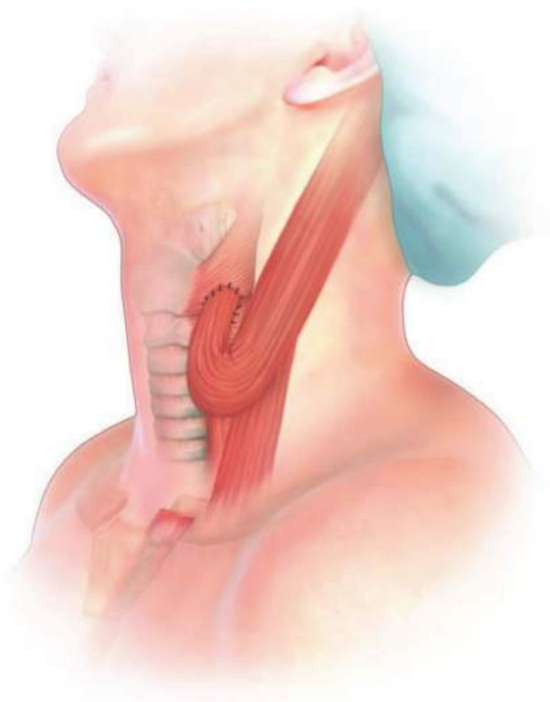


FIG 11 ● Sternocleidomastoid flap. The sternal head is dissected and rotated to cover the entire repair site. The flap is fixed to the repair with single interrupted sutures.

THORACIC PERFORATION REPAIR AND DRAINAGE

Skin Incision

- With the patient in lateral decubitus, left for perforations of the upper two-thirds and right for the lower third of the esophagus, the tip of the scapula is identified and an incision following the orientation of the underlying ribs is placed two fingerbreadths caudally (**FIG 12**).

Dissection

- The incision is carried through to the latissimus dorsi. The muscle is incised exposing the serratus anterior. The serratus anterior is preserved and retracted anteriorly. With single lung ventilation, the 5th intercostal space is entered by cutting the intercostal muscles immediately above the 6th rib. The 6th rib is sectioned anteriorly and posteriorly. A 1 to 2 cm portion of the 6th rib can be removed. In very high perforations, a 4th intercostal space may be chosen to aid in repair, and in very low perforations, a lower incision (6th, 7th, or 8th interspace) may be chosen.

FIG 12 ● Patient positioned in left lateral decubitus. The scapula is drawn along with the incision site two fingerbreadths below the tip of the scapula following the orientation of the underlying ribs.

Intercostal Flap Preparation

- The periosteum of the 5th rib is opened longitudinally in the center of the bone and retracted inferiorly. The neurovascular bundle is dissected off of the inferior border of the 5th rib using a periosteal elevator. The intercostal muscles and the neurovascular bundle are transected anteriorly and the resulting flap is moved posteriorly to avoid injury with retractors used to open the intercostal space (FIG 13).

Repair

- The site of perforation should be identified (FIG 14). The esophagus should be mobilized circumferentially above and below the perforation and Penrose drains should be placed around the esophagus to aid in retraction and repair (FIG 15A,B). The repair should proceed in one or two layers of interrupted nonbraided absorbable suture (3-0 polydioxanone [PDS]) over a bougie (FIG 16).

Intercostal Muscle Flap

- The previously prepared intercostal flap is approximated to the site of repair and fixed with interrupted horizontal mattress, 3-0 silk sutures (FIG 17).

Drainage

- The thoracic cavity is irrigated abundantly and two thoracic drains are inserted and positioned close to the site of perforation. Drains are fixed at the skin.

Closure

- The ribs are reapproximated with figure-of-eight sutures of heavy Vicryl. The lung is reexpanded before tying the sutures and appropriate drain position is confirmed. The serratus anterior is resewn to its fat and the latissimus dorsi muscle is repaired with running sutures of 0 Vicryl. The subcutaneous fat is reapproximated with a running suture of 2-0 Vicryl before closing the skin with staples.

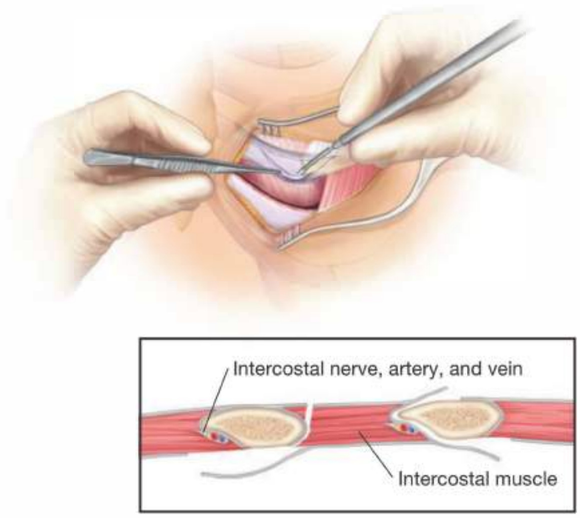


FIG 13 ● Dissection of intercostal flap. The intercostal muscles are dissected from the superior rib by removing the periosteum and following the lower border of the superior rib. Care is taken to preserve the neurovascular bundle with the flap as this is essential to flap viability. The dissection plane is depicted in the inset.

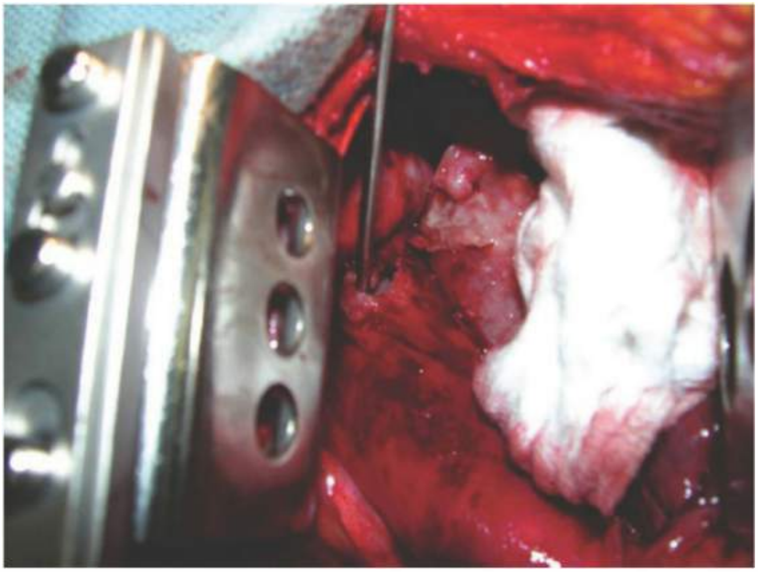


FIG 14 ● Metallic probe inside thoracic esophageal perforation.

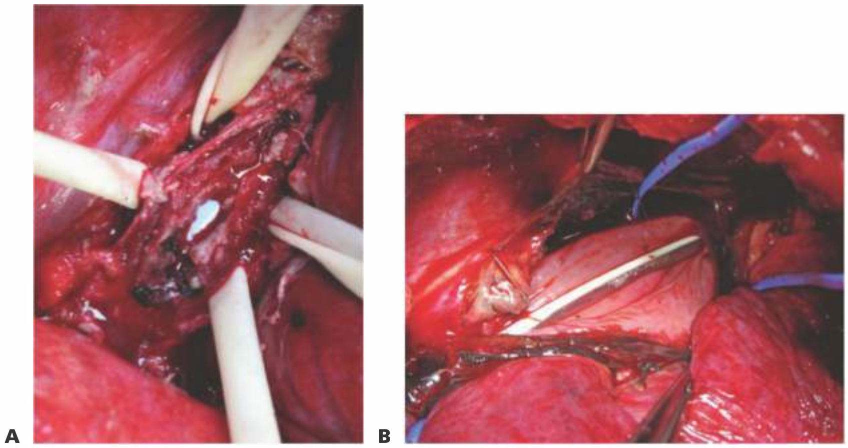


FIG 15 ● **A.** Thoracic esophageal perforation with bougie inside the esophageal lumen. **B.** Large thoracic esophageal perforation with nasogastric tube inside lumen.

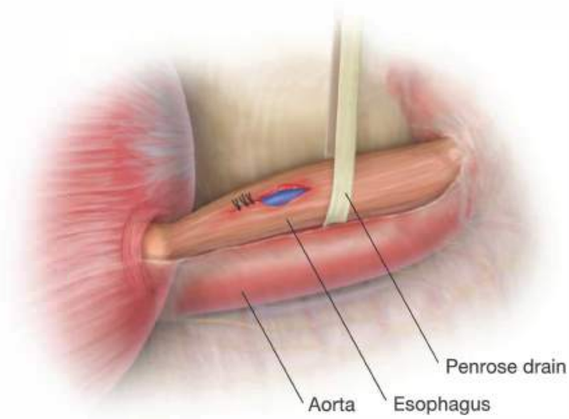


FIG 16 ● Single layer repair of thoracic esophageal perforation over bougie with single interrupted sutures.

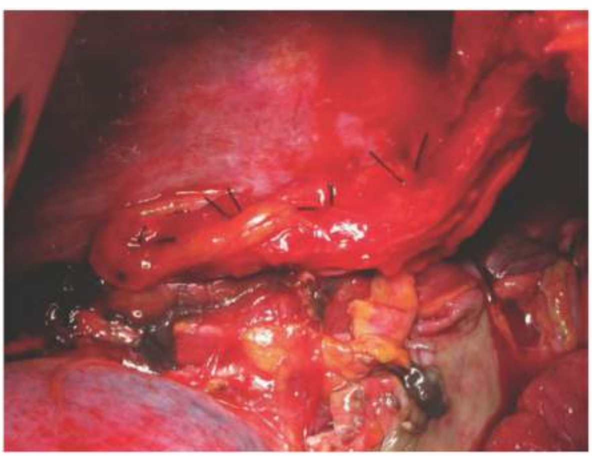


FIG 17 ● Intercostal muscle flap fixed to site of thoracic esophageal perforation repair. The flap is fixed with single interrupted sutures and covers the repair entirely.

ABDOMINAL PERFORATION REPAIR AND DRAINAGE

Skin incision

- A midline laparotomy is performed from the xiphoid process to the umbilicus.

Dissection

- The gastrosplenic ligament is dissected off of the greater curvature of the stomach using an energy vascular sealing device. The short gastric vessels are sealed and divided and the angle of His is dissected. The left and right crus are identified and the esophagus is dissected free. A Penrose drain is placed around the gastroesophageal junction for exposure.

Repair

- The site of perforation needs to be identified and the steps for repair are the same as for cervical and thoracic perforations. A Nissen fundoplication is then performed to cover the esophageal repair (see Part 1, Chapter 22). A fundoplication should not be performed in patients with history of achalasia. In such cases, a patch of omentum can be fixed on the repair with absorbable sutures.

Drainage

- The abdominal cavity is irrigated abundantly and Jackson-Pratt drains are placed around the area of repair.

Closure

- The rectus abdominis aponeurosis is closed with a running suture of PDS 1. The skin is then closed with staples.

ESOPHAGECTOMY AND DIVERSION

- In cases of severe sepsis, hemodynamic instability, a necrotic esophagus, and/or a very late presentation, esophagectomy and diversion is a lifesaving procedure. Resection and diversion is always a last option.

Skin Incision and Dissection

- Esophagectomy can either be performed using a transthoracic approach (right thoracotomy; see "Thoracic Perforation Repair and Drainage") or using a transhiatal approach through a midline laparotomy.

Resection

- The gastroesophageal junction is stapled off and a draining gastrostomy and feeding jejunostomy are performed. The entire esophagus is brought out through a left cervical incision (**FIG 18A**) and amputated just proximal to the perforation. As much proximal esophagus as possible should be left in place in order to aid in future restoration of GI continuity.

Stoma Formation

- The esophagus is then tunnelled under the skin of the left chest and brought out to the skin as an end esophagostomy. The stoma is sewn to the skin using 3-0 Vicryl or 3-0 PDS interrupted sutures and an enterostomal appliance is applied to the skin (**FIG 18B**). Three to 6 months after diversion, the GI continuity is restored using either a gastric pull-up or a colon bypass. Primary esophagectomy and anastomosis is rarely done in case of perforation.

Closure

- Closure is performed as previously described in the thoracic and abdominal perforation repair and drainage sections.

A

B


FIG 18 ● **A.** Thoracoabdominal esophagus dissected and brought out through a left cervical incision. **B.** End result of cervical esophagostomy with enterostomal appliance removed. Note that the conserved esophagus extends below the clavicle, showing preservation of a maximum length of tissue above the site of perforation.

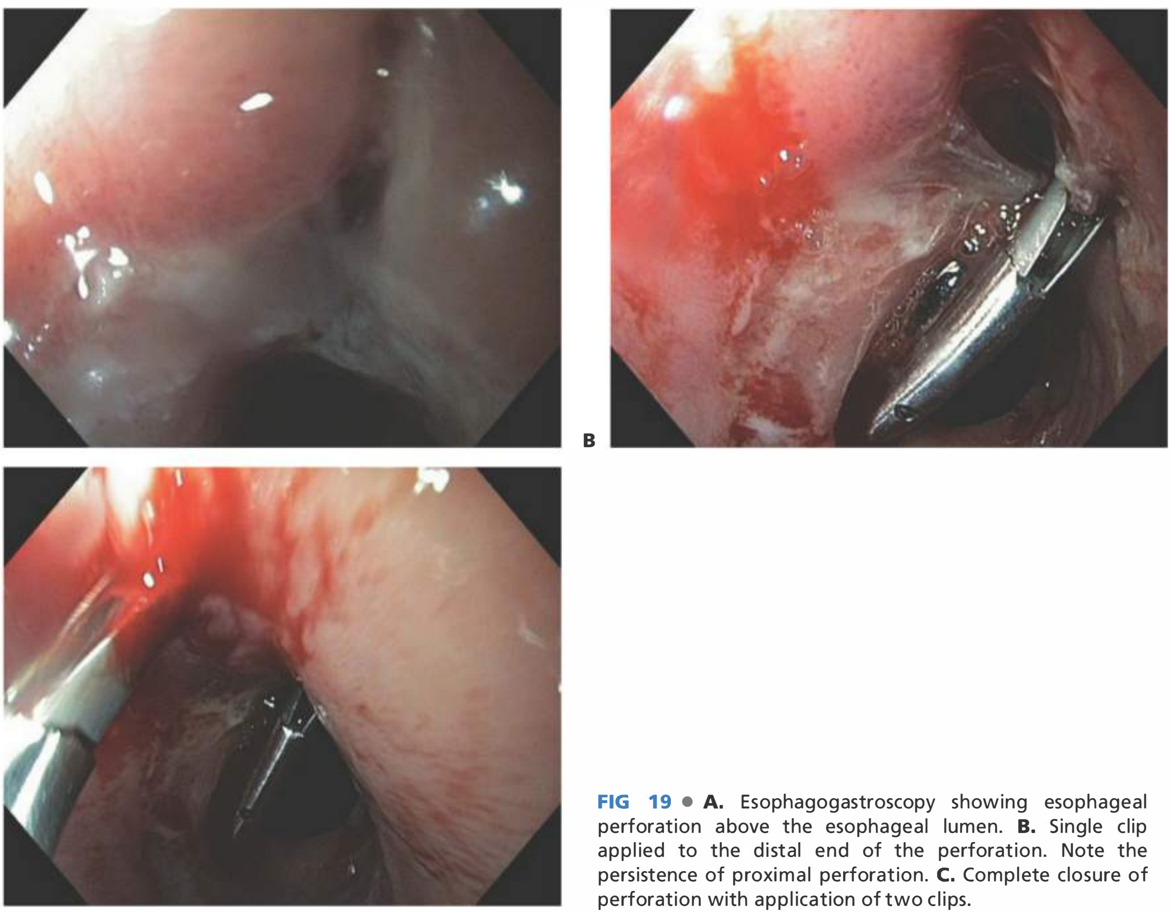
ENDOSCOPIC APPROACHES

Endoscopic Repair/Clipping

- In select cases of very early perforation in a clean esophagus and a very stable patient, an endoscopic closure of the mucosal defect can be attempted. This is typically performed in cases of endoscopic perforation where the perforation is immediately recognized and sent directly to a highly specialized center.
- The patient is placed under general anesthesia in the operating room and flexible endoscopy is performed. The mucosal defect should be inspected for any signs of ischemia, necrosis, or infection (see **FIG 4**).
- Distal obstruction should be ruled out using endoscopy prior to attempting endoscopic repair.
- If the patient is stable, the mucosal defect is small and the hole appears closable, a series of through-the-scope endoscopic clips may be applied from distal to proximal in order to attempt complete closure (**FIG 19A–C**).

Endoscopic Stenting

- Temporary endoluminal esophageal stenting is becoming more popular for the acute treatment of esophageal perforation.[2] The decision to use a stent in the esophagus for the treatment of esophageal perforation is based on the clinical status of the patient, on preoperative imaging and on the location, and the size and site of the perforation on intraoperative endoscopy.
- As experience with stenting in esophageal perforation is increasing, the indications are expanding and a stent can often be used in a very septic patient. If spillage can be controlled using a stent and percutaneous (chest tubes, pigtail drains) and/or thoracoscopic/laparoscopic adjunctive procedures are performed to allow for abscess drainage, one can often temporize a very sick patient quickly and save the patient from the long-term morbidity of an esophageal resection and diversion procedure.
- If a stenting approach is chosen, a percutaneous gastrojejunostomy is first placed to allow for gastric drainage and



A B C

FIG 19 ● **A.** Esophagogastroscopy showing esophageal perforation above the esophageal lumen. **B.** Single clip applied to the distal end of the perforation. Note the persistence of proximal perforation. **C.** Complete closure of perforation with application of two clips.

A B C

FIG 20 ● **A.** Guidewire in the esophageal lumen. **B.** Metallic stent. **C.** Plastic stent.

postpyloric feeding. A guidewire is then passed into the stomach and the stent is placed under endoscopic or fluoroscopic vision (FIG 20A). Fully covered metallic stents (FIG 20B) or silicone-polyester (plastic) stents (FIG 20C) should be used in cases of benign esophageal perforation so that they can be easily removed without causing esophageal damage. Stents are typically removed 4 to 8 weeks following perforation. In case of benign esophageal perforation, esophageal stent migration is typical due to the lack of stenosis or tumor. It is therefore important to use the largest diameter stent possible (typically 23 mm), a very long stent (to help with esophageal wall apposition and prevent migration), and to proximally cover the whole by at least 6 to 7 cm if possible.

CONSERVATIVE APPROACH

- In cases of esophageal perforation in patients who are hemodynamically stable, the perforation is discovered early (<24 hours) and there is objective evidence of a contained leak with a contrast study demonstrating contrast extravasation without pooling in the mediastinum and draining back into the esophagus, a conservative approach can be chosen.[3]
- These patients should be kept strict NPO with a nasogastric tube in place (inserted endoscopically). They should be placed on intravenous antibiotics, intravenous fluids, and intravenous proton pump inhibitors. They should be closely monitored for fever, tachycardia, and leukocytosis.
- If signs of sepsis develop, they should be taken to the operating room for endoscopic stenting or esophageal repair/diversion. In cases of successful conservative treatment of esophageal perforation, a Gastrografin swallow should be performed at 7 to 10 days following perforation to assess healing of the perforation.
- Nutrition can be provided using either nasogastric/nasojejunal feeding or total parenteral nutrition.

Gastrostomy/Jejunostomy

- Classically, esophageal repair in the neck, chest, or abdomen was performed in addition to a laparotomy or laparoscopy in order to perform a gastrostomy (for gastric drainage) and a feeding jejunostomy (for feeding). In cases where there is no peritoneal soilage, this can be accomplished in less than 5 minutes prior to esophageal repair using a Percutaneous Endoscopic Gastrostomy with Jejunal feeding limb (PEG-J) (FIG 21). A PEG-J performed prior to repair or diversion on the operating table at the time of endoscopy saves the patient a laparotomy and greatly expedites the operation.

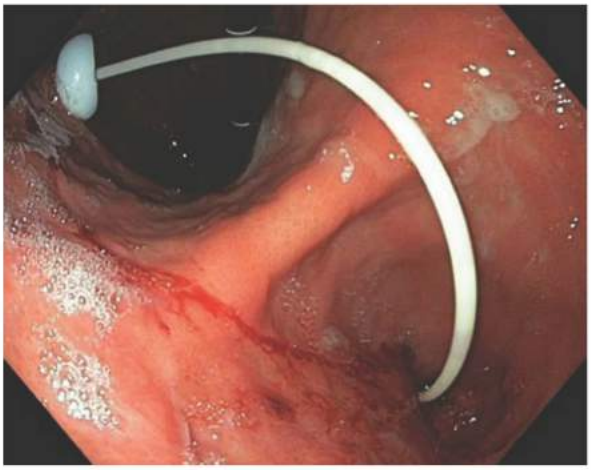


FIG 21 ● Endoscopic view of a PEG-J.

PEARLS AND PITFALLS

History	■ Symptoms of achalasia preclude the use of a Nissen fundoplication in abdominal perforations. ■ Obstructive symptoms should be addressed intraoperatively to avoid postoperative downstream pressure buildup on the esophageal repair.
Presentation	■ A high index of suspicion is required to diagnose esophageal perforations. ■ Diagnostic delays over 24 hours are associated with increased mortality.
Preoperative evaluation	■ Always perform on-table endoscopy under general anesthesia before making definitive decisions regarding surgical, endoscopic, or conservative treatment.
Endoscopic treatment	■ Esophageal stenting can be applied in selected stable patients. It can also be used as a bail out in patients who are extremely ill, in combination with percutaneous or video-assisted thoracic surgery (VATS) drainage, to temporize a septic patient.
Repair	■ Suturing of the esophageal defect is mandatory in perforations of the abdominal and lower two-thirds of the thoracic esophagus, whereas it is optional in more proximal (cervical) perforations. ■ Using flaps greatly reduces the risks of ongoing leaks postoperatively.
Drainage	■ Adequate drainage of the surgical site prevents formation of abscesses and, in the case of postrepair leak, allows for controlled leakage.
Underlying esophageal cancer	■ Primary repair of a perforated esophageal cancer is inappropriate.
Postoperative nutrition	■ Percutaneous Endoscopic Gastrostomy with Jejunal feeding limb (PEG-J) can make the operative management of intrathoracic and cervical esophageal perforation quicker, simpler, and less morbid.
Last resort	■ Esophagectomy and diversion should be a last resort as the operation is extremely morbid and many patients never go on to definitive reconstruction for restoration of GI continuity.

POSTOPERATIVE CARE

- Close monitoring of patients with esophageal perforation is mandatory and treating physicians should have a high index of suspicion for leaks. Patients should be kept NPO for 7 days postoperatively with a nasogastric tube or gastrostomy in place. Ins and outs should be monitored and the appearance of the liquid drained noted. Patients should be kept on intravenous antibiotics and intravenous proton pump inhibitors until oral contrast study 7 to 10 days postrepair.
- On postoperative days 7 to 10, a water-soluble contrast study should be performed. The absence of leak should be confirmed with a barium swallow before the nasogastric tube is removed and a liquid diet is begun. Diet is then progressed as tolerated and drains are removed.

OUTCOMES

- Outcome is dependent on multiple factors including the patient's hemodynamic status on presentation, the patient's age, the site of perforation, delay to diagnosis more than 24 hours, and the presence of underlying esophageal neoplasia.
- Mortality varies from 2% to 27% and morbidity from 53% to 81%.[4]

COMPLICATIONS

- Ongoing leak
- Tracheoesophageal or esophageocutaneus fistula
- Empyema
- Intraabdominal, mediastinal, thoracic, or cervical abscess
- Esophageal stricture
- Sepsis, septic shock

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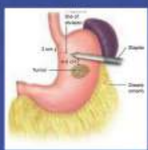
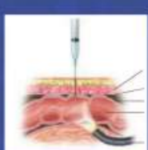
Part 2 Operative Techniques in Gastrointestinal Surgery





Chapter 1

Inguinal Hernia: Open Approaches

Michael D. Paul   Kamal M.F. Itani

DEFINITION

- Inguinal hernia is one of the most commonly encountered clinical problems for the general surgeon.
- An inguinal hernia is an opening in the myofascial plain of the oblique and transversalis muscles that can allow herniation of intraabdominal or extraperitoneal organs.
- There are three potential spaces for an inguinal hernia: (1) an indirect hernia occurs lateral to the inferior epigastric vessels and through the opening that accommodates the cord structures in men and the round ligament in women, (2) a direct hernia occurs through Hesselbach's triangle, and (3) a femoral hernia occurs through the femoral canal medial to the femoral vein.

DIFFERENTIAL DIAGNOSIS

- Patients present with complaints of either a bulge in the groin or groin pain.
- The differential diagnosis for a groin bulge includes inguinal lymphadenopathy, hydrocele, varicocele, a testicular mass, a cord lipoma, or an iliac or femoral aneurysm.
- The differential diagnosis for groin pain includes testicular pathology, ilioinguinal strain, or an athlete's hernia.

PATIENT HISTORY AND PHYSICAL FINDINGS

- The presence of an inguinal hernia can almost always be confirmed on physical examination. Both groins and testicles should be assessed for masses. A reducible mass is best felt with the patient standing and providing intermittent Valsalva such as a cough. A femoral hernia will be felt below the inguinal ligament, adjacent to the femoral vessels.

IMAGING AND OTHER DIAGNOSTIC STUDIES

- If the diagnosis cannot be definitely made with physical examination, ultrasound or computed tomography (CT) scan can be used to assess the integrity of the abdominal wall.

SURGICAL MANAGEMENT

- The bulk of surgical treatment is discussed in the "Techniques" section. Here, consider indications and other more general concerns, such as the following:

Preoperative Planning

- The role of routine antibiotic prophylaxis for elective inguinal hernia remains controversial. There is a body of literature indicating no statistically significant advantage to the use of antibiotic prophylaxis in the performance of routine inguinal hernia repair with or without the use of mesh. Nevertheless, many surgeons argue that antibiotic prophylaxis with a first-generation cephalosporin to cover skin flora is both inexpensive and safe and that such practice should not be considered inappropriate. In the acute setting of a small bowel obstruction secondary to an incarcerated hernia, appropriate perioperative antibiotics should be given within 60 minutes of the initial skin incision.
- Patients should be asked to void preoperatively. In most elective cases, a Foley catheter is not necessary.
- Deep vein thrombosis (DVT) prophylaxis with pneumatic compression devices starting prior to surgery and continuing in the recovery phase is now standard of care.
- Anesthesia options for inguinal herniorrhaphy include general, spinal, and local anesthesia with or without intravenous sedation. Emergent cases of small bowel obstruction secondary to an incarcerated inguinal or femoral hernias will require general anesthesia.

Positioning

- The patient is positioned supine with arms out on arm boards.

TECHNIQUES

- The approach to the inguinal canal is the same for all anterior groin hernia repairs.
- Gentle palpation of the inguinal area allows the identification of the spermatic cord. An oblique incision or incision along a skin crease or hairline centered around the cord structures is then made (**FIG 1**).
- Using electrocautery, the soft tissue is dissected to the superficial epigastric vessels, which are ligated. The dissection is then carried down through Camper's fascia and the more fibrous Scarpa's fascia. The next layer is the transparent innominate fascia and the external oblique aponeurosis. Palpation along the external oblique aponeurosis moving laterally and inferiorly should exclude a femoral hernia.
- The external ring is identified and is covered with the external spermatic fascia, which is continuous with the innominate fascia. The external oblique aponeurosis is opened with a scissor, starting medial at the external ring and moving superior/lateral parallel to the inguinal ligament (**FIG 2**). Elevating the fascia and using a scissor protects the ilioinguinal nerve from sharp or thermal injury. The ilioinguinal nerve lies just below the aponeurosis of the external oblique and anterior to the cord. If injury to the nerve occurs, it is best divided and excised proximally, allowing the nerve to retract into the muscle or preperitoneal space.
- The medial and lateral external oblique flaps are then dissected free. Insertion of Weitlaner retractors below

FIG 1 ● Incision for repair of an inguinal hernia is centered over the palpable spermatic cord along a hairline crease (*AB*, lower line). Alternatively, incision is done parallel to the inguinal ligament (*AB*, upper line towards *C* representing the anterior superior iliac spine).

the flaps greatly facilitates exposure of the spermatic cord. The iliohypogastric nerve can be identified running between the internal and external oblique superior and medial to the spermatic cord. It exits the external oblique medial and superior to the external ring (**FIG 3**).

- The spermatic cord is mobilized and isolated in the inguinal canal at the pubic tubercle but not medial to it (**FIG 4**). This will reduce the chance of damaging the posterior inguinal canal and any collateral circulation to the testes. A Penrose drain is placed around the cord structures and can be used to provide traction during dissection of the cord.
- The spermatic cord is explored for evidence of an indirect hernia. The cremaster muscle fibers are not divided but are split parallel to the cord. The genital branch of the genitofemoral nerve lies posterior in the cord and is best preserved by splitting the cremasteric muscles. Inspection on the anterior medial aspect of the cord will identify an indirect hernia (**FIG 5**).
- The indirect hernia sac is then dissected from the cord structures using sharp and blunt dissection. The sac is dissected down to the internal inguinal ring and freed from surrounding structures. Care must be taken to avoid damage to the vas deferens, which is closely associated with the sac proximally. The hernia sac is then reduced through the internal ring. The sac can also be transected and ligated. If ligated, the sac should be opened to assure that there is not a sliding component to the hernia.

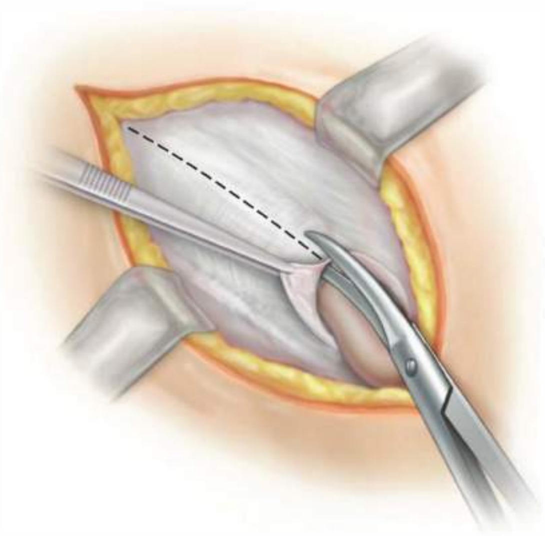


FIG 2 ● The external oblique is opened from the superficial ring toward the deep ring while avoiding injury to the ilioinguinal nerve.

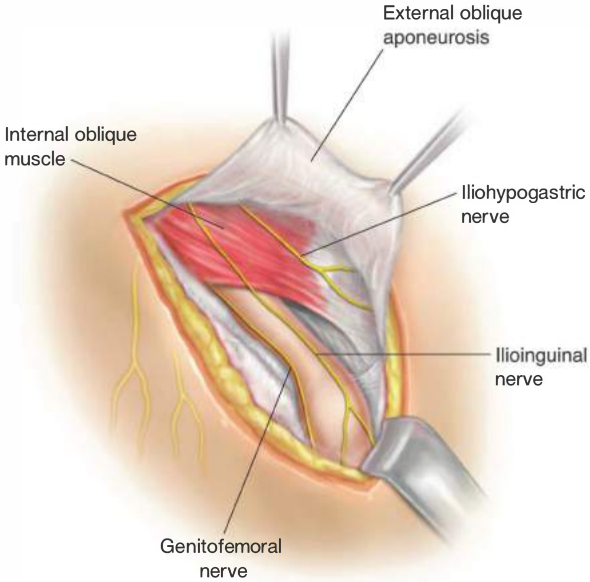


FIG 3 ● Location of the ilioinguinal and genitofemoral iliohypogastric nerves.

FIG 4 ● The isolation of the spermatic cord is done above the pubic tubercle to prevent injury to the inguinal floor.

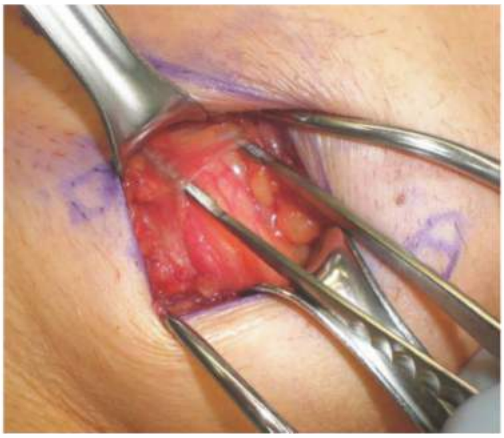


FIG 5 ● In very large inguinal hernias, it may be necessary to isolate the hernia sac prior to mobilization of the cord. Here, the cremasteric muscle fibers are split in order to access the indirect sac.

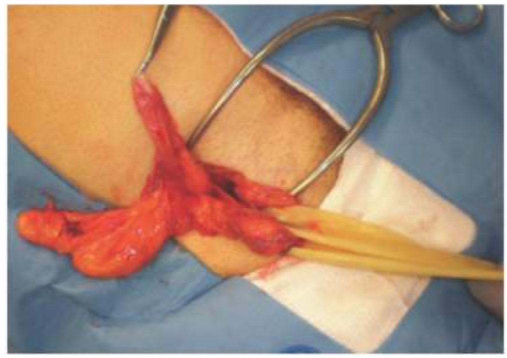


FIG 6 ● Cord lipomas, which can act as leads to a sac, should be resected in order to reduce the incidence of recurrent inguinal hernias. The hernia sac lies anteromedial to the cord and is separated from a large cord lipoma.

- In female patients, the round ligament can be completely transected, allowing for closure of the internal ring during repair.
- A cord "lipoma" is not a lipoma (suggesting growth of adipose tissue) but is rather extra or preperitoneal fat. It is usually associated with an indirect hernia but could also be present without an associated sac. Cord lipomas should be dissected free and resected as they can act as a lead point for a hernia sac (**FIG 6**).
- A sliding hernia is an indirect hernia that has part of its sac made up of retroperitoneal viscus. This could be bladder, cecum, or sigmoid colon. The safest method of managing a sliding hernia is a safe dissection of the indirect sac and simple reduction back to the preperitoneal space. The danger with high ligation of an indirect hernia sac, without proper inspection of the sac, is injury to the bowel within a sliding hernia.
- Following inspection of the spermatic cord and reduction of any indirect sac and excision of any preperitoneal fat, attention is turned to the posterior inguinal canal.
- Gentle retraction of the spermatic cord will facilitate exposure. Any defects or weakness of the floor should be assessed. In large direct hernias, a purse-string suture around the defect or imbrications of the floor with figure-of-eight sutures will reduce the direct bulge, allowing one to work unencumbered by it.

BASSINI REPAIR

- The Bassini repair is rarely performed today but remains the foundation for all hernia repairs. It is a primary tissue repair that consists of suturing of the transversus abdominis muscle, internal oblique muscle, and transversalis fascia medially to the inguinal ligament laterally.[1,2] It is an option to consider in cases where contamination is likely and the use of mesh becomes contraindicated.

Technique

- Bassini's original description of the procedure included resection of the cremasteric fibers. Although still advocated by some, it is not routinely done.
- After elevation and lateral retraction of the spermatic cord, the inguinal canal is carefully inspected for defects and weaknesses.
- The muscular and aponeurotic arch formed by the lower fibers of the transversus abdominis muscle and the internal oblique muscle is used to identify the medial edge of the repair.[3] In his repair, Bassini opened the transversalis fascia,[1] but most surgeons today would often omit this step and place the sutures between the aponeurotic arch and the deeper transversalis fascia to the inguinal ligament. If the anatomic layers are not clear, as in recurrent hernia surgery, opening the floor and clearly defining the anatomy will ensure the incorporation of the three anatomic layers medially: the internal oblique muscle, the transversus abdominis muscle, and the transversalis fascia.
- If the decision is made to open the inguinal canal floor, it is done by incising the transversalis fascia from the pubic tubercle to the internal inguinal ring. Care should be taken not to injure the inferior epigastric vessels, which are directly posterior to the transversalis fascia. Once the transversalis fascia is opened and the undersurface of the fascial flaps is exposed, one can easily identify the three anatomic layers described earlier and more carefully inspect the femoral canal.

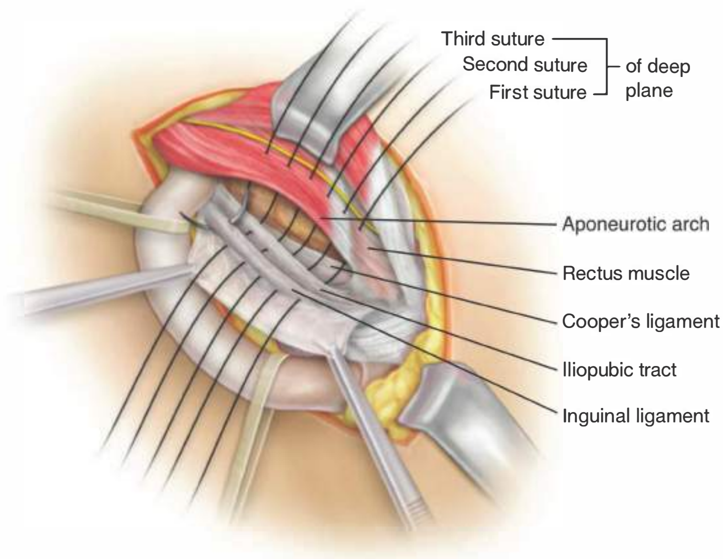


FIG 7 ● If the transversalis fascia is opened in a Bassini repair, the iliopubic tract may be incorporated into the lateral stitch.

- Once the muscular aponeurotic arch and the inguinal ligament are properly exposed and a femoral hernia is ruled out, single interrupted permanent polypropylene sutures are used to perform the repair. The first stitch is the most medial and should include the lateral edge of the rectus sheath if possible. It is placed from the rectus sheath and aponeurotic arch to the fascia overlying the pubic tubercle and not the inguinal ligament. This is an important technical point in order to reduce recurrence at the pubic tubercle, a common site.
- Subsequent sutures should be placed from the muscular aponeurotic arch, incorporating all three layers, to the inguinal ligament. Medially, each suture is taken 2 cm from the edge of the arch. Laterally, the suture should incorporate few fibers of inguinal ligament, thus avoiding the underlying femoral vessels. Different fibers should be incorporated with each suture to avoid tearing the inguinal ligament. Upon reaching the internal inguinal ring, the ring is tightened, allowing the tip of a forceps to pass through the ring and avoiding strangulation of the cord structures.
- If the transversalis fascia has been opened, the iliopubic tract will be identified. The medial stitch should first incorporate the iliopubic tract and then the inguinal ligament (**FIG 7**).
- The spermatic cord is returned to its normal anatomic position, lying superior to the newly reconstructed inguinal floor, and closure of the superficial layers is performed in the standard fashion (**FIG 8**).
- In order to decrease tissue tension after the repair is completed, a relaxing incision can be made vertically for few centimeters on the anterior rectus sheath parallel to the repair line. This will allow relaxation of the aponeurotic arch toward the inguinal ligament.

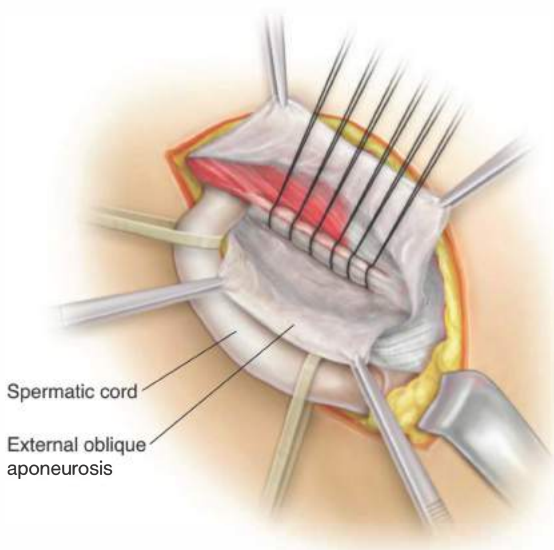


FIG 8 ● The Bassini repair is carried lateral until the internal ring is re-created.

SHOULDICE REPAIR

- After Bassini, the Shouldice repair is the most popular inguinal hernia tissue repair.[4] It continues to be used as the primary inguinal hernia repair in the Shouldice clinic and by others who trained at the Shouldice clinic.[5] It can also be used in situations where mesh is contraindicated such as in contaminated cases.

Technique

- Like the Bassini repair, the Shouldice repair starts with a resection of the cremasteric muscle as an important step of the repair. Although some still advocate this step, we do not think that this adds to the durability of repair and it potentially exposes the genital branch of the genitofemoral nerve to injury.
- The transversalis fascia is opened from the medial aspect of the internal ring to the fascial thickening of Cooper's ligament. This should be done with caution as the inferior epigastric vessels will be encountered just below the transversalis fascia. The opening of the transversalis fascia allows identification of all three layers of the posterior wall (transversalis abdominis muscle, internal oblique muscle, and transversalis fascia). Flaps of transversalis fascia are developed medially and laterally by carefully sweeping the underlying preperitoneal fat (**FIG 9**).
- Dissection of the lateral flap should be carried to Cooper's ligament to identify any femoral hernias and clearly expose the iliopubic tract. Although not done at our institution, incision of the superficial thigh fascia (cribriform fascia) to assess the femoral canal and to improve mobility of the external oblique has been reported and practiced at the Shouldice Hospital in Ontario.
- Originally performed with stainless steel wire, this repair is now performed with 2-0 Prolene sutures. A four-layer repair is performed using two continuous sutures. The first layer begins medially, anchoring the suture from the transversalis fascia to the fascia overlying the periosteum of the pubic tubercle. Leaving a portion of suture long enough to tie to, the stitch is run laterally, approximating the posterior rectus sheath to the iliopubic tract. When the rectus sheath can no longer be brought to the iliopubic tract without tension, the stitch is transitioned to the posterior transversalis fascia and is run superior and lateral until the internal ring is re-created (**FIG 10**).

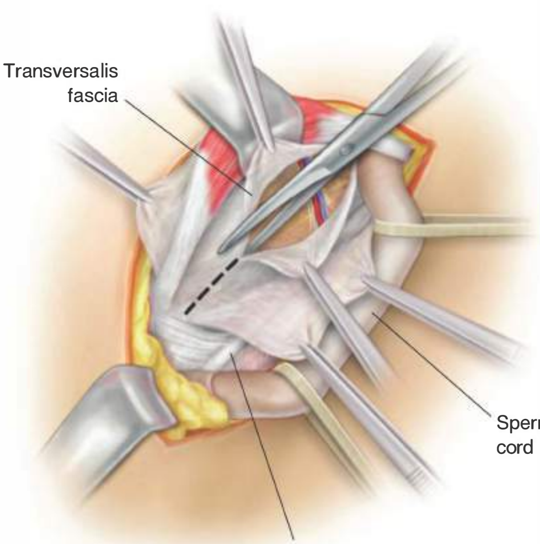


FIG 9 ● In a Shouldice repair, the transversalis fascia is opened. It is necessary to protect the inferior epigastric vessels from injury.

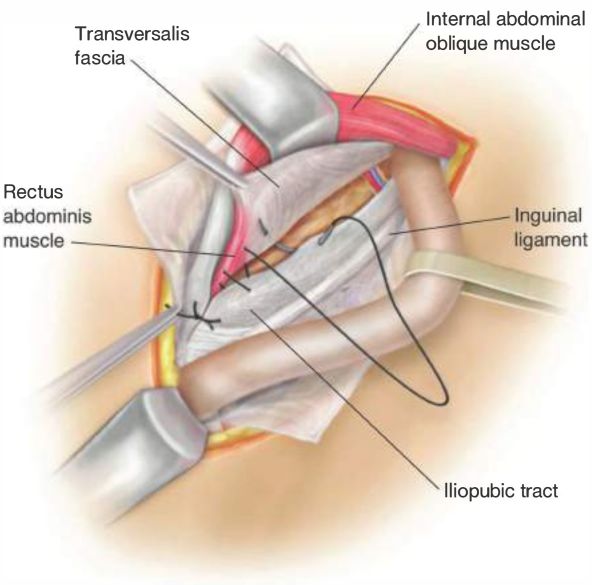


FIG 10 ● The first row in a Shouldice repair incorporates the aponeurotic arch by taking posterior bites through the transversalis fascia and approximating the arch to the ileopubic tract.

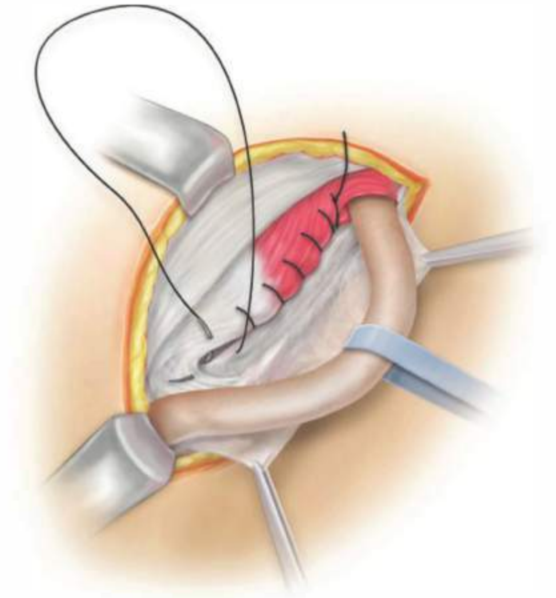


FIG 11 ● Starting at the internal ring, the third suture layer of a Shouldice repair incorporates the internal oblique and the underlying transversus abdominis medially, which are approximated to the undersurface of external oblique just above and parallel to the inguinal ligament laterally.

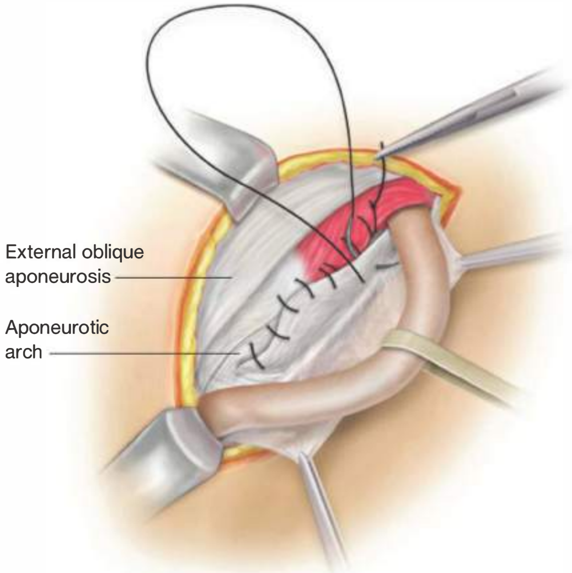


FIG 12 ● In the Shouldice repair, the fourth layer reapproximates the internal oblique to the undersurface of the external oblique, thus effectively reenforcing the third layer.

- The suture is then reversed, and a second layer is started using the same Prolene suture. The second layer approximates the three layers, including the free edge of the medial transversalis fascia, the internal oblique, and the transversus abdominis to the inguinal ligament. The second suture line is brought over the anchoring stitch, reinforcing the medial aspect of the repair, and tied to the anchoring stitch of the first suture line. This effectively imbricates the first layer.
- The third and fourth layers are also run continuously. Starting at the internal ring, the first stitch is blindly placed in the internal oblique and transversus abdominis and approximated to the posterior external oblique aponeurosis, just above the inguinal ligament. This is run medially, creating a ridge just superior and parallel to the inguinal ligament (**FIG 11**).
- The fourth layer is run back to the internal ring, buttressing the third layer, again taking the transversus abdominis and internal oblique, and approximating them to undersurface of the external oblique. The suture is tied to its tail (**FIG 12**).

THE MCVAY REPAIR OR COOPER'S LIGAMENT REPAIR

- The Cooper's ligament repair is a primary tissue repair that was described and advocated by Dr. McVay in 1958. Following 300 cadaver dissections, he noted that the internal oblique and external oblique do not attach to the inguinal ligament. Rather, they attach to the pubic bone at the location of Cooper's ligament attachment.[6] He concluded that repair of the inguinal defect would be anatomically correct if the three layers (internal oblique aponeurosis, transversus abdominis, and transversalis fascia) were sutured to Cooper's ligament and then transitioned to the inguinal ligament following closure of the femoral myopectineal defect.
- The repair provides closure of the femoral, indirect, and direct spaces and, as such, can be used to repair any hernia defect that may occur in the groin.[7] However, and due to the tension created by this repair, the risk of injury to the femoral vessels, and the risk of recurrence at the suture transition from Cooper's ligament to inguinal ligament, this repair is now mostly reserved for femoral hernias. The postoperative morbidity and mortality increase significantly in patients undergoing emergent repair, highlighting the importance of repairing femoral hernias in an elective setting.

Technique

- Following examination of the spermatic cord, the posterior wall of the inguinal canal is opened from the deep inguinal ring to the pubic tubercle. Care should be taken to avoid injury to the inferior epigastric vessels that lie just posterior to the transversalis fascia near the deep ring.[8]

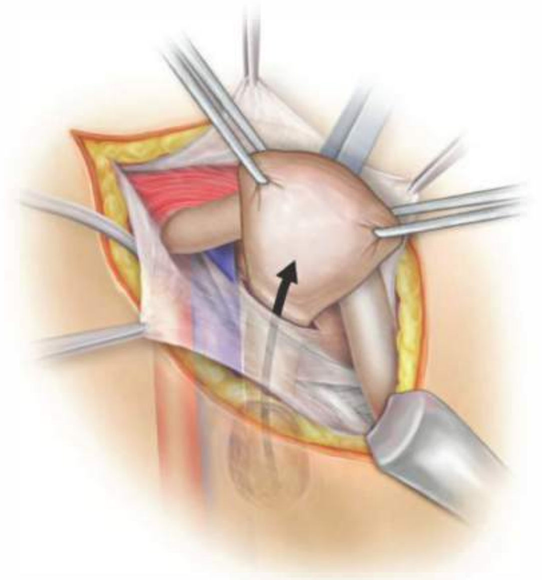


FIG 13 ● When addressing a femoral hernia, the sac is opened and its contents inspected prior to reduction of the sac.

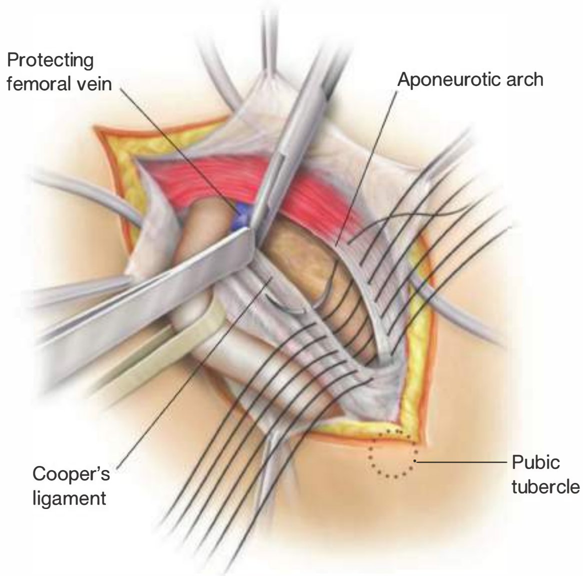


FIG 14 ● In a McVay repair, the transversus abdominis, internal oblique aponeurosis, and transversalis fascia are approximated to Cooper's ligament.

- This provides exposure to the preperitoneal space (space of Bogros), femoral vein, and femoral canal. The femoral hernia sac is found medial to the femoral vein and is reduced.
- If an incarcerated or strangulated femoral hernia cannot be reduced with traction from the preperitoneal space and pressure from below the femoral ring on the anterior thigh, the medial lacunar ligament can be incised to enlarge the femoral ring. If still unable to reduce the hernia, the inguinal ligament can be divided and then repaired following reduction of the hernia (**FIG 13**).
- Incising the posterior wall of the inguinal canal exposes the three aponeurotic layers: the internal oblique muscle and aponeurosis, the transversus abdominis muscle and aponeurosis, and the transversalis fascia. Starting medially, simple interrupted sutures are used to approximate the internal oblique aponeurosis, transversus abdominis muscle and aponeurosis, and the transversalis fascia to Cooper's ligament (**FIG 14**).
- A transition stitch is placed, incorporating the triple layer, Cooper's ligament, the femoral sheath at its medial aspect, and the inguinal ligament. If the femoral sheath cannot be identified, it may be omitted. The femoral sheath is intimately associated with the femoral vein. If bleeding occurs following a stitch in the femoral sheath, it should be immediately removed and direct pressure applied. It should not be tied as this would result in tearing of the femoral vein. If the stitch is placed too lateral on Cooper's ligament, the femoral vein can be compressed leading to thrombosis (**FIG 15**).
- The remainder of the inguinal floor is repaired by approximating the triple layer to the inguinal ligament and continuing, lateral, to the level of the internal ring (**FIG 16**).
- This repair creates tension. The distance to Cooper's ligament from the aponeurotic arch of the transversus and internal oblique can be up to 8 cm. To release this tension, a relaxing incision is required. This involves

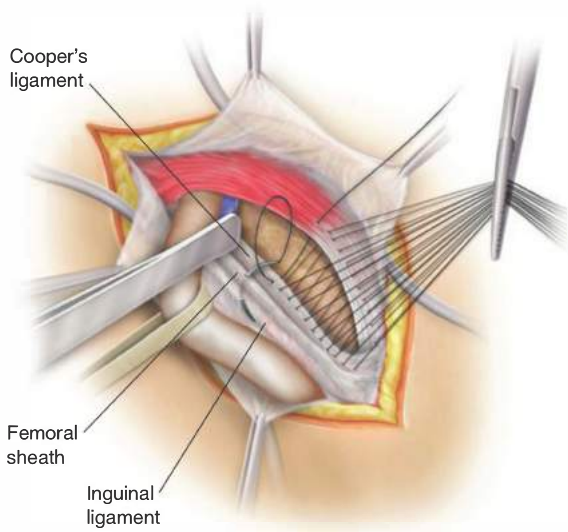


FIG 15 ● The transition stitch of a McVay repair incorporates Cooper's ligament, the medial femoral sheath, and the inguinal ligament. If bleeding occurs, the stitch is immediately removed and pressure should be held.

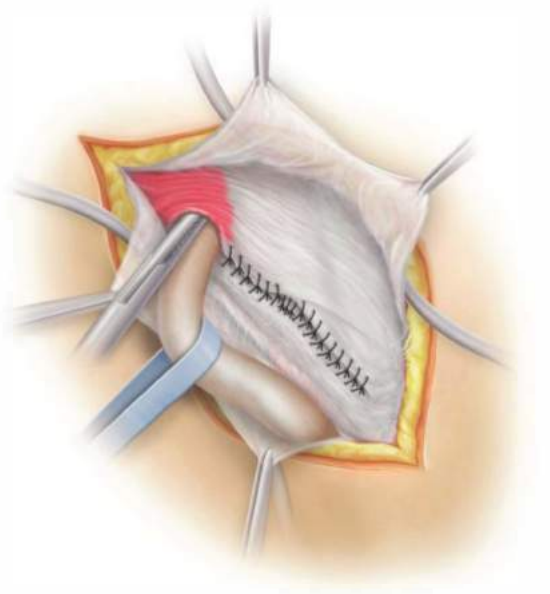


FIG 16 ● The final step of a McVay repair is the approximation of the aponeurotic arch to the inguinal ligament beyond the transition stitch in order to re-create the internal ring.

first exposing the rectus sheath behind the external oblique aponeurosis. Sparing the external oblique component, the rectus sheath is then incised vertically from the tubercle extending cephalad for approximately 6 cm along its lateral edge. The relaxing incision should be performed before the sutures are tied (**FIG 17**).

- The external oblique and skin are closed as described previously.
- Alternatively, a mesh can be used to perform a McVay repair. This is outlined in the "Lichtenstein Repair" section. Laterally, the mesh is sutured to Cooper's ligament up to the point where the femoral vein exits at which point the suture is transitioned to the inguinal ligament.

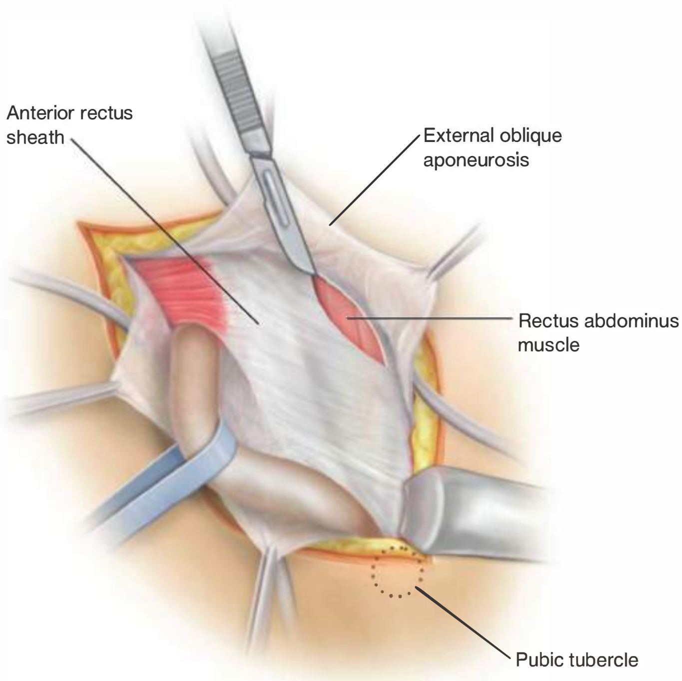


FIG 17 ● A relaxing incision performed on the rectus fascia will relax the repair and should be performed prior to tying the sutures.

LICHTENSTEIN REPAIR

- The use of prosthesis in inguinal herniorrhaphy is a dynamic field with frequent introduction of new devices, prosthesis, and modifications in technique. Although we cannot include all of them, a thorough understanding of the mechanics and anatomy will provide the foundation that new technology can build on. The Lichtenstein hernia repair uses prosthetic material to bridge the muscular aponeurotic defect in the inguinal region, creating an onlay mesh repair. It is an operation that is straightforward and is considered to be a "tension-free" repair.[9,10]

Technique

- After the spermatic cord has been evaluated for an indirect hernia, attention is then focused on the inguinal floor.
- Any protrusion of a direct hernia can be imbricated to flatten the posterior wall.
- A sheet of at least 3 in × 6 in mesh, preferably consisting of soft polypropylene, is fashioned so that the mesh overlaps the rectus by 1 to 2 cm and reaches the inguinal ligament. The mesh should extend underneath the external oblique past the deep inguinal ring. A slit is made on the proximal end of the mesh to accommodate the spermatic cord. This creates two tails of mesh. In females, if the round ligament is ligated, obviously, no slit is required (**FIG 18**).
- The mesh is first placed underneath the spermatic cord. With the medial aspect of the mesh overlying 2 to 3 cm on the pubic tubercle, a Prolene suture is used to anchor the mesh. The suture should include the fascia overlying the tubercle but not the periosteum. Overlapping the pubic tubercle with mesh is important as this is a frequent site of recurrence (**FIG 19**).
- The first stitch is run continuously from the patch to the inguinal ligament every 1 cm. This stitch is continued until it runs past the deep inguinal ring.
- The medial sutures are interrupted, attaching the patch to the rectus sheath, and eventually will include the internal oblique muscle or aponeurosis. These sutures should be spaced every 2 to 3 cm and are placed to prevent migration of the mesh. The mesh should wrinkle rather than lay flat in order to accommodate shrinking of the mesh and prevent tension.
- The tails are then sutured together around the spermatic cord and to the inguinal ligament, creating a new internal ring. The medial tail should lie anterior to the lateral tail. The tails are then tucked superiorly underneath the external oblique aponeurosis, extending at least 3 cm past the internal ring.
- The spermatic cord is then placed in its anatomic position lying on top of the mesh and the external oblique is closed over the cord recreating the external inguinal ring.

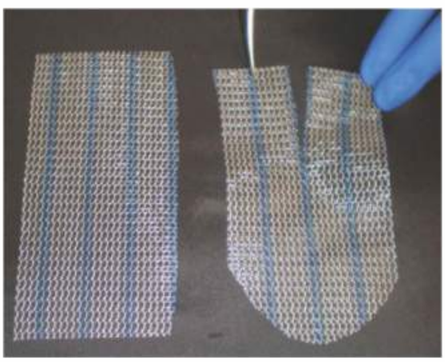


FIG 18 ● Mesh consisting of soft polypropylene fashioned from a 3 in × 6 in piece of mesh for a Lichtenstein repair.

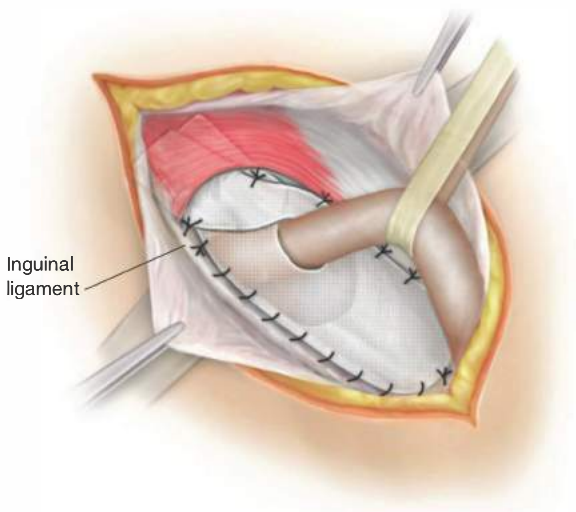


FIG 19 ● In a Lichtenstein repair, the mesh is used to bridge the aponeurotic arch medially and the inguinal ligament laterally.

PROLENE HERNIA SYSTEM AND PLUG SYSTEM

- First introduced in 1998, the Prolene Hernia System (PHS) is an evolution of both the Lichtenstein repair and the preperitoneal approach for inguinal hernia repair. Whereas the Lichtenstein approach uses solely an onlay mesh and the preperitoneal approach uses solely an underlay approach, the PHS uses both (**FIG 20**). It was designed to completely cover the myopectineal orifice, treating indirect, direct, and femoral defects.[11,12] Direct and indirect hernias may be approached differently and are presented separately.

Technique

Indirect hernia approach

- After examination of the spermatic cord and complete reduction of the indirect sac, the floor of the inguinal canal is examined. If the posterior wall of the inguinal

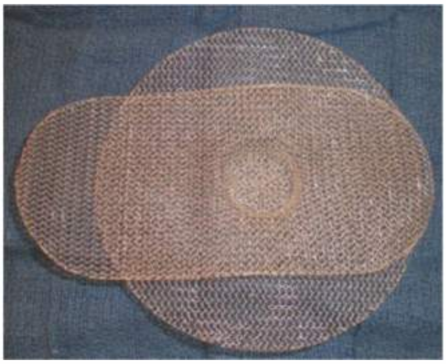


FIG 20 ● PHS mesh comes in three different sizes: small, medium, and extended. The extended mesh is shown in this photograph.

canal looks intact, the preperitoneal space is entered through the deep inguinal ring.

- The preperitoneal space is accessed through the internal ring. The preperitoneal fat and peritoneum are separated from the transversalis fascia. This is facilitated by introducing a Raytech sponge through the internal ring and doing this dissection bluntly with care not to injure the inferior epigastric vessels. The borders of dissection should be inferior to the pubic tubercle, below Cooper's ligament, and lateral to past the deep inguinal ring. This creates a space where the posterior leaflet of the mesh will cover all defects within the myopectineal orifice.

Direct hernia approach

- If the direct hernia is easily reduced, the method described earlier for developing the preperitoneal plane can be used. Alternatively, the preperitoneal space can be accessed directly through transversalis fascia. The transversalis fascia is entered, and the epigastric vessels are identified. A Raytech sponge may be used to create a space that extends below the pubic tubercle and inferior to Cooper's ligament. Because the dissection of the preperitoneal space was started more medially than the indirect method, it is important to ensure adequate dissection of the lateral defect. The space should be extended past the deep ring, ensuring adequate coverage of the lateral myopectineal orifice.

Insertion of Prolene hernia system mesh

- The PHS mesh consists of two leaflets connected in the middle (FIG 20). Proper preparation of the mesh is integral for proper deployment. The circular posterior leaflet is designed to sit in the preperitoneal space and the oblong oriented leaflet is designed to lie on top of transversalis fascia with the short end toward the pubic tubercle. Insertion of the posterior leaflet starts with folding the oblong portion of the mesh and holding it with a ring forceps close to the connector. This will allow easier insertion of the posterior leaflet of the mesh through either the internal ring or the opening made into transversalis fascia by pushing the mesh with the ring forceps (FIG 21).

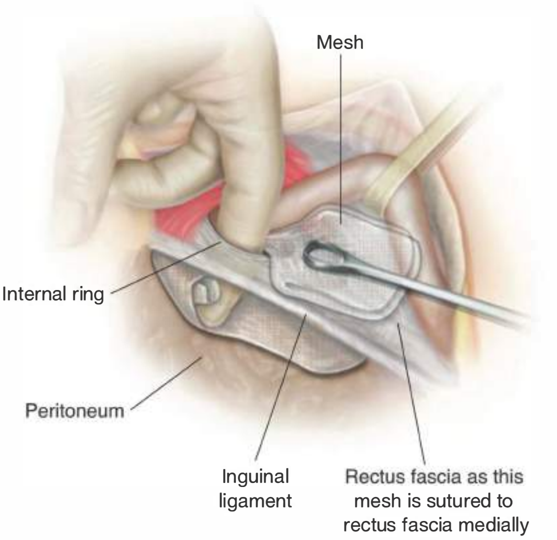


FIG 21 ● In a PHS repair, the posterior leaflet of the mesh sits below transversalis fascia above the peritoneum and reduced sac and covers the femoral defect. The anterior leaflet of the mesh lies above transversalis fascia and is sutured to the inguinal ligament laterally and rectus fascia medially.

- The mesh is then fully inserted through the internal ring, or the direct defect, creating an umbrella shape of the circular mesh. When gently pulling the anterior leaflet mesh out of the defect, the posterior leaflet should expand above the preperitoneal fat and peritoneum. This could be assisted by gently pushing the edges of the posterior mesh with the back of a forceps. It is important to ensure that this mesh expands to below the pubic tubercle, below Cooper's ligament, and lateral to cover the internal ring (FIG 22).

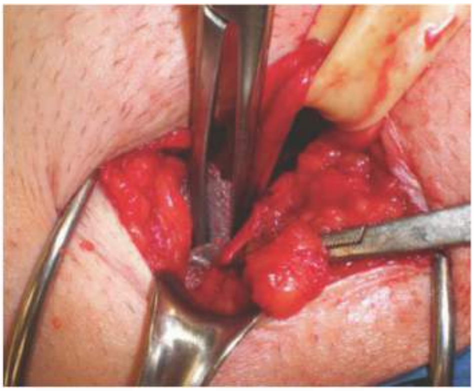


FIG 22 ● Insertion of the posterior leaflet of the PHS mesh.

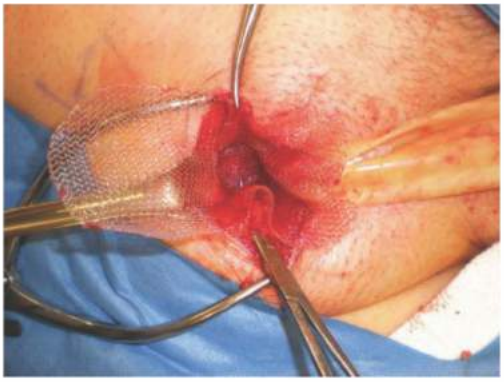


FIG 23 ● The PHS mesh with the posterior leaflet in place.

- The connector between the anterior and posterior leaflets is allowed to sit in the internal ring or within the opening made into transversalis fascia. This opening can be tightened around the connector with one or two interrupted 2-0 Prolene sutures (**FIG 23**).
- The anterior leaflet of the mesh is then treated as a Lichtenstein repair. A 2-cm overlap is allowed between the anterior leaflet of the mesh and the pubic tubercle. The anchoring suture to the fascia overlying the pubic tubercle is run between the lateral edge of the anterior leaflet and the inguinal ligament up to the level of the internal ring. The suture is then tied to itself. Medially, the mesh is anchored with few interrupted sutures to the rectus fascia.
- A slit is made in the lateral border of the anterior leaflet to accommodate the spermatic cord. The edges of the slit are then approximated to each other around the cord and to the inguinal ligament. The proximal portion of the anterior mesh is tucked flat underneath the external oblique aponeurosis proximally.
- The external oblique aponeurosis is closed in the standard fashion.

Closure

- The spermatic cord is placed in its normal anatomic position on the re-created floor of the inguinal canal.
- The external oblique aponeurosis is then closed with a continuous absorbable suture starting proximally and moving distally, thus re-creating the external inguinal ring. The ilioinguinal and iliohypogastric nerves should be protected during this step to avoid injury and entrapment (**FIG 24**).

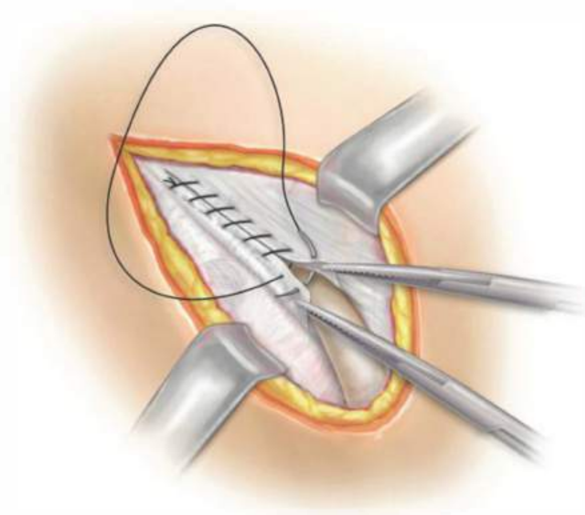


FIG 24 ● The external oblique is reapproximated, avoiding the ilioinguinal or iliohypogastric nerve.

- Several interrupted absorbable sutures are placed to reapproximate Scarpa's fascia and the subcutaneous tissue layers (**FIG 25**).
- The skin is closed with a running absorbable subcuticular suture and an occlusive dressing is placed.
- Following the removal of the sterile drapes, the testicles at the site of repair should be examined. If retracted, gentle traction on the scrotum will reduce the testicle back to its anatomic position. If left in the inguinal canal, it may permanently scar in thatlocation.

FIG 25 ● Scarpa's fascia is reapproximated.

PEARLS AND PITFALLS

Unable to locate the hernia defect	■ If unable to locate a direct or indirect hernia defect, then open the inguinal floor medial to the inferior epigastric vessels to examine the femoral canal.
Primary repair on tension	■ If the tissue quality is poor, use a mesh prosthesis to allow for a tension-free repair. ■ If mesh is contraindicated, a relaxing incision in the anterior rectus fascia should be performed. ■ Avoid use of mesh in contaminated operative fields.
Meticulous hemostasis	■ Patients undergoing hernia repair are often on antiplatelet or anticoagulants for cardiac disease. Meticulous hemostasis is important to prevent postoperative hematoma and wound complications.

POSTOPERATIVE CARE

- Most patients are discharged on the day of repair. Patients should void prior to leaving the recovery area.

OUTCOMES

- Elective repair of inguinal hernia is associated with low recurrence rates. Tension-free mesh repairs have the lowest rates of recurrence in adult populations. The overall recurrence rate is 3% to 5% for mesh repairs and 10% to 15% for suture repairs.[13]

COMPLICATIONS

- The rate of complications after inguinal herniorrhaphy has been reported between 15% and 50%.[14] When evaluating patient-centered outcomes, the overall rate of complications is consistently above 30%. The knowledge of complications, experience with handling them, and anticipation of adverse events can reduce their occurrence and guide informed consent.
- The most frequent complication is the development of a seroma. This has been reported to be between 2.4% and 13.6%. The introduction of bacteria by aspiration of a seroma has been widely reported. In the presence of mesh, any attempt at aspiration should be reserved to patients with suspected infection for diagnostic purposes. A seroma should spontaneously resolve over 6 to 8 weeks. Careful ligation of vessels, limiting dissection of soft tissue, and closure of dead spaces can reduce seroma formation.
- The risk of hematoma is reported between 5.5% and 6.5%. Meticulous hemostasis and knowledge of the vascular anatomy of the groin can reduce occurrence. Small hematomas may be treated conservatively; however, large hematomas inducing significant pain or creating tension will usually require evacuation.
- The risk of hemorrhage requiring transfusion is very rare. Intraoperative injury to major vessels is most likely to occur when suturing to Cooper's or the inguinal ligament. The femoral artery and vein are bordered by Cooper's ligament posteriorly and the inguinal ligament anteriorly. Superficial bites under direct vision should reduce the chance of injury. If an injury does occur, immediate removal of the suture, without tying the suture, and holding direct pressure usually prevent excessive bleeding. If the injury is not recognized, or the suture is tied resulting in a tear of the femoral vein, the inguinal ligament should be divided and a vascular repair should be initiated.
- The reported rate of surgical site infection in clean, nonemergent, inguinal hernia repairs ranges from 0.5% to 3%. This rate of infection is higher for recurrent and emergent hernia operations. Guiding principles of surgical infection prevention are applicable. In case of infection, early opening of the wound and appropriate antibiotic therapy for cellulitis and systemic symptoms will treat the majority of superficial infections. Deep surgical site infections, which are likely associated with foreign material such as suture or mesh, require fastidious wound care and drainage. Although usually not required in the early stages of therapy with early recognition and proper wound care, the mesh may ultimately need to be removed or debrided.
- Urinary retention is reported to occur in 0.2% to 2.42% of the cases. Urinary retention is lowest in patients having regional anesthesia compared to general anesthesia. For those patients with retention, bladder catheterization is required. Bladder injury should be rare. In the case of an iatrogenic injury during a sliding hernia, a two-layer repair of the bladder with absorbable suture will suffice.
- Ischemic orchitis occurs in less than 1% of the cases. It may progress to testicular atrophy, but its clinical course is difficult to predict. Ischemic orchitis is most often caused by thrombosis of the testicular vein within the spermatic cord but can also be from arterial injury. A Doppler ultrasound can evaluate blood supply to the testicles. Reducing cord dissection, preventing overly tight internal ring reconstruction, and transecting large distal hernia sacs and leaving them in situ can reduce this risk.
- Injury to the vas deferens should be rare. When an injury is recognized, and surgical repair is indicated, microsurgical repair with an operating microscope gives superior outcomes. However, repair may also be performed over a 0 Prolene suture, which is brought through the vas at a point distal to the reanastomosis. The Prolene is then brought through the skin and removed on day 3. If unable to repair an injured vas, ligation with permanent suture, and preventing further dissection of the vas, may allow reconstruction in the future. When the vas is injured by rough handling or becomes entrapped by mesh, painful ejaculation or dysejaculation can develop from the resulting partially obstructed lumen.

- Chronic or severe pain following inguinal herniorraphy is reported in 10% to 14% of the cases. It remains a perplexing and challenging problem. It is associated with preoperative chronic pain and with recurrent inguinal hernia repair.[15] The identification and protection of the ilioinguinal, genitofemoral, and iliohypogastric nerves are important in preventing nerve entrapment injuries. If a nerve is injured, it should be transected and ligated proximally, allowing it to retract into the muscle or preperitoneal space. Operative treatment with planned resection of the three nerves can improve or resolve the pain. However, a multidisciplinary pain team approach is imperative for optimal patient outcomes.

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Chapter 2

Inguinal Hernia: Laparoscopic Approaches

Benjamin K. Poulose Michael D. Holzman Rebeccah B. Baucom

DEFINITION

- Inguinal hernias can be divided into indirect, direct, and femoral based on location.
- Inguinal hernia repair is one of the most common procedures performed by general surgeons in the United States, with 750,000 to 800,000 cases annually.
- Inguinal hernia will affect nearly 25% of men and less than 2% of women over their lifetime.
- The majority of femoral hernias occur in women (around 70%), but indirect inguinal hernias are still the most common type of hernia in women.
- Indirect inguinal hernias result from a patent processus vaginalis and are responsible for most pediatric inguinal hernias.

ANATOMY

- The myopectineal orifice includes both the inguinal and femoral regions. The inguinal ligament divides the myopectineal orifice into the inguinal region superiorly and the femoral region inferiorly.
- The boundaries of the inguinal canal are as follows: anteriorly, the aponeurosis of the external oblique and the internal oblique muscle laterally; posteriorly, the transversalis fascia and the transversus abdominis muscle; superiorly, the arch formed by the internal oblique muscle; inferiorly, the inguinal ligament; medially, the aponeurosis of the external oblique and its insertion on the pubic symphysis (**FIG 1**).
- An indirect hernia passes with the spermatic cord (or round ligament, in women) through the inguinal canal via the internal and external rings.
- A direct hernia passes through the posterior wall of the canal (i.e., the transversalis fascia and transversus abdominis), medial to the inferior epigastric vessels, above the inguinal ligament. This region is considered Hesselbach's triangle.
- Femoral hernias pass through the femoral canal, medial to the femoral vessels, inferior to the inguinal ligament.
- The nerves at risk for traction injury in most anterior inguinal hernia repairs include the ilioinguinal nerve, iliohypogastric nerve, and the genital and femoral branches of the genitofemoral nerve.

PATHOGENESIS

- Indirect hernias occur as a result of a patent processus vaginalis and are congenital. The hernia involves a peritoneal sac passing through the inguinal canal alongside the spermatic cord or round ligament.

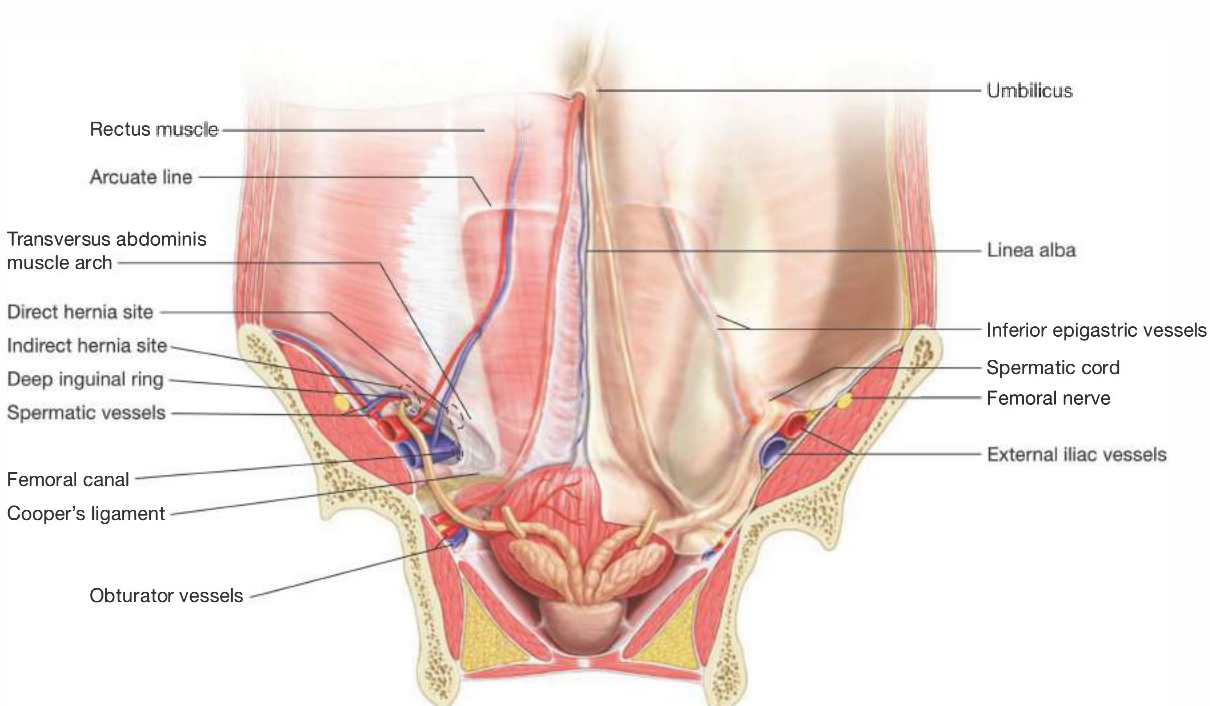


FIG 1 ● Anatomy of the inguinal canal, intraabdominal view.

- Direct hernias tend to occur secondary to increased intraabdominal pressure. Predisposing factors include chronic cough, constipation, straining and difficulty with urination, obesity, and ascites.

NATURAL HISTORY

- The natural history of untreated inguinal hernias is not fully known, although many believe that progression is inevitable. Traditionally, repair of all inguinal hernias has been recommended to prevent progression, hernia symptoms, and strangulation.
- Watchful waiting is a reasonable strategy especially in men with minimal symptoms, as the rate of acute hernia incarceration with bowel obstruction, strangulation of intraabdominal contents, or both is less than 2 per 1,000 patient-years.[1]

PATIENT HISTORY AND PHYSICAL FINDINGS

- Most patients present with a groin bulge as their primary complaint. Over time, this tends to increase and may be associated with pain or discomfort in the groin, thigh, or testicle.
- Some are asymptomatic and detected on physical exam by a primary care physician.
- Significant pain at initial presentation, particularly if not accompanied by an obvious bulge, may not be due to hernia. Often, these patients will have chronic pain even after groin exploration.
- Patients who develop progressive symptoms with increasing hernia size tend to have the best outcomes after surgical repair with significant improvement in pain.
- Physical examination is the best way to diagnose inguinal hernias, and both sides should be evaluated for the presence of a hernia. The patient should be examined supine and upright, with a finger palpating the external ring while the patient performs a Valsalva maneuver. A bulge detected below the inguinal ligament in the medial thigh suggests a femoral hernia.

IMAGING AND OTHER DIAGNOSTIC STUDIES

- Adjunctive imaging studies are rarely required for diagnosis of inguinal hernia.
- Ultrasound may be helpful but is dependent largely on the skill of the sonographer. Valsalva maneuvers should be employed, and the exam should be performed with the patient supine and upright.
- Some inguinal hernias can be seen on computed tomography (CT), although small studies suggest that the sensitivity and specificity are only 85% and 65% to 85%, respectively. Therefore, if a hernia is not visualized on CT, the diagnosis is not ruled out.
- The role of magnetic resonance imaging (MRI) with and without Valsalva is unclear but may be available at some centers. MRI is most useful in differentiating sports-related injuries from true inguinal hernias.

DIFFERENTIAL DIAGNOSIS

- The differential diagnosis for a groin bulge includes hernia, lymphadenopathy, hydrocele, abscess, hematoma, femoral artery aneurysm, or undescended testicle.

NONOPERATIVE MANAGEMENT

- Patients with minimally symptomatic hernias may be candidates for nonoperative management or watchful waiting.[1] This approach entails follow-up after 6 months and annually by a care provider, along with instructions regarding the signs and symptoms of acute incarceration or strangulation.
- Delay of repair for 6 months has been shown not to have an adverse effect on surgical outcomes.[2]
- Patients who experience significant pain with activity, those who have prostatism or constipation, and those with overall good health status are likely to benefit most from surgical repair.[3]
- After 2 years, about 25% of patients who are minimally symptomatic will develop worsening symptoms and request surgical repair.[1]

SURGICAL MANAGEMENT

- Techniques for the laparoscopic management of inguinal hernia include the transabdominal properitoneal approach (TAPP) and the totally extraperitoneal (TEP) technique.
- Laparoscopic repair is especially useful for recurrent or bilateral inguinal hernias.
- A recent meta-analysis comparing open and laparoscopic repairs (TAPP and TEP) for primary unilateral hernias demonstrated that both laparoscopic approaches resulted in less chronic groin pain and numbness compared to open repair. TAPP and open repairs had a lower risk of recurrence compared to TEP. TAPP was associated with a higher risk of perioperative complications compared to open repair.[4]

Preoperative Planning

- General anesthesia is usually required for laparoscopic repairs, whereas open repairs can be performed with the use of local anesthesia.
- Immediately prior to surgery, the patient should be instructed to void or a Foley catheter should be placed. Most patients can adequately void preoperatively, precluding the need for a urinary catheter, which may increase the risk of urinary retention as well as infection.
- For recurrent hernias, it is imperative that the surgeon review previous operative reports. In general, the approach used to repair a recurrence should use fresh surgical planes to facilitate the repair. For a previous open repair that has recurred, a laparoscopic approach is usually favored. If a mesh plug has been used, a TAPP approach may be significantly easier than TEP due to the high chance of peritoneal violation and need to debulk the plug.
- For a previous laparoscopic repair that has recurred, an open approach may be easier to perform. Given the variety of laparoscopic inguinal hernia techniques used, many have found that repeat laparoscopic repair of a recurrence is possible in experienced hands.
- Caution should be taken in patients with previous prostatectomy or entrance into the space of Retzius, which can make laparoscopic repair much more challenging. In these cases, serious consideration should be given to an anterior

approach. As with repairing laparoscopic inguinal hernia repair recurrences, a laparoscopic approach can be attempted, if deemed advantageous, by an experienced laparoscopic hernia surgeon.

Positioning

- The patient is positioned supine with arms tucked and legs secured in order to prevent slippage with changes in table position during the procedure.
- The surgeon stands on the contralateral side from the hernia being repaired.

LAPAROSCOPIC TRANSABDOMINAL PROPERITONEAL INGUINAL HERNIA REPAIR

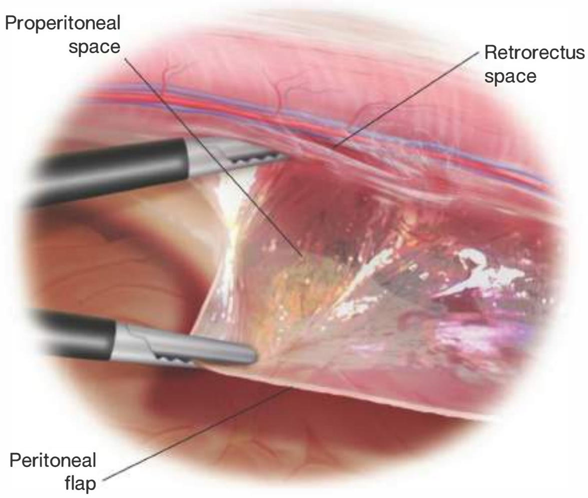
Establishment of Pneumoperitoneum and Port Placement

- The first trocar is placed at the level of the umbilicus, typically beginning in the umbilicus and extending the incision inferiorly. Pneumoperitoneum can be established either with a Veress needle or by placing a 12-mm Hasson port.
- Two 5-mm ports are then placed lateral to the rectus sheath approximately 1 to 2 cm above the level of the umbilicus (**FIG 2**). A 5-mm 30-degree laparoscopic is used and is placed in the port ipsilateral to the hernia. The surgeon uses the umbilical port and port contralateral to the hernia.
- The patient is placed in the Trendelenburg position displacing the pelvic viscera cephalad.

Peritoneal Incision

- The inferior epigastric vessels are identified on the side of the hernia. During a TAPP, if there is a high suspicion for inguinal hernia by history and physical examination, dissection commences on the symptomatic side even if no obvious hernia is seen from the intraperitoneal view. Note that chronically incarcerated properitoneal fat may occupy the hernia defect precluding clear visualization of the defect itself.
- The peritoneum is incised with Metzenbaum scissors beginning lateral to the inferior epigastric vessels (**FIG 3**). This dissection can typically be done without the use of electrosurgery. The correct plane of dissection in the TAPP repair is the true properitoneal plane. It is extremely easy to inadvertently dissect the retrorectus plane with this approach (**FIG 3**). Should this occur, dissection can proceed (similar to the TEP approach) but dissection into the retrorectus space without the benefit of balloon tamponade can incur increased blood loss. Dissection during TAPP should proceed between the peritoneum and transversalis fascia. The peritoneal flap is mobilized high up on the lower abdominal wall, extending laterally to the anterior superior iliac spine and medially to the ipsilateral medial umbilical fold.
- Care should be taken to avoid injury to the inferior epigastric vessels which lie posterior to the rectus muscles in the retrorectus plane. Maintaining a plane of dissection in the true properitoneal space minimizes the risk of injury to these vessels.

FIG 2 ● Port placement. **A.** For TAPP, ports are placed at the umbilicus and lateral to the linea semilunaris at the level of the umbilicus. **B.** TEP ports are placed in the midline at the umbilicus, 2 cm above the symphysis pubis, and the final in between the first two, at least 4 cm cranial to the second port.



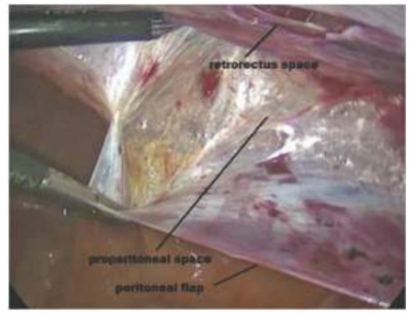


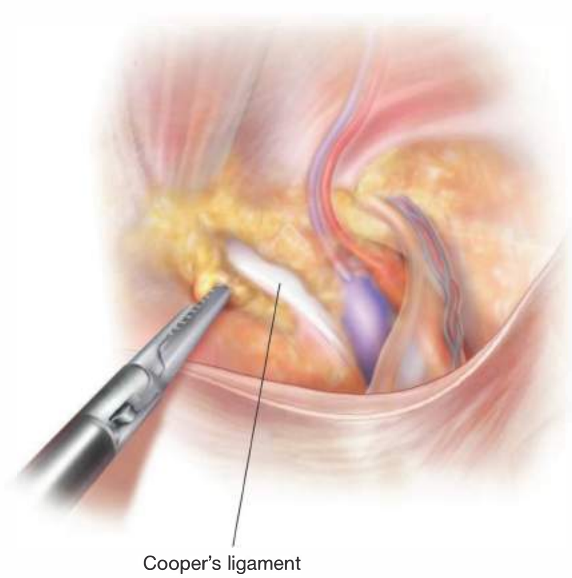
FIG 3 ● Creation of the peritoneal flap during TAPP. Beginning lateral to the epigastric vessels, the peritoneum is incised and the properitoneal space dissected, creating a flap. The retrorectus space, seen at the top of this figure, may be inadvertently entered, resulting in increased bleeding.

Dissection of the Properitoneal Plane

- Beginning laterally, retract the peritoneum medially, and dissect the properitoneal plane, leaving the fat against the abdominal wall to preserve small nerves and vessels.
- The inferior epigastric vessels are again identified and the properitoneal plane is developed medial to these vessels toward Cooper's ligament. During the initial learning curve of this procedure, the overwhelming tendency is to dissect too far medially and posteriorly into the region of the bladder. Confirmation of the trajectory of dissection toward Cooper's ligament can be obtained by a brief intraperitoneal view. Once Cooper's ligament has been identified, it is exposed for about 2 cm anticipating fixation at its superior aspect (**FIG 4**). A direct sac usually obscures Cooper's ligament until the sac is reduced entirely into the true pelvis.
- After Cooper's ligament has been identified, a dissection lateral to the inferior epigastric vessels is commenced attempting to dissect the properitoneal fatty tissue anteriorly while maintaining integrity of the peritoneum. This dissection is taken to the level of the iliopubic tract.

Reduction of the Hernia

- At this point, attention is turned to an indirect hernia sac if present, and it is dissected away from the cord structures. The peritoneum is now separated from the transversalis fascia overlying the inferior epigastric vessels. As the indirect hernia sac is approached, gentle but persistent cephalad traction is applied to reduce the hernia sac. Typically, if it can be done safely, the entire sac is reduced into the true pelvis. As the sac is reduced, the medial vas deferens and lateral testicular vessels are identified. In women, the round ligament is identified. The sac is dissected away from these structures. In women, the round ligament can often be separated from the peritoneum.



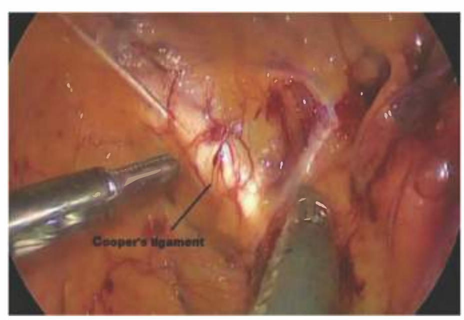


FIG 4 ● Cooper's ligament. Dissection proceeds medially toward Cooper's ligament. Once identified, approximately 2 cm of the superior aspect of Cooper's ligament is cleared for mesh fixation.

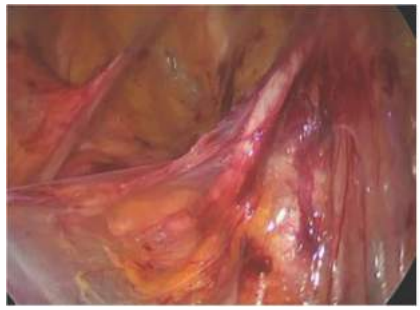


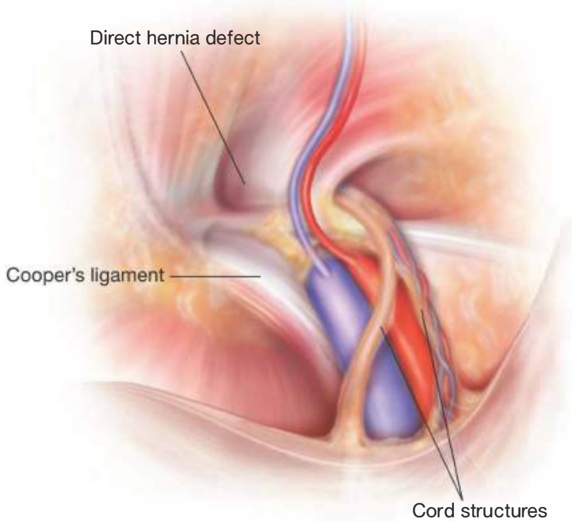
FIG 5 ● Dissection of peritoneum off posterior structures. Once the hernia is reduced, the peritoneum is separated from the cord structures and iliac vessels to allow adequate exposure of the myopectineal orifice. This allows room for generous mesh overlap and is a key step in preventing hernia recurrence.

Should this not be possible, efforts are made to divide the peritoneum along the axis of the round ligament, reapproximating the peritoneum after an adequate dissection has been performed. Division of the round ligament should be avoided if possible to minimize risk of pain from transection of the genital branch of the genitofemoral nerve. However, if transection is necessary to perform an adequate hernia repair, the round ligament can be divided between clips or ligatures.

- Once the hernia is reduced, the peritoneum is separated from the iliac vessels, vas, and testicular vessels posteriorly toward the umbilicus (**FIG 5**). This ensures a generous exposure of the entire myopectineal orifice. In addition, separation of the cord structures from the peritoneum ensures the ability to place a solid piece of mesh across the myopectineal orifice without the need for keyhole creation (**FIG 6**). Should a keyhole configuration be employed, the dissection proceeds caudally to the vas and testicular vessels, beginning at the level of the internal ring. Care should be taken to dissect well posteriorly to allow mesh overlap

Mesh Placement and Fixation

- An appropriately sized (usually 14 cm [transverse axis] × 12 cm [craniocaudal axis]), lightweight, macroporous mesh should be chosen which will cover the hernia defect as well as the entire myopectineal orifice.



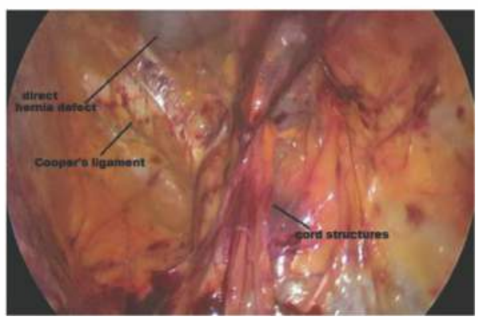
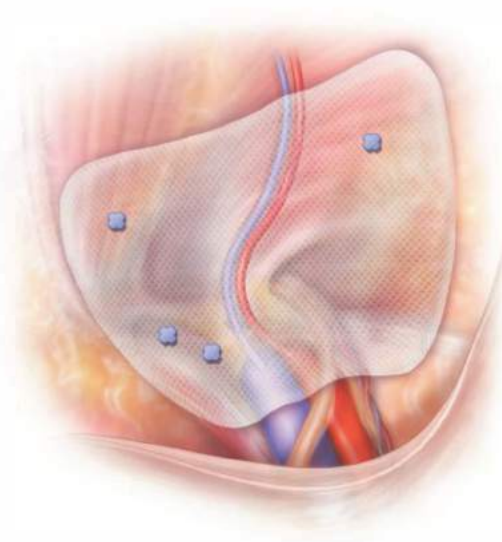


FIG 6 ● Completed dissection. The hernia has been reduced and dissection completed prior to mesh placement. Note the direct hernia defect; Cooper's ligament, which has been cleared superiorly; and the cord structures.



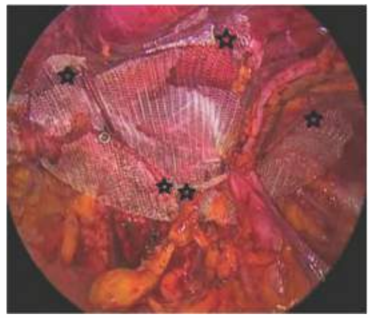
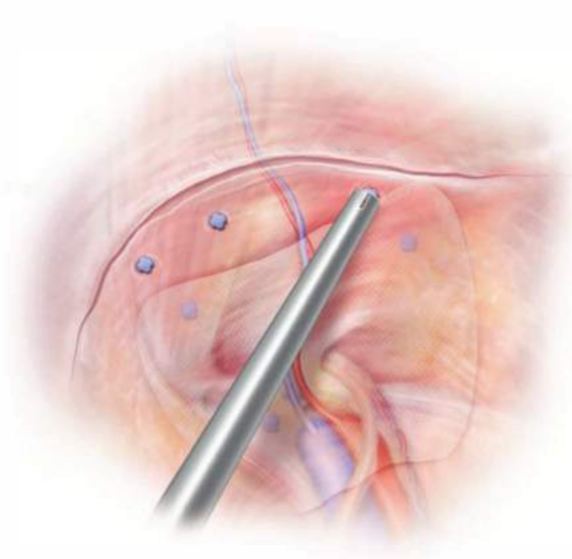


FIG 7 ● Mesh fixation. The mesh can be either a solid piece or one with a keyhole and should be taut. Fixation tacks are used sparingly: two above Cooper's ligament one in the posterior rectus sheath, and one laterally, well above the iliopubic tract.

- The mesh is then grasped medially and inserted into the 12-mm port, aiming toward Cooper's ligament. A Maryland dissector can be used to position the lateral and superior aspect of the mesh.
- Prior to fixation, precise placement of the mesh over the entire myopectineal orifice is ensured. Care is taken to ensure at least 3 cm of overlap over any hernia defect.
- Minimal fixation is used to prevent migration of the mesh (**FIG 7**). For indirect hernias, two tacks are placed just above Cooper's ligament, one high medially over the posterior aspect of the rectus sheath, and one high laterally well above the iliopubic tract. For direct defects, some additional fixation is usually necessary to avoid early migration and recurrence. In general, no tacks should be placed below Cooper's ligament or below the iliopubic tract. Counterpressure should be used to feel the tip of the tacking device on all tacks except those placed adjacent to Cooper's ligament. There is little data to support any one type of fixation (absorbable vs. permanent). Initial results suggest that avoiding mechanical fixation with the use of sealants or glues may be feasible, especially with a TEP approach; however more conclusive information is needed.[5,6]

Closing the Peritoneal Flap and Incisions

- The peritoneal flap can usually be closed with tack fixation, taking care to avoid injury to the inferior epigastric vessels (**FIG 8**). All attempts are made to minimize



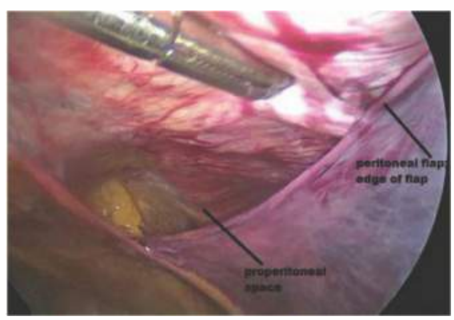


FIG 8 ● Peritoneal flap closure for TAPP. The peritoneal flap is closed with sequential tacks.

exposure of dissected tissue and mesh to the peritoneal cavity. During flap closure, care is taken to ensure that the posterior aspect of the mesh does not buckle or twist, which can act as a lead point for recurrence.

- After desufflation, trocars are removed under direct visualization. The 12-mm port site is closed with 0 Vicryl, and skin is approximated with 4-0 Monocryl sutures.

TOTALLY EXTRAPERITONEAL INGUINAL HERNIA REPAIR

Establishment of the Operative (Properitoneal) Space and Port Placement

- A 1- to 2-cm longitudinal skin incision is made inferior to the umbilicus and the subcutaneous tissues are divided. The anterior rectus sheath is identified just lateral to linea alba on the ipsilateral side of the hernia. The anterior rectus sheath is then divided using electrosurgery. The rectus muscle is retracted laterally and the retrorectus space is entered. An endoscopic balloon dissector is advanced immediately beneath the rectus muscle and advanced to the pubic symphysis (**FIG 9**). A 10-mm 0-degree laparoscope is placed into the lumen of the balloon and it is fully inflated and held in position for 2 minutes to achieve hemostasis. The balloon is removed and either a Hasson cannula (with stay sutures) or a balloon-tipped cannula is inserted into the extraperitoneal space. Usually, action of the balloon dissector dissects both the retrorectus space and the properitoneal space. This space is insufflated to a pressure of 12 mmHg and a 10-mm 30-degree laparoscope is used for visualization. The patient is placed in Trendelenburg position. Two 5-mm operating ports are inserted under direct visualization in the lower midline. The lowest is placed 2 cm above the pubic symphysis. The second port is placed at least 4 cm cranial from the first port (**FIG 2**). Use of a finder needle with local anesthetic can assist in placement of these ports.

Dissection of the Properitoneal Plane, Reduction of the Hernia, Mesh Placement, and Fixation

- These steps proceed similarly to that described for the TAPP approach discussed previously.

Desufflation

- After adequate hemostasis has been assured and mesh placement deemed appropriate, the 5-mm operating ports are removed and the insufflation removed. The peritoneum should be visualized closing the dissected space. Care should be taken to ensure that the mesh remains flat against the abdominal wall without folding, buckling, or twisting. The Hasson or balloon-tipped cannula is then removed and the anterior rectus sheath closed.

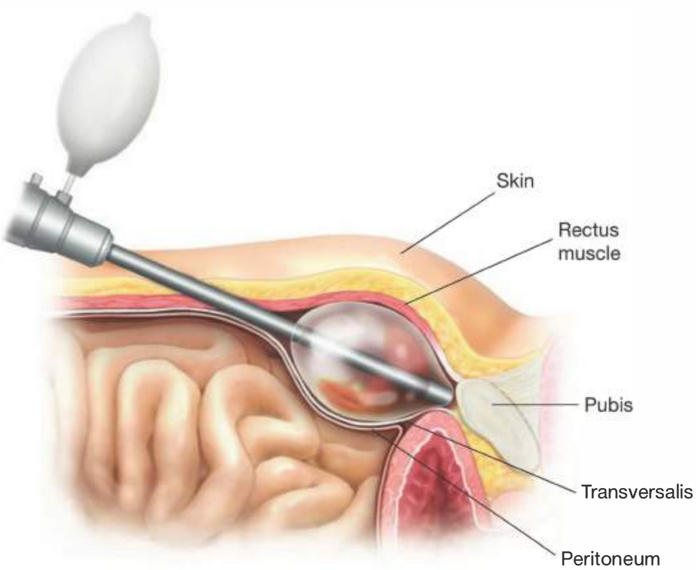


FIG 9 ● Endoscopic balloon dissector, TEP. The balloon dissector is inserted into the retrorectus space, advanced toward the pubic symphysis, and fully insufflated for 2 minutes to allow adequate hemostasis.

PEARLS AND PITFALLS

TEP—entrance into properitoneal space	■ Entrance into the properitoneal space during TEP should be performed at least 5-mm below the umbilicus as the peritoneum and transversalis fascia are fused to the umbilical stalk, preventing easy mobilization. Typically, the retrorectus space is first entered, with the balloon dissector expanding this plane. The dissector usually also expands the properitoneal plane. In some instances, the transversalis fascia may remain intact, requiring laparoscopic mobilization into the true properitoneal space.
TAPP—properitoneal dissection	■ Care is taken to enter the plane between the peritoneum and the transversalis fascia. If the transversalis fascia is inadvertently entered, attempts should be made to get back into the properitoneal plane. If this cannot be done, the dissection can proceed in the retrorectus space anterior to the transversalis fascia. This is usually a less hemostatic plane; care should be taken to avoid excessive bleeding.
TEP—avoidance of pneumoperitoneum	■ Maintaining integrity of the peritoneum and avoidance of pneumoperitoneum facilitates exposure with the TEP approach. Tears in the peritoneum should be repaired with either clips, absorbable loop ligatures, or sutures. A Veress needle can be placed into the peritoneal cavity in the upper abdomen to vent the pneumoperitoneum and reestablish visualization in the extraperitoneal space. Inability to control the peritoneal gas leak may necessitate conversion to a TAPP approach.
TAPP/TEP—avoidance of injury to aberrant obturator vessels and corona mortis venous plexus	■ Dissection of Cooper's ligament often exposes aberrant obturator vessels and the corona mortis venous plexus. Great care should be taken to avoid injury to these structures as hemostasis can be challenging. Additionally, these structures should be taken into consideration when mesh fixation is used adjacent to Cooper's ligament.
TAPP/TEP—large direct hernia sac	■ With large direct sacs, identification of Cooper's ligament can often be challenging. When a sizable direct hernia is encountered, the sac is reduced early in the dissection to identify Cooper's ligament.
TAPP—large indirect hernia sac	■ Reduction of a large indirect hernia sac is one of the most challenging maneuvers in laparoscopic inguinal hernia repair. Often, medial and lateral retraction of the sac can help facilitate dissection of the sac away from the cord structures and inferior epigastric vessels. Manual reduction (externally with fingers) can sometimes help dissect the entire sac back into the true pelvis. If complete reduction is unable to be achieved, transection of the sac can be performed. The testicular vessels and vas are clearly identified and separated from the tenacious sac. Laparoscopic clips are used to clip the proximal aspect of the sac and the sac is divided, allowing the open distal aspect of the sac to "parachute" back into the inguinal canal. The sac can then be mobilized in the standard fashion to facilitate mesh placement.

POSTOPERATIVE CARE

- In addition to the typical postoperative monitoring for hydration and adequate analgesia, it is important that the patient be monitored for urinary retention in the immediate postoperative period and a Foley catheter inserted, if needed.
- Diet can be advanced quickly within 12 hours postoperatively. Ambulation can resume once appropriately recovered from anesthesia. Patients are typically ready for discharge on the day of surgery.
- Constipation and straining should be avoided postoperatively. Light activity can be resumed within 1 day of surgery. Patients should be advised to avoid strenuous activity for at least 3 to 4 weeks postoperatively.

OUTCOMES

- Recurrence after TAPP appears to be equivalent to open repair, and TEP has a slightly higher risk of recurrence.[4]
- Overall, TEP and TAPP have been associated with less chronic pain than open repair.[4]

COMPLICATIONS

- Complications after inguinal hernia repair (whether open or laparoscopic) include surgical site infection, seroma or hematoma, mesh infection (all <1%), hernia recurrence (2% to 5% for primary inguinal hernia; around 10% for recurrent hernia), and chronic groin pain (around 0.5%).
- Men with bilateral hernias should be counseled regarding the slightly increased risk of decreased fertility associated with bilateral laparoscopic inguinal hernia repairs.[7]
- TAPP has been associated with an increased risk of intraabdominal and vascular injury, although this risk is low (<1%).
- Laparoscopic repair (TAPP and TEP) carries the risk of port site hernias (approximately 0.1% to 2%).

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Chapter 3

Incisional Hernia: Open Approaches

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DEFINITION

- An incisional hernia is a defect in the musculoaponeurotic layer of the abdominal wall occurring at the site of a prior incision. The sine qua non of any hernia is the presence of a fascial defect. Typically, a hernia is a protrusion of intraperitoneal abdominal contents through the defect, usually contained within a "sac" of peritoneum and covered with skin and perhaps subcutaneous fat. In certain circumstances such as the sequelae of an open abdomen, there may not be a true peritoneal sac nor a cutaneous cover.
- There are certain circumstances in which a pseudohernia can mimic a true hernia. Flank incisions can denervate the lateral abdominal wall, causing flaccidity and an outward bulge appearing to be a "hernia," even though the musculoaponeurotic layers are intact. Diastasis of the rectus muscles will also lead to a bulge especially on straining, but in both these circumstances, there is no actual defect in this musculoaponeurotic layer.
- Incisional hernias are classified as **incarcerated** when the contents of the hernia sac cannot be reduced back into the confines of the peritoneal cavity and **strangulated** when incarceration leads to vascular compromise and ischemia of the incarcerated contents. Strangulated contents may be salvageable if reduction can be accomplished prior to irreversible ischemia and necrosis.
- Incisional herniorrhaphies are designed to obliterate the musculoaponeurotic defect and restore continuity to the abdominal wall. This process may be accomplished in a number of ways but fall into three basic categories: (1) A primary repair with reapposition of the separated musculoaponeurotic edges is the simplest type of repair; (2) synthetic and biologic prostheses to restore abdominal wall continuity without primary apposition of the musculoaponeurotic layers, covering the defect in a bridging fashion with a "patch." Generally, repairs in this fashion are performed as an underlay or overlay with a substantial amount of overlap beyond the musculoaponeurotic edge (usually ≥5 cm) because sewing the prosthesis directly to the edges leads to an unacceptably high rate of hernia recurrence; and (3) a component separation technique, which are extensive, anterior or posterior lateral relaxing incisions to allow for greater tissue mobility, medialization of the rectus muscles, and decreased tension. The component separation is often reinforced using synthetic or biologic prostheses as underlays or overlays.

DIFFERENTIAL DIAGNOSIS

- The differential diagnosis of incisional hernias involves anything else that could cause a mass effect of the abdominal wall.
  - *Pseudohernias* arising from flank incisions and *diastasis recti* may be mistaken for true hernias. Diastasis recti is usually seen in the absence of a previous midline incision. Flank pseudohernias may require imaging such as computed tomography (CT) of the abdomen to demonstrate that the musculoaponeurotic layers of the abdominal wall are intact.
  - Neoplastic masses, such as desmoid tumors or other soft tissue tumors, such as lipomas and sarcomas, can potentially be mistaken for hernias, especially an incarcerated hernia, because they do not change with straining or coughing and obviously cannot be reduced.
  - Infections causing fluid collections, such as an abscess or seroma formation after prior herniorrhaphy or abdominoplasty, can cause bulging that could be mistaken for a hernia and can occur or become evident weeks to years after the herniorrhaphy.

PATIENT HISTORY AND PHYSICAL FINDINGS

- The most common symptom is discomfort or pain directly over the site of the hernia, especially when standing or otherwise increasing intraabdominal pressure; referred pain like a radiculopathy is rare. Patients will complain of a bulge, loss of abdominal wall support (often with back pain), or a feeling that they are "falling out" if the hernia is large. Patients often find the hernia cosmetically unacceptable. Localized borborygmi may also be evident to the patient, as may visible peristalsis.
- Hernias may cause varying degrees of intestinal obstruction—acute, chronic, or intermittent. Predisposing factors include chronic or acute incarceration and a small hernia neck, especially with a relatively large protrusion of intraabdominal content relative to the neck size. Intermittent, partial small intestinal obstruction may manifest as cramping, abdominal pain, or emesis, and patients may have learned to massage the hernias to provide relief. Acute or chronically incarcerated hernias may cause more severe obstructive symptoms, including acute, complete small intestinal obstruction or chronic, partial obstruction. Although much less common, large bowel obstruction may occur and manifest as constipation or acutely as obstipation.
- Examination of the patient with an incisional hernia should be performed in both the supine and erect positions. This approach may provide valuable information to the examiner—reducibility, the extent to which the hernia protrudes, and to what extent the abdominal domain has been lost. The two most prevalent findings on physical exam are the presence of a bulge over or lateral to the prior incision and a palpable fascial defect. If the hernia reduces spontaneously in the supine position, the examination can be aided by having the patient perform a Valsalva maneuver, standing, or both. Usually, the hernia can be elicited merely by having the patient lift his or her head off the examination table. Subtle and smaller hernias can be difficult to detect and may manifest during examination as a gentle,

slowly developing bulge under the examiner's fingers; in the obese patient, small hernias may be difficult or impossible to appreciate.

- The edges of the hernia defect should be determined circumferentially by palpation with the patient supine and relaxed. The dimensions are important in determining whether musculoaponeurotic apposition will be possible at the time of repair. Beware the possibility of a "Swiss cheese" hernia, that is, small multiple defects along the fascial incision, especially when the fascia had been closed previously with interrupted sutures; smaller defects may not be palpable.
- As noted previously, an incarcerated hernia must raise other possibilities in the differential diagnosis, such as seromas, abscesses, and both benign and malignant abdominal wall masses.
- The examiner should palpate carefully over any prior port site after a laparoscopic procedure for a subtle defect or "mass."
- Intramural hernias, where at least the most superficial musculoaponeurotic layer remains intact, can occur after lateral celiotomies where the abdominal wall has several layers. Spigelian hernias can present as intramural hernias. Intramural hernias are rare and can be difficult to diagnose and often impossible to feel. A Valsalva maneuver during CT or even ultrasonography may be diagnostic when physical exam and even a passive CT cannot demonstrate the hernia.
- For very large hernias that remain evident with the patient supine, an estimation should be made as to the extent to which the herniated contents have lost domain; that is, there is no longer adequate room within the abdominal cavity to accommodate the extruded contents after attempted reduction back into the coelomic cavity. CT of the abdomen is also particularly helpful in this regard. Loss of domain can preclude fascial apposition, even with concomitant component separation or relaxing incisions. Substantial loss of domain will cause undue tension in repairs, respiratory compromise, and an increased risk of recurrence after repair. Severe loss of domain precludes repair.

IMAGING AND OTHER DIAGNOSTIC STUDIES

- The best imaging technique for incisional hernia is CT. CT provides excellent and actionable information regarding the size and configuration of the hernia defect, can provide a visual estimate of loss of domain and other potential pathologies in the differential diagnosis, and will aid in planning of the operation. In large, complex hernias, the information can assist with decisions regarding the procedure of choice as well as the potential for adjunctive measures such as tissue (skin surface area) expanders. For flank hernias, CT can rule out a pseudohernia and is important to define the status of the oblique muscles cranial and caudal to the defect, as well as the paraspinal muscles, which will need to serve as fixation points for the hernia prosthesis.
- Routinely obtaining a CT to define the hernia defect, position, and size is controversial. For straightforward incisional hernias easily felt and defined at examination, CT has little benefit. For large, complex, or recurrent hernias, especially after prior repairs, CT can provide a wealth of information to define size and conformation, position of any prior prosthetics, issues of abdominal domain, unappreciated additional defects, and the status of the abdominal musculature such as loss or atrophy of specific muscle layers—critical information when planning a concomitant component separation.
- Magnetic resonance imaging (MRI) is acceptable but provides no more information than CT while being more expensive, time consuming, and difficult for the patient (and for many physicians as MRI is more difficult to interpret). Ultrasonography can be helpful, especially with the diagnosis of intramural hernias but is not generally useful and provides far less information than CT.

SURGICAL MANAGEMENT

Timing of Operation

- Although most incisional herniorrhaphies are elective operations, acutely incarcerated hernias are surgical emergencies, particularly when strangulation is suspected. Signs of strangulation may include: nausea and vomiting; peritonitis; acutely inflamed, indurated skin overlying the hernia; new onset of constant severe hernia pain; and the signs and symptoms of local or systemic sepsis.
- As a general rule, elective incisional herniorrhaphy should be delayed until optimum conditions for repair have been achieved; this approach will decrease recurrence rate. Timing of repair, however, is relative to the patient and the hernia; for example, a small-necked hernia considered at high risk for incarceration would prompt an earlier repair especially if symptomatic, whereas a patient with multiple, potentially remediable risk factors for recurrence, such as obesity, poorly controlled diabetes, tobacco use, malnutrition, constipation, or chronic cough, would argue for a delayed approach until these issues are addressed. More immediate concerns that should delay repair for the shorter term would include, open wounds on the abdominal wall, cellulitis, panniculitis, or cutaneous candidiasis; distant infections such as pneumonia or urinary tract infection; and uncontrolled, potentially reversible medical conditions such as diabetes, congestive heart failure, and chronic obstructive pulmonary disease (COPD). A nonmature ("nonpinchable") split thickness skin graft overlying the hernia is a relative indication for delay, as is waiting to receive recoverable operative notes from prior abdominal operations prior to operation.

Open versus Laparoscopic Repairs

- The topic of open versus laparoscopic repairs is controversial. Each has advantages and disadvantages, and the data regarding hernia recurrence, pain, and postoperative complications are roughly comparable. There are factors that may predispose toward one or the other approach in a particular patient; a surgeon routinely performing hernia repairs should be conversant with both. A recent Cochrane review examined 10 randomized controlled trials with a total of 880 patients comparing laparoscopic versus open ventral hernia repairs. They did not note any difference in recurrence rates or postoperative pain intensity. Laparoscopic repairs carried a greater risk of enterotomy and incurred greater in-hospital costs, but they were associated with a decreased risk of wound and mesh infection and shortened hospital stay.
- Factors favoring open repair: Theoretically, returning the abdominal musculature to its normal position of continuity could be expected to restore optimal anatomic and physiologic functionality of the mechanics of the abdominal wall, although

this remains unproven. Apposition of the musculature in its anatomic position is more easily accomplished in an open procedure. Although fascial apposition can be accomplished laparoscopically, as can a limited component separation, these are performed more efficiently and completely in an open procedure, and more complex component separations including the rectus sheath rollover technique can be accomplished. The fascial apposition performed laparoscopically usually leaves a cosmetically undesirable ridge of skin and subcutaneous fat above the repair. Dense adhesions, especially those resulting from an open wound and subsequent split thickness skin grafting, make a laparoscopic repair difficult or impossible.

Preoperative Planning

- Several factors can affect the recurrence rate of incisional hernia repair. With a recurrence rate of 10% to 30% or greater, attention to the factors that adversely affect recurrence rate in the preoperative phase is warranted.
  - Weight loss: If patients are substantially overweight, certainly if they meet medical criteria for severe obesity, an attempt at weight loss prior to repair is warranted. If the patients are not able to lose weight successfully after a reasonable period of time, however, it may be reasonable to proceed with repair.
  - Tobacco use: Experts in abdominal wall reconstruction are in general intolerant of tobacco use prior to hernia repair, certainly within 6 weeks prior to the repair and especially if a components separation is planned. The adverse effects of tobacco use on wound healing are well documented in the medical literature. It is worthwhile noting that nicotine substitutes such as gum would be expected to cause the same vasoconstriction and tissue ischemia as inhaled and oral tobacco products.
  - Abdominal wall strain: Voluntary and involuntary abdominal wall contractions can place an immense strain on a fresh abdominal wall reconstruction—coughing, constipation, emesis, and straining to urinate all place stresses on the abdominal wall that could have an adverse effect on herniorrhaphy. Any remediable causes of these problems should be addressed prior to operation.
  - Routine screening: It is worthwhile to make certain that patients are up-to-date with routine medical maintenance and screening such as colonoscopy so that other necessary intraabdominal conditions can be treated concomitantly, beforehand, or sequentially with the herniorrhaphy as appropriate.
  - Routine health maintenance: A general preoperative clearance is useful to make certain the patient is medically optimized for operation. Common diseases, such as hypertension, diabetes, COPD, and coronary artery disease, should be evaluated and optimized prior to operation to minimize perioperative risk.
  - Incisional hernia repair is usually a clean case. Because enterotomies can occur and repairs usually entail the placement of either a synthetic or biologic prosthesis, perioperative prophylactic antibiotics are indicated. Bowel preparation is not indicated. A preoperative shower with chlorhexidine gluconate (Hibiclens®) is prescribed at the preference of the surgeon. Adhesive drapes, such as Ioban™ (3M Corp, Minneapolis, MN) and Steri-Drape™ (3M Corp), are used frequently for the theoretic purpose of "isolating skin bacteria" from the wound and any prosthesis used, but strong evidentiary studies to support their use are lacking.
  - Many hernia cases will require advance notice to ensure that necessary materials and equipment are available.
    - Planned fixation of the prosthesis to the pubis or anterior iliac spine may require the use of a bone drill or bone anchors.
    - Specialized, procedure-specific equipment such as a Reverdin needle
    - Biologic prosthetics (fetal bovine, porcine, or human dermis and others) are expensive and may be stocked in limited supply. Be certain that the prosthesis required in size, thickness, and type is in stock and available the day of operation, as well as alternatives should the originally planned material not be usable as planned.

Positioning

- Most incisional hernias can be repaired with the patient supine; the drapes should extend at least 10 to 15 cm above and below the extent of the previous incision. There may be unappreciated defects discovered at the time of operation along the entire extent of the previous incision.
- For flank hernias, adequate exposure is paramount. Depending on the incision, a vertically placed bump under the spine providing lateral position may give sufficient access, whereas for more lateral incisional hernias, a complete lateral position may be necessary. See the following "Techniques" section.

Varieties of Repair

- The optimal repair of an open incisional hernia is a controversial topic. We will present our choices for what we consider the acceptable and optimal repairs, as well as general considerations that are valid regardless of the other technical details. For most purposes, we consider fascial apposition with a prosthesis underlay in the retrorectus or preperitoneal position to be the best repair for most open incisional hernias.

Choice of Mesh

- In general, the synthetic (alloplastic) meshes are preferable when there is no contamination precluding their use, whereas biologic prostheses are preferable when microbial contamination is present. There are innumerable choices for both synthetic and biologic prostheses and little to support the superiority of one particular type over another within their respective classes. It is useful to categorize broadly the various products by functional use. The most important distinction is synthetic versus biologic. The biologic prosthetics are in general more resistant to bacterial colonization and infection and may be chosen in a contaminated field, but they may remodel and weaken over time, especially when used in a bridging fashion. The synthetics are stronger than the biologic meshes and do not remodel, although a varied extent of shrinkage does occur, depending on the prosthetic material. The synthetics may be further subdivided into barrier and nonbarrier meshes. Barrier meshes are designed to allow them to be apposed to the abdominal viscera are in theory minimize adhesions to the side facing intracorporeally. Nonbarrier synthetics should only be used in a protected space, such as the preperitoneal or retrorectus spaces.

Procedure Categorization

Open

- Fascial apposition alone
- Fascial apposition with prosthesis underlay
  - Protected space mesh placement (preperitoneal and retrorectus)
  - Intraperitoneal mesh placement
- Fascial apposition with prosthesis overlay
- Components separation

Laparoscopic

- Prosthesis underlay
  - Suture fixation with tacks
  - Tack fixation alone
- Fascial apposition
- Components separation

WIDE ONLAY TECHNIQUE OF INCISIONAL HERNIORRHAPHY

- The concept behind this wide onlay repair is that the procedure can remain fully extraperitoneal, and the meshed prosthesis provides a large surface area for transgrowth through the mesh and thus a wide tissue fixation.

Placement of Incision

- The entire prior skin incision is excised along with any underlying fibrosis back to healthy epidermis and subcutaneous fat in attempt to minimize infection (**FIG 1A**).
- Dissection proceeds directly down to the hernia sac, being careful not to enter the sac. If the incision is longer than the hernia defect, only the skin and subcutaneous tissues that are chronically scarred with concerns for healing need be excised. This type of repair can be accomplished totally extraperitoneally. The lateral aspect of the hernia sac is mobilized medially back to the fascial defect. This maneuver may be accomplished purely by blunt dissection, but if the interface of sac and subcutaneous tissue is scarred, sharp dissection may be required (**FIG 1B**).

Creation of Space for Prosthesis

- The skin and subcutaneous tissue flaps are mobilized for at least 5 to 7 cm lateral to the edge of the hernia defect. This plane is created just anterior to the abdominal wall fascia (anterior rectus fascia and possibly out to the external oblique fascia or aponeurosis more laterally) to allow a wide, lateral overlap of the prosthesis. A 5- to 7-cm skin and subcutaneous flap is mobilized off the midline fascia past the cranial and caudal extents of the hernia defect (**FIG 1C**).

Reapproximation of Fascia Edges

- A decision needs to be made whether and how the fascial edges of the defect can be reapproximated (**FIG 2A**) or only bridged or "patched" by the prosthesis

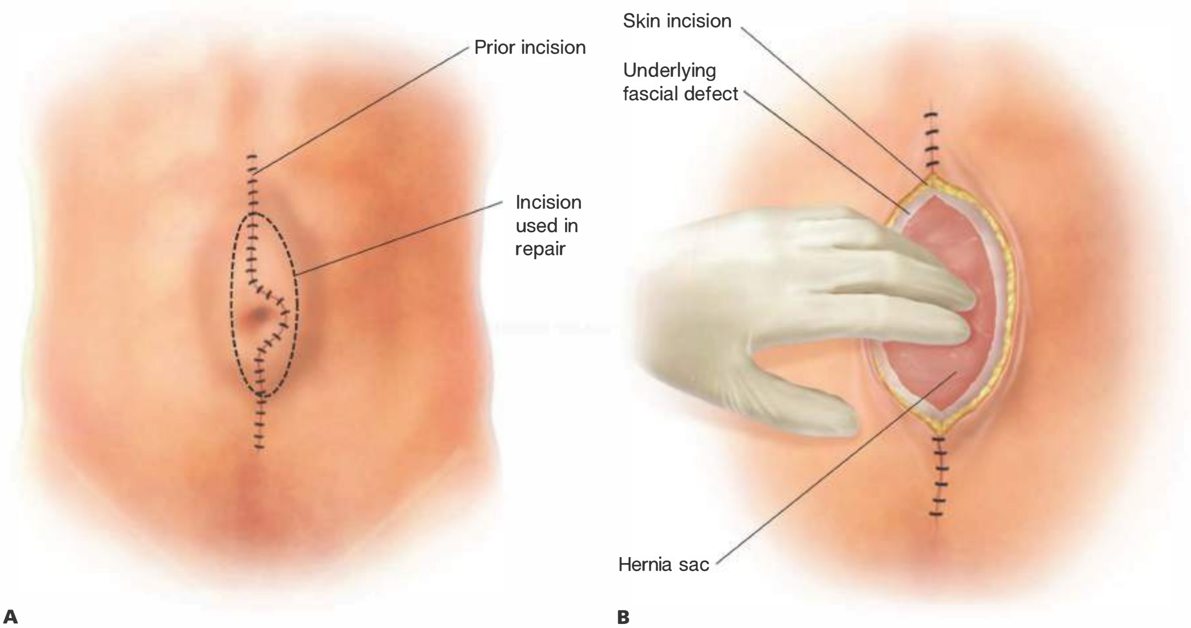
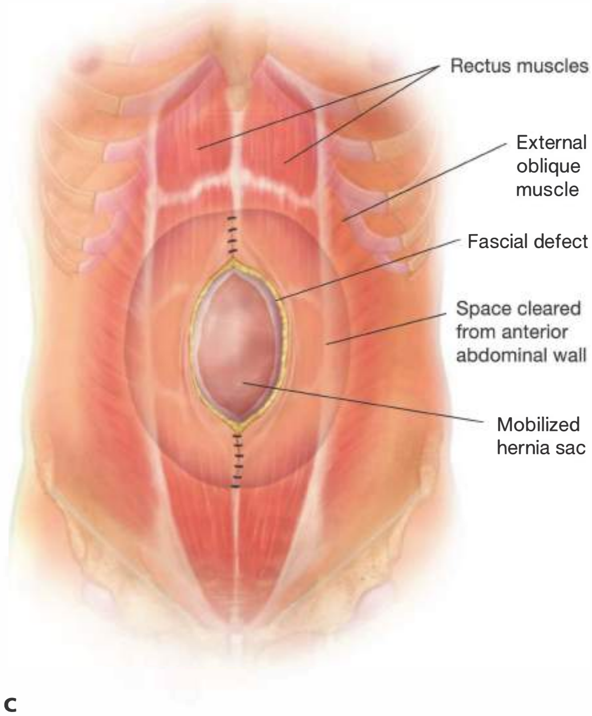


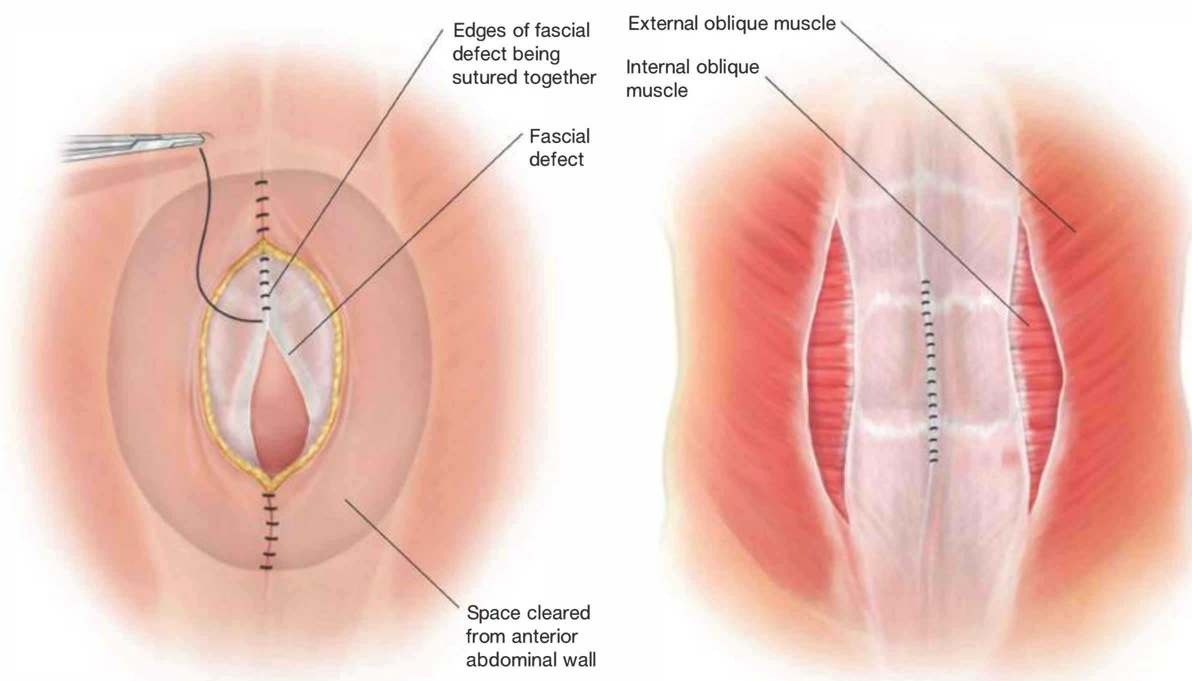
FIG 1 ● Incision and mobilization of hernia sac. **A.** The incision is centered over the hernia excising the prior incision; all subcutaneous scars should be excised back to healthy, vascularized subcutaneous tissue. **B.** The hernia sac is mobilized laterally to the medial edge of the hernia defect; try to not violate the hernia sac. *(continued)*

TECHNIQUES



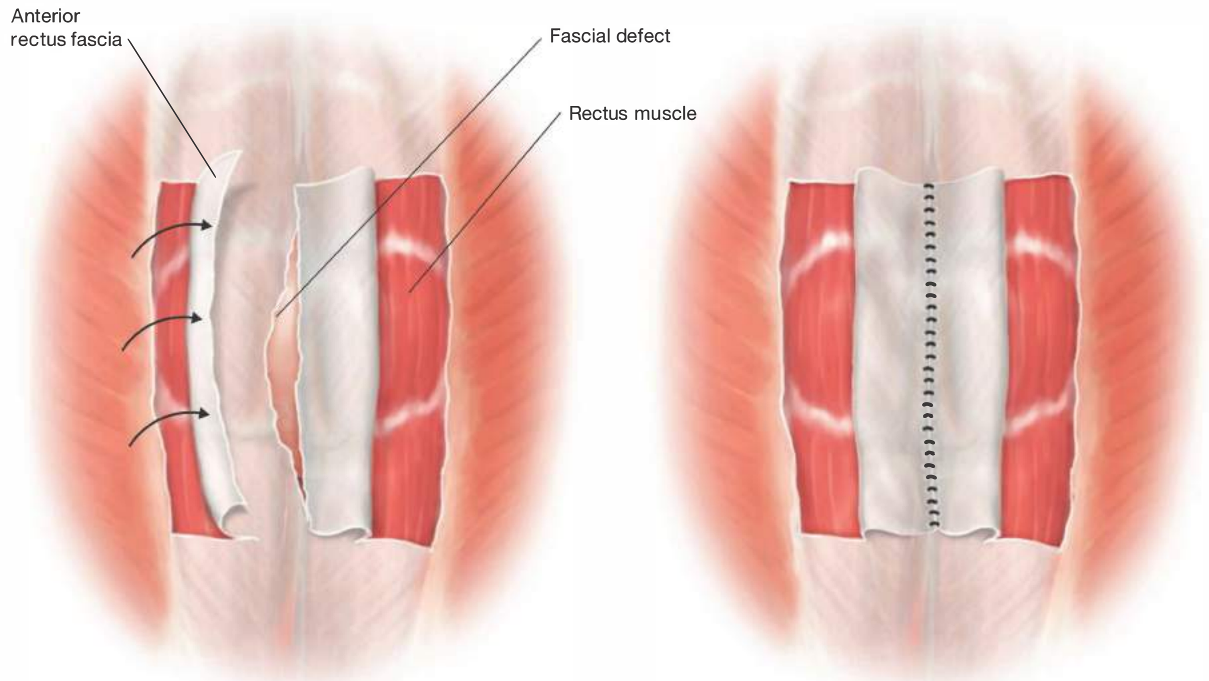
C

FIG 1 ● *(continued)* **C.** The anterior surface of the abdominal wall musculature is mobilized circumferentially at least 5 to 10 cm from the edges of the hernia defect to provide a wide surface area to allow transgrowth through the onlay meshed prosthesis for a stable tissue incorporation/fixation.



A B

FIG 2 ● Closure of hernia defect prior to placement of meshed prosthesis. **A.** *Primary reapproximation*—when possible, the medial edges of the defect are reapproximated with a running suture closure. **B.** Anterior components separation—when the defect cannot be approximated primarily, the external oblique muscle/aponeurosis can be incised 1 to 2 cm lateral to the lateral border of the rectus muscle to allow medialization of the rectus muscle for primary closure of the defect. *(continued)*



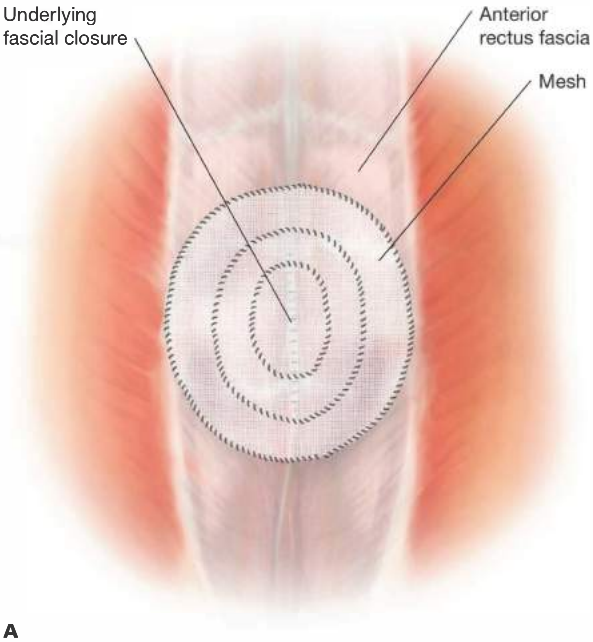
C

FIG 2 ● *(continued)* **C.** *Rectus rollover*—another alternative to the anterior lateral "release" or "relaxing" incision in **B** figure is to incise the anterior rectus fascia and mobilize the fascia medially to allow it to "rollover" medially for primary fascial closure—note, this technique does not fully medialize the rectus muscles but does allow fascial approximation over the hernia defect (see insert).

(**FIG 2B**) (see Part 2, Chapter 5). If the fascial edges are to be sutured together, some dissection under the fascial edges may be necessary to place the fascial sutures safely. Most surgeons believe that reapproximation of the fascial edges reinforced by a prosthesis provides a superior outcome compared to a bridge or patch of a persistent fascial defect. If the defect is wide and would require a more complicated abdominal wall reconstruction, the advantages and disadvantages should be considered. In this situation, the skin flaps can be dissected further laterally beyond the lateral border of the rectus muscle; then the external oblique fascia and muscle can be transected being careful not to disrupt the internal oblique muscle/fascia—a form of anterior components separation—this maneuver allows the rectus muscle to be "medialized" and the medial edges of the fascia to be sewn together (**FIG 2C**) (see Part 2, Chapter 5, for more in-depth description). This maneuver allows 4 to 6 cm of medialization of the rectus muscles on both sides. Another option to "approximate" the fascial edges of the defect is a rectus rollover technique (**FIG 2C**). With this technique, the anterior rectus fascia is incised just medial to its lateral border, mobilized off the underlying rectus muscle, and "rolled" medially. These edges of the rolled anterior rectus fascia can be sutured together in the midline. Note that the rectus muscles are not medialized with this technique.

Placement of Prosthetic Mesh

- A large sheet of prosthetic mesh is then sized to cover the anterior abdominal wall hernia defect and to extend a further 5 to 7 cm from the hernia defect (so-called "wide onlay") on all sides of the defect. The lateral edges of the prosthesis are sewn to the anterior abdominal wall fascia circumferentially with #0 or no. 1 suture material (e.g., 0 or no. 1 polydioxanone) (**FIG 3**). The use of absorbable versus permanent sutures is controversial. Proponents of permanent sutures believe that permanent sutures minimize the possibility of late migration or dislodgement of the prosthesis, whereas those surgeons favoring the longer lasting absorbable suture (such as polydioxanone) believe that permanent sutures can lead to suture granulomas and ultimately contamination and infection of the prosthesis. Although there is no good evidence supporting either argument, we prefer the absorbable suture provided there will be a large surface area for mesh transgrowth.
- In progressively smaller concentric circles, one or two additional suture fixation of the prosthesis to the underlying anterior abdominal wall can also be placed (**FIG 3A**). If the repair is a bridge repair, these concentric circles should not extend medial to the edges of the fascial defect because the underlying hernia sac and viscera can be injured. A porous synthetic prosthetic and not a solid prosthetic (ePTFE) is used to achieve the goal to provide a



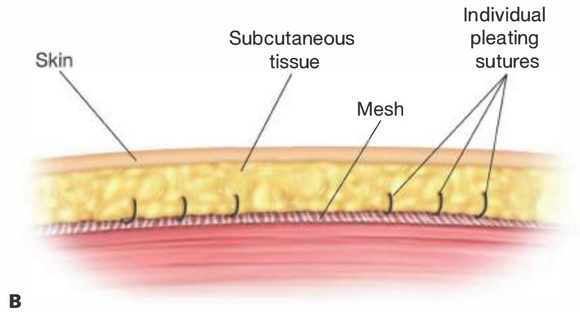


FIG 3 ● Implantation of meshed prosthesis. **A.** The prosthesis is sutured to the anterior surface of the fascia of the anterior abdominal wall. Several concentric circles of suture fixation can be performed. **B.** *Pleating of subcutaneous space*—in an attempt to obliterate dead space, the posterior aspect of the lateral skin/subcutaneous flap created to allow a wide onlay repair can be sewn to the anterior abdominal wall fascia. Prior to closing the skin, several closed suction drains are placed in this subcutaneous space and brought out cranially (skin is cleaner cranially than caudally) lateral to the lateral edge of the mobilized skin/subcutaneous flaps (not shown).

wide surface area for transgrowth through the mesh for tissue fixation.

- If an anterior components separation is performed, the prosthesis extends laterally to the lateral transected edge of the external oblique aponeurosis (a very wide onlay repair) or just 5 to 7 cm lateral to the medial edge of the hernia defect which is usually to the lateral edge of the rectus muscle.
- If a rectus rollover is performed, the prosthesis should extend 5 cm lateral to the site of incision in the anterior rectus fascia to provide solid points of fascial fixation of the prosthesis.
- For situations where there is bacterial contamination (clean–contaminated cases) or active infection, albeit treated, a synthetic mesh is contraindicated, and a bioprosthesis would be a better choice.

Wound Closure

- Most surgeons place one or two closed suction drains in the large subcutaneous space to prevent a seroma. When the drains should be removed is controversial; for a bioprosthesis, drains are mandatory to prevent a seroma.
- Prior to closing the skin, a pleating technique may be used, whereby the posterior adipose surface of the skin/subcutaneous flaps can be sewn to the anterior surface of the prosthesis in attempt to minimize the "dead space" and the possibility of seroma (**FIG 3B**).

RECTRORECTUS SUBLAY REPAIR: MODIFIED RIVES-STOPPA REPAIR

- Many believe that this repair has the best results of all current incisional herniorrhaphies. Whether it is better than a wide, intraperitoneal sublay (IPOM) can be debated, but there are no studies comparing the two repairs. This modified Rives-Stoppa repair is based on the principle of wide surface area of a meshed synthetic prosthesis placed in a very vascular field—the retrorectus space (to allow a stable, reliable anterior and posterior transgrowth for mesh fixation). Importantly, the prosthesis is neither in the less vascular subcutaneous space where the risk of infection and seroma is greater nor is the prosthesis direct in contact with the intraperitoneal viscera. Moreover, in most patients, the repair can be accomplished extraperitoneally.

Placement of Incision

- As with other repairs, the incision should be made directly over the hernia defect with resection of the skin incision and the underlying, poorly vascularized scar tissue. The skin incision preferably should not extend all the way up to the xiphoid or all the way down to the pubis but rather stay 5 to 8 cm away from xiphoid and pubis.

Mobilization of Retrorectus Space

- As described in the first technique (**wide onlay technique of incisional herniorrhaphy**), the subcutaneous hernia sac is mobilized back to the hernia defect for the entire circumference of the defect. The hernia sac, though, is neither incised nor opened unless a concomitant, "clean" intraperitoneal procedure is planned—for example, adhesiolysis, insertion of an adjustable gastric band, and so forth. It could

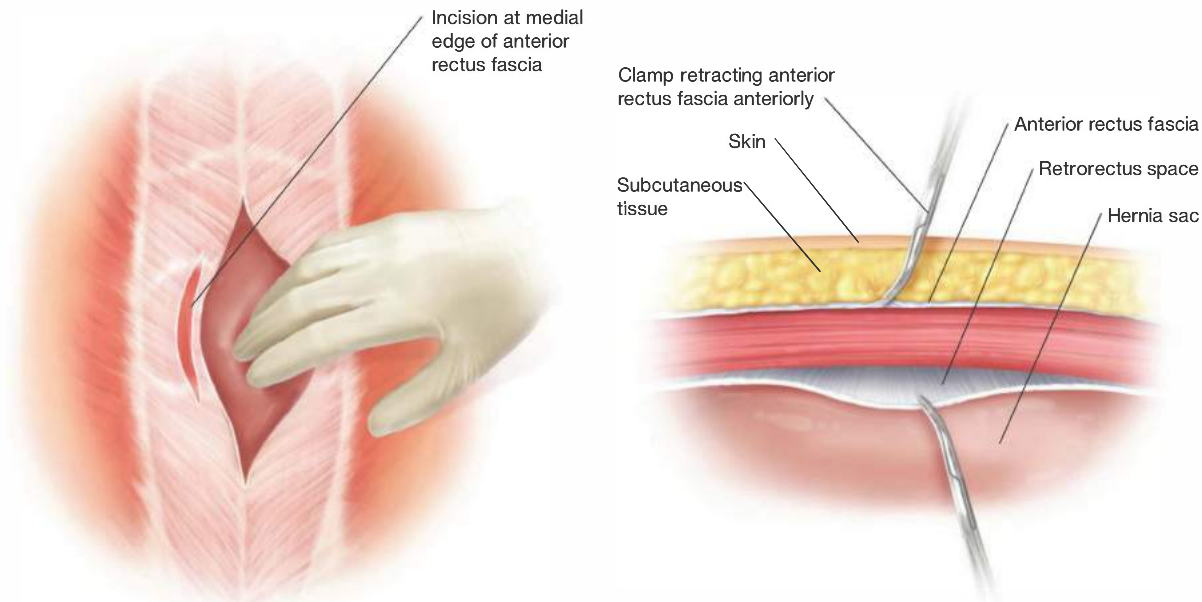


FIG 4 ● Dissection of retrorectus space. **A.** An anterior rectus fasciotomy is made at the medial edge of the rectus muscle (at lateral edge of the hernia defect) allowing access to the avascular retrorectus space. **B.** Lateral dissection is facilitated by retracting the medial edge of the anterior rectus fascia anteriorly and the medial edge of the posterior rectus fascia medially and posteriorly. Much of this dissection can be blunt.

be argued that clean–contaminated procedures, such as an elective cholecystectomy or hysterectomy do not pose a clinically significant bacterial contamination load despite being clean–contaminated procedures, but considering the morbidity and requirement for at least one additional procedure in the event of mesh infection, the authors tend to refrain from performing even these minimally contaminating procedures concomitantly in most circumstances. Certainly, other "clean–contaminated" procedures such as gastrectomy, small or large bowel resections, appendectomy, biliary drainage procedures, or most bariatric operations other than a band would be considered by most to be an indication to use a bioprosthesis rather than a permanent synthetic mesh.

- Next, the medial edge of the anterior rectus fascia is incised at the lateral edges of the hernia defect, thereby exposing the vertical fibers of the underlying rectus muscle (**FIG 4A**). The rectus muscle is dissected and retracted anterolaterally to expose the firm, white surface of the posterior rectus fascia (**FIG 4B**).
- There are minimal, if any, adhesions between the posterior surface of the rectus muscle and the anterior surface of the posterior rectus fascia, except medially where the transfascial sutures from the originally fascial closure had been placed. The benefit of this retrorectus space is that it is virtually avascular to dissect and very easily mobilized.
- Care must be taken to preserve the inferior epigastric vessels (artery and vein) cranially near the xiphoid where they will course from medially near the xiphoid to the midrectus muscle anterior to the posterior rectus fascia before entering the rectus muscle. Caudally, the deep inferior epigastric vessels arise from the external iliac vessels medial to the internal inguinal ring and course cranially in the preperitoneal space caudal to the semicircular line and then on the anterior surface of the posterior rectus fascia before entering the rectus muscle with one or more branches. This inferior epigastric arcade is important to preserve because it provides the blood supply to the rectus muscles and equally important from the rectus muscles to the overlying skin and subcutaneous tissue via the "perforator vessels." One advantage of the rectorectus repair (in contrast to the wide onlay technique) is that mobilization of a lateral skin/subcutaneous flap (and the obligate transection of the important perforators) is not necessary, maximizing the blood supply to the skin edges and minimizing the subcutaneous "dead space."
- The retrorectus space should be mobilized to the lateral border of the rectus muscle, the cranial and caudal extent of the hernia defect/hernia sac (**FIG 5**). The anterior rectus fascia and the linea alba need to be preserved cranially and caudally to the hernia defect to allow for fixation of the prosthesis.
- The cranial edge of the intact midline fascia is grasped with a Kocher clamp and retracted anteriorly to allow cranial mobilization of a space (if possible preperitoneally) for at least 7 cm or up to the xiphoid (**FIG 6A**). This requires transection of the insertion of the posterior

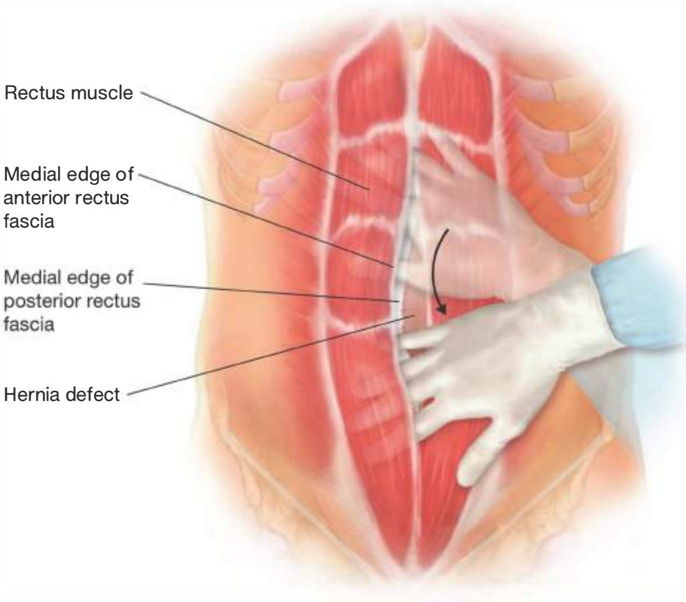


FIG 5 ● Extent of retrorectus space. Lateral dissection is carried out to the lateral edge of the rectus muscle, cranially if necessary up to and anterior to the costal margin, and caudally if necessary down to the pubis, also exposing Cooper's ligaments if extensive fixation is necessary.

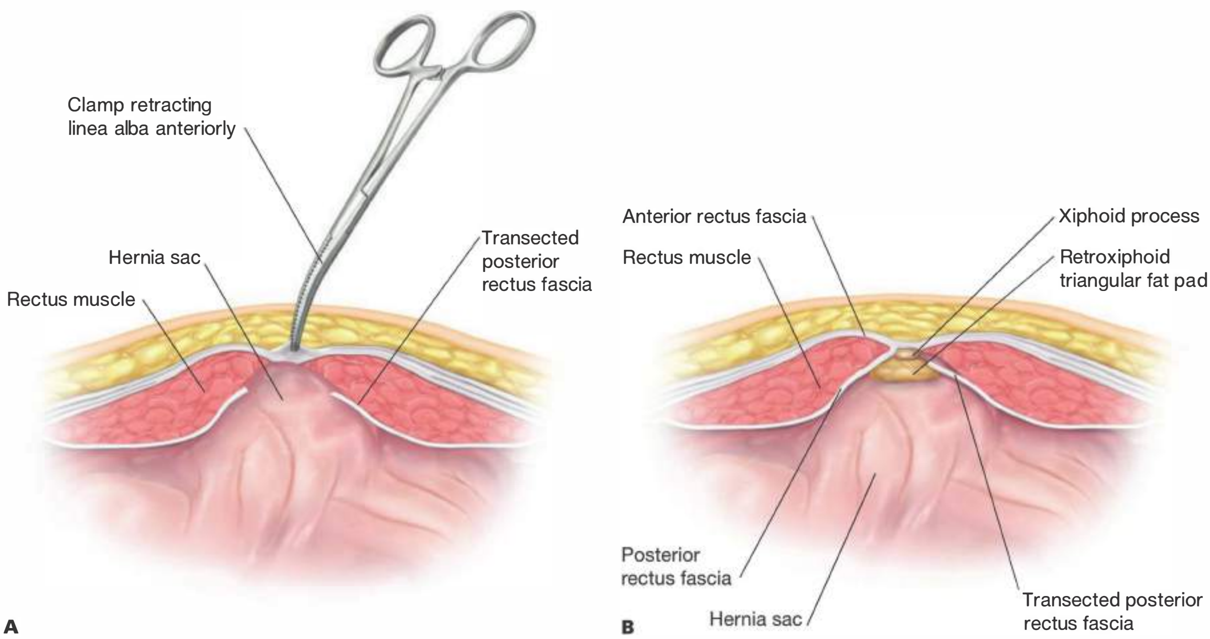


FIG 6 ● Cranial dissection of retrorectus space. **A.** The cranial dissection is aided by placing a clamp on the midline fascia at the cranial-most extent of the hernia defect. Next, the medial insertion of the posterior rectus fascia into the anterior rectus fascia is transected, being careful not to disrupt the continuity of the anterior rectus fascia with linea alba cranially. This can often be completed extraperitoneally. **B.** When it is necessary to mobilize fully up to the xiphoid, the medial fascial insertions of the posterior rectus fasciae to the lateral xiphoid are transected and the triangular fat pad posterior to the xiphoid is mobilized posteriorly off the posterior surface of the xiphoid, allowing creation of a subdiaphragmatic space 3 to 5 cm behind the xiphoid/distal sternum. *(continued)*

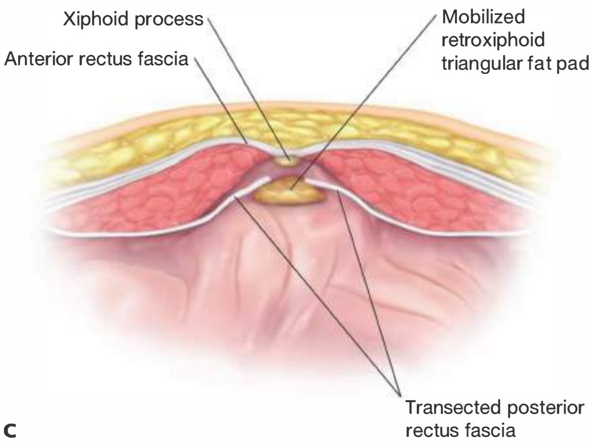


FIG 6 ● *(continued)* **C.** Fully mobilized retrosternal space, allowing the mesh to cross the midline behind the xiphoid.

rectus fascia at the medial edge of the rectus muscle bilaterally, being careful not to disrupt continuity of the anterior rectus fasciae with the linea alba; this maneuver may be performed totally in the preperitoneal space. If the prior celiotomy incision extends cranial to the edge of the hernia defect, the surgeon should palpate further cranially for areas of Swiss cheese defects or areas of fascial weakness; if found, then the retrorectus space needs to be extended beyond the upper most defect. This maneuver may require being intraperitoneal if the preperitoneal space was transgressed previously. If there is not, 7 cm of good, solid, anterior rectus/linea alba cranial to the defect or if the defect extends to the xiphoid, then the insertion of the posterior rectus fascia onto the anterior rectus fascia will have to be transected up to its junction with the xiphoid (**FIG 6B**). Also, the preperitoneal "triangular" fat pad posterior to the xiphoid needs to be mobilized posteriorly off the undersurface of the xiphoid for 5 cm cranially—this is easy and is an avascular plane; this maneuver will allow the prosthesis to extend under the xiphoid and distal sternum to maximize the cranial surface area for tissue ingrowth/fixation (**FIG 6C**).

- A similar maneuver is performed caudally (**FIG 7**). Caudal to the semicircular line, the posterior rectus fascia disappears, and further caudal mobilization of the retrorectus space now becomes preperitoneal. If the prior celiotomy incision did not extend caudal to the caudal extent of the hernia defect, then this entire maneuver can often be done extraperitoneally. If the prior fascial incision extends further caudally, the peritoneal cavity may need to be entered. Note, any redundant peritoneum and *all* the hernia sac should be preserved to allow the peritoneum to be closed deep to the prosthesis caudally. This space should be mobilized at least 7 cm, if not 10 cm, being certain again that the overlying fascia is neither weak nor has any Swiss cheese defects. If necessary, mobilize all the way to the pubis (and maybe even mobilize posterolaterally to Cooper's ligaments for additional bony points of fixation of the prosthesis if the musculofascial tissue of the anterior abdominal wall is weak or attenuated. Note, as discussed previously, the lateral mobilization of the retrorectus space here should be accomplished fully under vision because it is here that the deep inferior epigastric vessels are most frequently injured.
- Several caveats: *First*, the retrorectus space extends cranial and anterior to the costal margin; the rectus muscle does not insert on the costal margin but rather on the ribs 3 to 5 cm cranial to the costal margin. *Second*, the intercostal nerves that supply the rectus muscle and

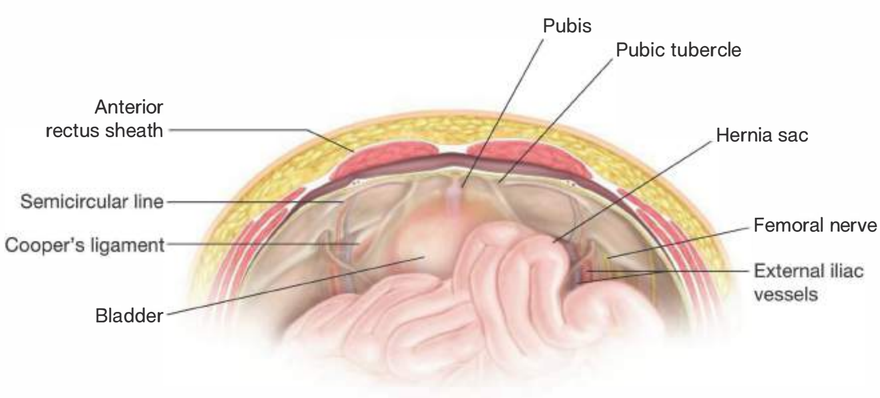


FIG 7 ● During caudal dissection of retrorectus space past the semicircular line, the posterior rectus fascia transitions to the peritoneum, and now, further caudal dissection is in the avascular preperitoneal space. Blunt dissection continues down to and posterior to the pubis if necessary, and lateral to expose Cooper's ligaments medial to the external iliac vessels. Care must be taken to protect the iliac vessels and especially the deep inferior epigastric artery and vein, which are at the lateral aspect of the rectus muscles posteriorly; this maneuver should be done under vision.

overlying skin course on/near the anterior surface of the internal oblique muscle lateral to the rectus muscle but perforate into the retrorectus space at the lateral-most border of the posterior rectus fascia—these nerves should be preserved. *Third*, if there has been loss of rectus muscle and the retrorectus space is narrow, the space can be extended to the space posterior to the internal oblique muscle but anterior to the transversus muscle. This will preserve the innervation of the rectus muscle by the intercostal nerves which run on/within the internal oblique muscle. A posterior component separation can be performed if necessary (see Part 2, Chapter 5).

- Full mobilization of the retrorectus space should extend 5 to 7 cm cranial to the hernia defect, 7 to 10 cm to the hernia defect, and to the lateral edge of the retrorectus space.

Reconstruction of the Continuity of the Posterior Rectus Fascia across the Midline

- Every attempt should be made to reapproximate the posterior rectus fascia in the midline, not only to isolate the retrorectus space from the viscera but also to serve as the deep fascial layer "closing" the hernia defect (**FIG 8**). This maneuver may be difficult at the cranial and caudal extent of the retrorectus space or with very wide hernia defects. If not possible to reapproximate the posterior rectus fasciae or to cover the exposed intraabdominal visceral with autogenous tissue (redundant sac, peritoneum, or rarely omentum), then consideration should be given to bridging this defect with an absorbable prosthetic such as polyglycolic acid (Vicryl® mesh, Ethicon, Inc or Dexon® mesh, Covidien, Inc) posterior to the synthetic mesh. Use of the expensive bioprosthetics for this "bridge" is not indicated, because this bridge will *not* be the stable, durable part of the hernia repair.

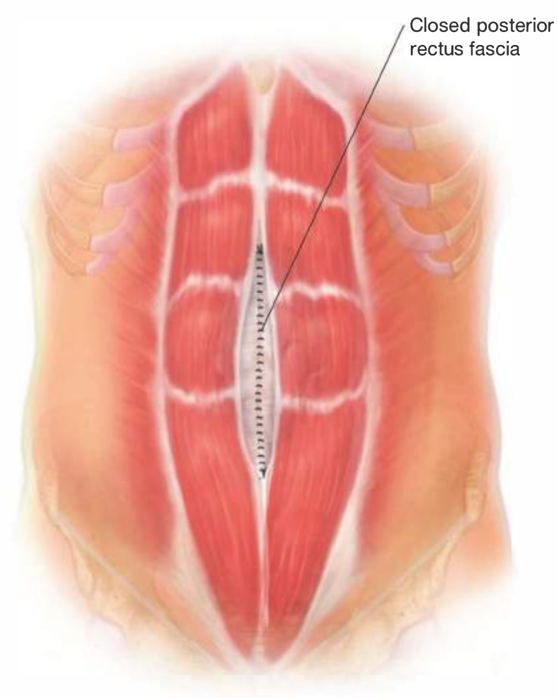


FIG 8 ● Closure of the posterior rectus fascia. The medial edges of the posterior rectus fascia are approximated in the midline, whereas the still-intact hernia sac is pushed posterior to this closure. If the peritoneal sac is disrupted and the posterior rectus fascia cannot be approximated in the midline, an inlay of absorbable synthetic mesh (Vicryl mesh, Ethicon, Inc) can be used to separate the intraperitoneal content from the permanent mesh to be placed in the retrorectus space.

Insertion of the Prosthesis

- This repair is best accomplished with a meshed prosthesis. We prefer a large-pore, lightweight type, such as ULTRAPRO™ (polypropylene, Ethicon, Inc), unless the patient is a laborer or a high-performance athlete, in which case we choose a heavyweight mesh, such as Prolene® mesh (Ethicon, Inc). This repair is designed for a meshed prosthesis and, because the repair is fully extraperitoneal, there is no indication for ePTFE or a "coated" mesh—transgrowth from both the anterior and posterior surfaces of the retrorectus space is encouraged.
- We position a 12 × 12–in sheet of meshed prosthesis diagonally—this increases the craniocaudal length available. This orientation allows a rapid and reliable fixation of each corner of the prosthesis to help in determining the appropriate sizing of the mesh.
- The mesh is fixed cranially and caudally. Cranially, a 1-cm horizontal mattress stitch is placed through the mesh just lateral to the midline after doubling back the corner of the mesh onto itself. We use a no. 1 polydioxanone suture for nonbony points of fixation. A suture passer is inserted through a stab wound in the skin into the retroxiphoid space (we prefer to use the more blunt, disposable Endo Close™ [Covidien, Inc] or the Reverdin needle rather than the non-disposable metal Carter-Thomason device). The surgeon's hand is positioned between the entry site of the suture passer and the peritoneum to prevent inadvertent puncture into the peritoneal cavity (**FIG 9A**). One end of the suture previously placed in the mesh is grasped by the suture passer and pulled back out the stab wound (**FIG 9B**); this process is repeated to withdraw the other end of the suture (**FIG 9C**) being certain to insert the suture passer through the fascia about 1 cm from the first pass such that when tied together, there is at least a 1.5 cm area of fascia incorporated in the knot. An identical suture fixation is performed on the other side of the midline.
- If the mesh extends posterior to the xiphoid, we use two permanent sutures (no. 1 polypropylene). After placing a horizontal stitch through the mesh, the suture passer is inserted through the most caudal part of the sternum

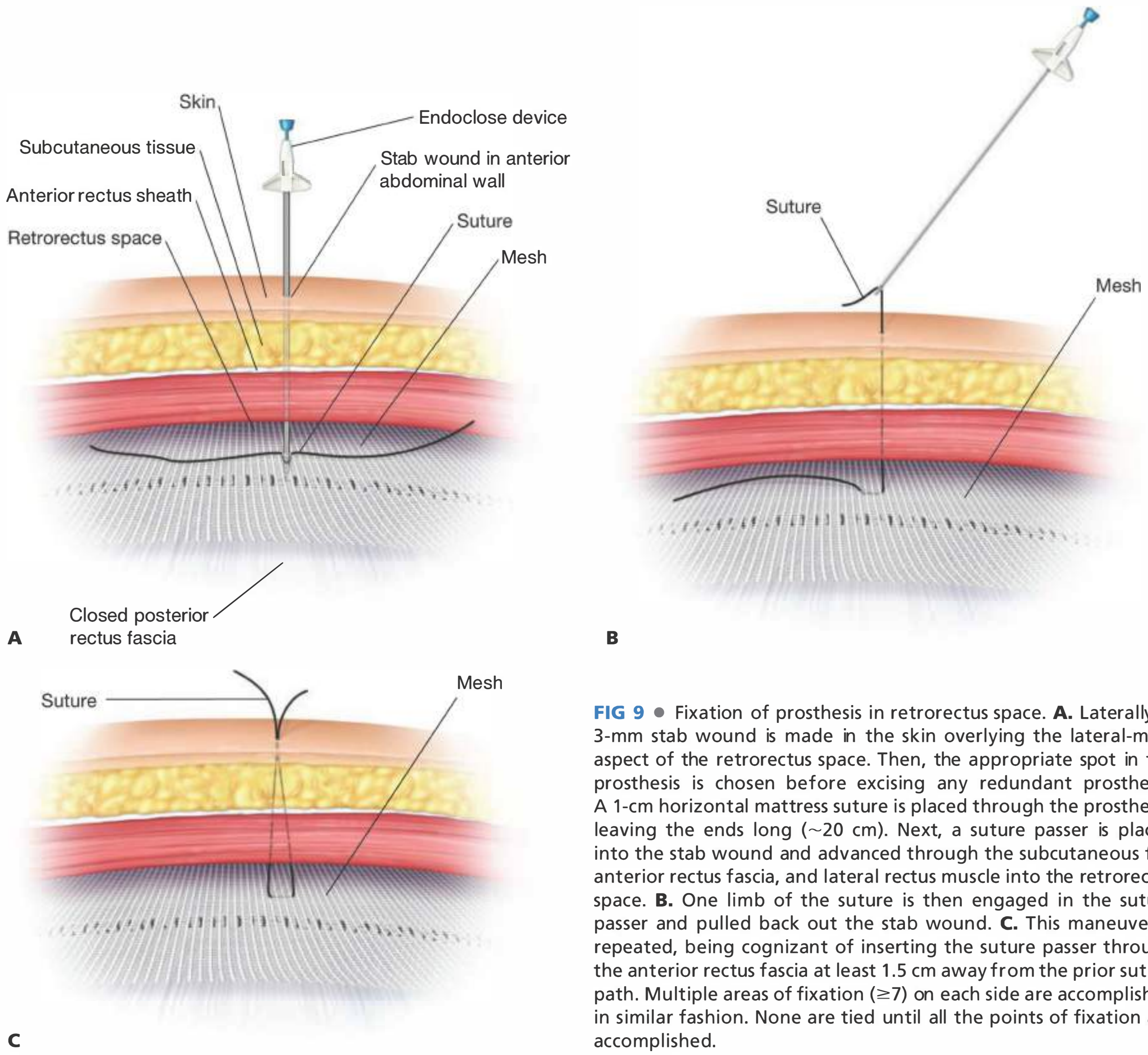


FIG 9 ● Fixation of prosthesis in retrorectus space. **A.** Laterally, a 3-mm stab wound is made in the skin overlying the lateral-most aspect of the retrorectus space. Then, the appropriate spot in the prosthesis is chosen before excising any redundant prosthesis. A 1-cm horizontal mattress suture is placed through the prosthesis, leaving the ends long (~20 cm). Next, a suture passer is placed into the stab wound and advanced through the subcutaneous fat, anterior rectus fascia, and lateral rectus muscle into the retrorectus space. **B.** One limb of the suture is then engaged in the suture passer and pulled back out the stab wound. **C.** This maneuver is repeated, being cognizant of inserting the suture passer through the anterior rectus fascia at least 1.5 cm away from the prior suture path. Multiple areas of fixation (≥7) on each side are accomplished in similar fashion. None are tied until all the points of fixation are accomplished.

rather than just through the cartilaginous xiphoid; this maneuver requires some force to push the suture passer through the bony sternum.

- The mesh is fixed at the caudal end of the retrorectus space. The mesh should be minimally taut but not under tension because some amount of mesh shrinkage is expected—more if the heavyweight/small-pore mesh is used.
- If the prosthesis extends to the pubis, a permanent suture is used for mesh fixation to the pubis, leaving about 3 cm of mesh that will extend posteriorly between the bladder and the pubis. A no. 1 polypropylene suture on a heavy needle is first passed through the mesh and then into the bone of the pubis and back out 1 to 2 cm from the insertion. This suture fixation is not to the periosteum but rather into the bony part of the pubis. The needle is then passed back through the mesh 1 cm from the other end to give 1 cm of mesh between the entry and exit points of the mesh. We use a minimum of four to five suture fixations through the pubis and pubic tubercle and, on occasion, two or three similar sutures to the medial aspect of Cooper's ligaments bilaterally. As another alternative, Mitek bone anchors (DePuy, Norwood, MA) may be used or a small passage through the pubis can be created using a bone drill. Use of a laparoscopic tacker is not recommended and should be avoided—the fixation is not durable enough.
- Once the prosthesis is sutured cranially and caudally, the fixation begins laterally. We place a Kocher clamp

on the medial edges of the anterior rectus fascia and bring the two sides in opposition to allow an accurate measurement of the lateral distance from the midline for the lateral point of mesh fixation. The mesh should be flat, without wrinkles. Start with the middle of the retrorectus space. The corners of the mesh should be the middle of the distance from the cranial and caudal extent of the repair. A 3-mm stab wound is then made on the anterior abdominal wall about 2 or 3 cm lateral to the lateral edge of the retrorectus space—this provides a bit more "lateral" pull and is easier to pass the suture passer into the retrorectus space. The mesh is folded over on itself to provide a two-layer fixation point in the mesh, and a horizontal suture is placed. The two sutures are pulled out the stab wound individually being certain that the two insertions of the suture passer are at least 1 cm apart on the fascia. The insertion of the suture passer should be done fully under vision to be certain that the inferior epigastric artery/vein complex is not injured, that the suture passer does not go through the posterior rectus fascia, and that an exposed nerve is not incorporated in the horizontal suture.

- Cranially and caudally, three additional transmural fixation sutures are placed per side.
- Prior to tying down the transmural sutures, the excess prosthesis is excised. As the sutures are tied down, the knot is pushed through the subcutaneous tissue to lie on the anterior surface of the fascia. The surgeon's hand should be placed in the retrorectus space to be certain that the mesh is pulled up firmly when the knot is tied.
- Once the mesh is fixed in place (**FIG 10A**), we put one or two closed suction drains into the retrorectus space anterior to the mesh but posterior to the rectus muscle. The drains exit the abdominal wall cranially rather than caudally where there are more skin bacteria (**FIG 10B**). The drains are removed the next day and are there only to evacuate any blood or fluid that forms in the first 24 hours postoperatively. Because this retrorectus space is compressed both anteriorly and posteriorly, seroma formation is rare.

Special Situations

- *Special situation 1*. If the medial aspect of the rectus muscle has been resected or has atrophied, the mesh can be placed lateral to the rectus muscle by developing a plane posterior to the internal oblique muscle and

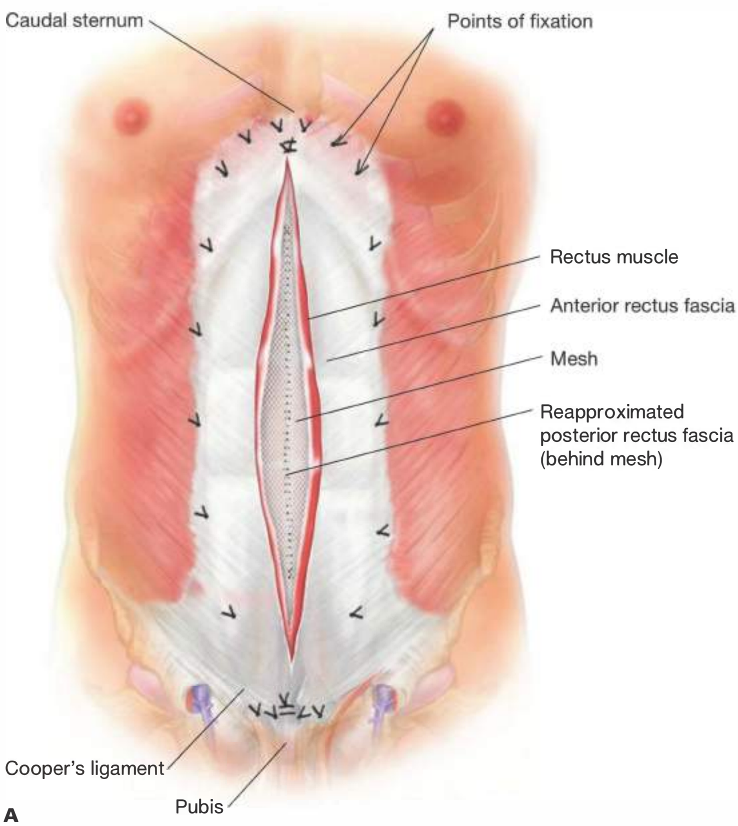


FIG 10 ● Circumferential fixation of the prosthesis. **A.** The prosthesis is fixed at the lateral, cranial, and caudal edges of the retrorectus space. If necessary, the prosthesis is sewn/fixed to the distal sternum and pubis. If the security/strength of fascial fixation is questionable cranially, the prosthesis can be sewn to the costal margin and caudally to Cooper's ligaments. The prosthesis should be flat and without wrinkles but should not be taut because some shrinkage is inevitable. *(continued)*

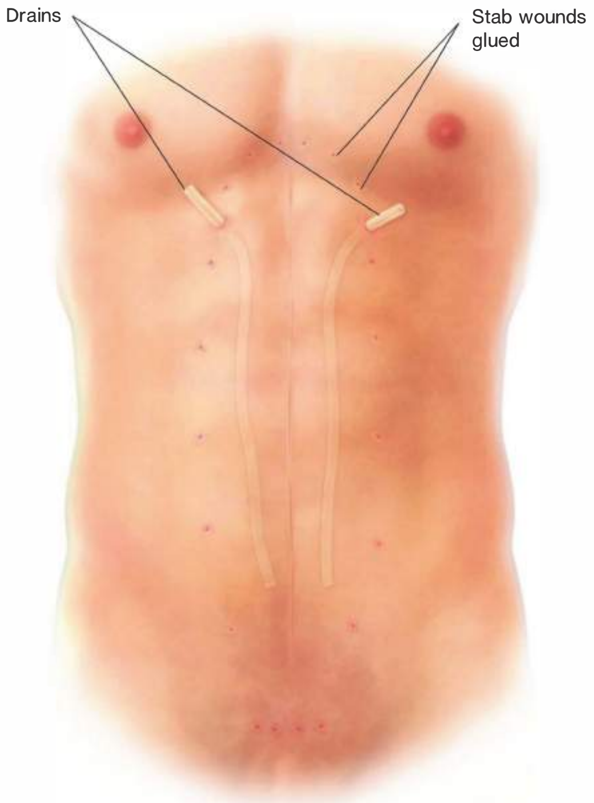


FIG 10 ● *(continued)* **B.** One or two closed suction drains are placed anterior to the prosthesis and brought out cranially.

anterior to the transversalis muscle (or even truly preperitoneal if that plane can be developed). In this case, the transmural sutures are passed much more laterally through the external oblique muscle/aponeurosis and internal oblique muscle.

- *Special situation 2*. If the retrorectus space extends anterior to the costal margin, we extend the mesh into this space to maximize overlap. On occasion, the mesh can be fixed to the costal margin for added support using a no. 1 polypropylene suture.

Closure of the Wound

- Once the mesh is secured, the medial borders of the anterior rectus fascia are reapproximated anterior to the prosthesis with a running no. 1 polydioxanone suture. Ideally, the rectus fasciae are sutured over the mesh, even if under moderate tension. If the fascia cannot be reapproximated, then consideration should be given to performing a components separation technique to allow autologous tissue closure over the mesh. We try not to bridge a fascial defect with a retrorectus repair (and thus exposing the mesh to the subcutaneous space) unless there are extenuating circumstances preventing either an intraperitoneal sublay (covered anteriorly with the peritoneum or the hernia sac or the ability to add a components separation technique to allow midline fascial closure) (see Part 2, Chapter 5).
- The subcutaneous tissue is closed with a running 2-0 polyglycolic acid suture and the skin with a dermal (subcuticular) 3-0 polyglycolic acid suture. The stab wounds are glued with Dermabond™ (Ethicon, Inc).

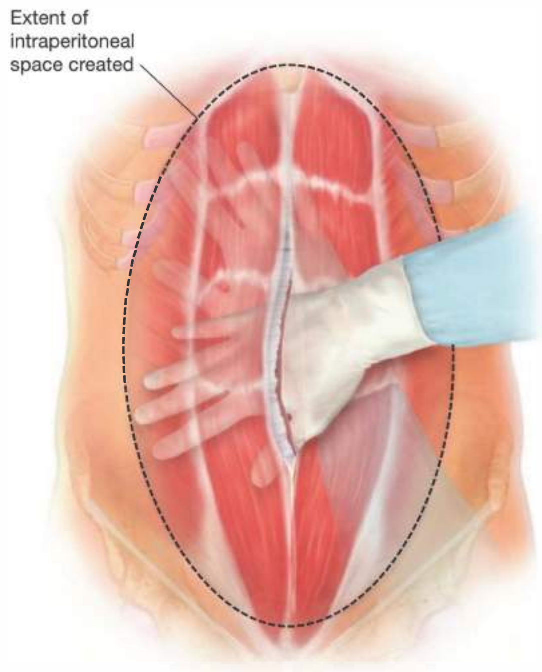
INTRAPERITONEAL SUBLAY REPAIR (ALSO REFERRED TO AS INTRAPERITONEAL ONLAY MESH)

Placement of Incision

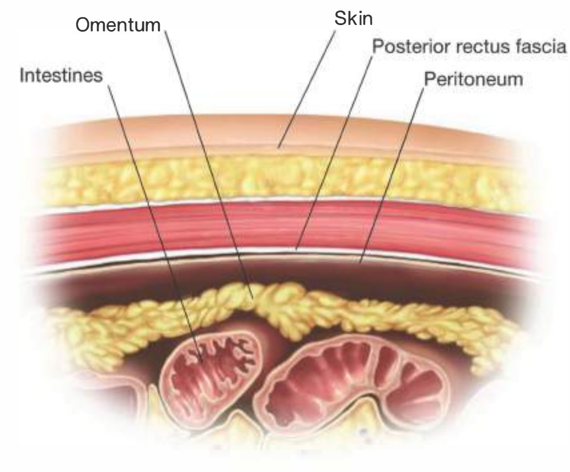
- The incision should be centered over the defect, resecting the prior incision and associated subcutaneous scarring. Because the placement of the prosthesis will be intraabdominal, the length of the incision needed will be determined by the amount of intraperitoneal adhesions and the ability to work through the incision created to place the prosthesis safely.

Creation of Space for Prosthesis

- Because the prosthesis will be placed intraperitoneally, there is no need to mobilize skin and subcutaneous flaps unless a concomitant components separation is planned; thus, the peritoneal cavity should be entered directly through the hernia sac (provided this can be done safely). The hernia sac should not be further mobilized or resected at this time; it will be used as an autogenous tissue barrier to close over the intraperitoneal prosthesis (as described later).
- If there are no concerns about obstructing adhesions (obstructive symptoms preoperatively), the dissection should free the intraperitoneal viscera off the posterior surface of the abdominal wall for 5 to 7 cm from the hernia defect circumferentially (**FIG 11**).
- If the hernia defect extends to the xiphoid, a space is created under the xiphoid by mobilizing the underlying triangular fat pad cranially for 5 cm.
- If the hernia defect extends to the pubis, then the preperitoneal space posterior to the pubis is dissected by mobilizing the space anterior to the bladder to allow fixation of the prosthesis to the bony pubis. For large hernias, this retropubic preperitoneal space can be further mobilized to allow a broader fixation of the prosthesis to Cooper's ligaments on both sides.
- Whenever possible, the omentum should be preserved and positioned between the posterior surface of the



A



B

FIG 11 ● Intraperitoneal mobilization. The posterior surface of the anterior abdominal wall is dissected free of any attachments of intraperitoneal content (bowel, omentum, liver) (see **B**). An intraperitoneal free space is dissected 5 to 7 cm cranial, lateral, and caudal past the edges of the fascial defect.

prosthesis and the intestine—this maneuver will minimize adherence of the bowel to either the prosthesis.

Choice of Prosthetic

- The prosthetic should allow transgrowth from abdominal wall but not adherence to the intraperitoneal contents. Several choices are available. Prostheses made from ePTFE have been used, and there will be no adherence of the viscera to its posterior surface, but there will also be no transgrowth into its anterior surface—therefore, we do not suggest using an ePTFE prosthesis. Several "composite-type" prostheses are available; these prostheses have two panels that are bound together—the anterior panel is a meshed synthetic prosthetic (usually polypropylene or polyester) that allows transgrowth, whereas the posterior panel is a thin layer of ePTFE that will prevent adherence of the intraabdominal viscera. The third type of prosthesis is a meshed synthetic prosthetic (polypropylene, Dacron, or polyester) with its underside coated ("protected") with a nonadhesive, proprietary barrier designed by the manufacturer to be hydrolyzed or reabsorbed in the first several days or weeks postoperatively; in so doing, this barrier is designed to prevent the intraabdominal viscera from adhering to the posterior surface of the synthetic mesh. In contrast, the anterior surface of the meshed prosthesis allows transgrowth from the posterior surface of the abdominal wall.

Placement/Fixation of the Prosthesis

- The prosthesis is fashioned to provide 5 to 7 cm of extension beyond the hernia defect circumferentially. The size of the prosthesis will vary depending on whether the fascial edges of the defect will be able to be sewn together or whether the defect will be bridged or patched; now is the time to determine this before mesh fixation.
- The mesh is sewn in place with multiple transmural sutures and not just by sewing the prosthesis to the posterior fascial layers of the abdominal wall. It is best to start with the four "corners" to size the prosthesis. A stab wound is made at least 7 cm lateral to the edge of the defect. Sutures are then passed through the abdominal wall using some form of suture passer. See the details for suture placement as described for the retrorectus repair (see **FIG 9**). The points of fixation require an intact fascia and not just muscle or fat through which the suture is passed.
- Attempts to fix the prosthesis to the undersurface of the abdominal wall from within the peritoneal cavity are not as reliable; such attempts are relatively blind, and although the posterior rectus fascia can be caught in the suture reliably, sutures placed lateral to the rectus muscle may only include the transversus abdominis and internal oblique fasciae (and not the external oblique fascial aponeurosis) which are not as strong or reliable for points for fixation.
- We place transmural sutures at 1- to 2-cm intervals circumferentially (**FIG 12**). As a general rule, the distance between the sutures should be roughly equivalent to the width of the horizontal mattress suture bites in the prosthesis.
- The goal of the suture fixation is twofold—first, to immobilize the prosthesis with a strong, stable anterior

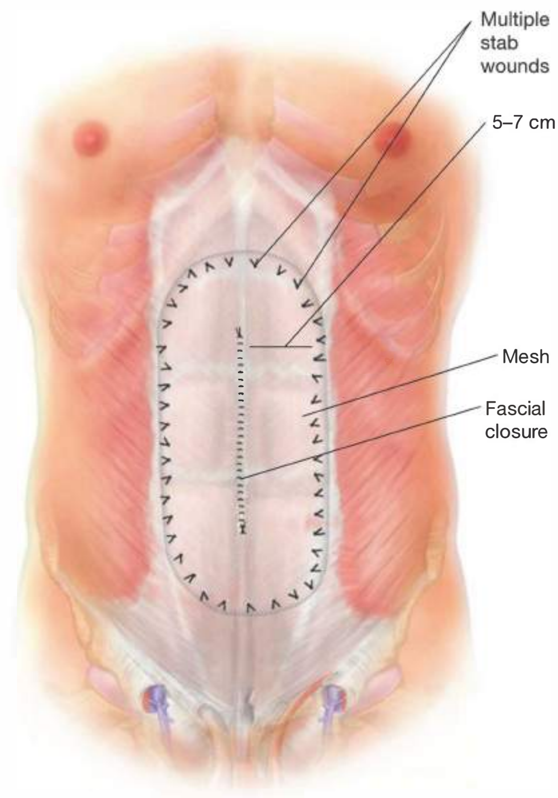


FIG 12 ● Placement of prosthesis. Using stab wounds and the suture passer (see **FIG 9**), multiple stab wounds are placed at 1.5-cm intervals for placement of transmural suture fixation. Because the prosthesis is intraperitoneal, many more areas of fixation are necessary to prevent intraperitoneal content from slipping anterior to the mesh between the points of fixation.

fixation and second, to obliterate completely any space between points of fixation where a loop of bowel can slip between the anterior surface of the prosthesis and the posterior surface of the abdominal wall. We stress that the transmural sutures should be placed close enough that there is *no* possibility that a loop of bowel can "herniate" between these transmural sutures. An alternative technique is to place several laparoscopic ports laterally to allow access after the wound is closed; then a laparoscopic tacker can be used to tack down the edges of the mesh between points of suture fixation, similar to the laparoscopic repair. We do not consider the use of a laparoscopic tacker alone without the use of multiple closely spaced transabdominal sutures to provide an adequately fixed, durable repair.

- For hernias that extend up to or within 5 cm of the xiphoid, the transmural fixation needs to pass directly through—not the xiphoid—but the distal sternum into the retrosternal intraperitoneal space. We use two permanent sutures in this region. These fixation sutures will fixate the prosthesis solidly and durably under the xiphoid, minimizing suture pullout. Technically, this may be accomplished in a number of ways. The Endo Close™ (Covidien Surgical) suture passer may be used, although it may become dulled or the tip bent and may need to be replaced. Suture with a CTX or larger needle can be partially straightened and passed through the distal sternum with some effort. The Reverdin needle is an excellent alternative, allowing passage of suture from the internal to external direction; the sharpness and heavy body of the instrument facilitate its use for this purpose. Again, avoid the too-sharp non-disposable metal Carter-Thomason suture passer.
- When the hernia extends caudally down to or within 5 cm of the pubis, the prosthesis should be sewn to the pubis. We use at least four separate no. 1 polypropylene sutures on a large, heavy needle. The needle should be passed through the bone of the pubis—not just the periosteum. If the tissues are too dense to allow passage of the needle, a penetrating towel clamp can be used to create a small passage through the bone or a bone drill may be needed. Alternatively, Mitek bone anchors may be used. Use of the laparoscopic tackers is not recommended—these limited points of fixation are not reliable. An additional 3 to 4 cm of the prosthesis can be positioned posteriorly between the bladder and the posterior surface of the pubis.
- Additional medial transabdominal fixation sutures can be placed circumferentially if there is concern about stability of the lateral fixation sutures.

Closure of the Wound

- We place one or two temporary, closed suction drains anterior to the prosthesis to encourage close apposition of the peritoneum to the prosthesis.
- The peritoneum and/or the preserved hernia sac is closed anterior to the mesh, providing an autologous layer of tissue on top of the mesh.
- The fascial edges of the hernia should be reapproximated. If there is tension, relaxing incisions or components separation should be contemplated to allow for fascial closure. To restore anatomic position of the abdominal wall musculature, close the fascial defect, and provide another layer of autogenous tissue over the prosthesis. Alternatively, a more "closed" type of components separation, either "laparoscopic" or "minimal incision," perforator-sparing type can be performed understanding that these approaches will only yield 3 to 4 cm of a medial advancement on each side (see Part 2, Chapter 5). If the edges of the fascia cannot be reapproximated, one can bridge the defect with an inlay of absorbable mesh of polyglycolic acid using Dexon™ (Covidien Surgical) with the aim of temporarily relieving the tension on the lateral fixation points. Use of second layer of a permanent synthetic prosthetic is not indicated because the hernia repair has already been accomplished with the intraperitoneal permanent prosthesis. Use of

the expensive bioprostheses is discouraged because of prohibitive cost (versus the temporary absorbable mesh) and the lack of defined efficacy either in relieving lateral tension or equally important as providing a durable, onlay-type patch repair.

- The incision is then closed with a running 2-0 polyglycolic suture and the skin with a running 3-0 polyglycolic acid dermal suture. The stab wounds are glued with Dermabond™ (Ethicon, Inc).

COMBINED RECTUS ROLLOVER/ COMPONENT SEPARATION WITH PROSTHESIS UNDERLAY

General Considerations

- This is a combination of several techniques to provide maximal medial reapproximation of the musculoaponeurotic walls. It is particularly useful for large midline defects when the abdominal wall musculature is largely intact. Closure of defects up to 15 cm in width are possible with this combination technique.
    - The rectus rollover is a modification of a components separation technique. The anterior rectus sheaths are incised vertically just medial to their lateral borders along their entire length. The anterior rectus sheaths are then dissected off the muscle to a point 2 cm lateral to the medial edge of the rectus muscles. During suturing, the sheath is rolled anteromedially (**FIG 13**).
    - The external oblique can be incised vertically just lateral to the rectus sheath as done for components separation (see Part 2, Chapter 5).
    - An underlay prosthesis is placed intraperitoneally, preperitoneally, or retrorectus and secured with interrupted, transabdominal, horizontal mattress sutures.
- Skin flaps are raised off the musculoaponeurotic walls bilaterally as for the wide onlay technique. Care must be taken to not incise or buttonhole the fascial layers, but no fat should remain on the musculoaponeurotic wall.
- A vertical incision is made in the anterior rectus sheath, about 1 cm medial to the lateral border (see **FIG 13**). The anterior rectus sheath is mobilized off the anterior surface of the rectus abdominis with electrocautery progressing in a medial direction to about 2 cm lateral to the medial border of the rectus muscles.
- A components separation division of the external oblique can then be created laterally, if needed, using a vertical incision of the external oblique about 1 to 2 cm lateral to the lateral border of the rectus sheath (see Part 2, Chapter 5).
- An underlay prosthesis is chosen based on the principles outlined earlier in this chapter. Sizing is to provide an overlap of at least 5 cm circumferentially; ideally, the prosthesis will be sutured just outside the lateral border of the rectus sheath. Horizontal mattress sutures are placed using a large needle such as a CTX or a suture passer. The width of the horizontal mattress sutures should be about 1.5 cm, and the spacing of the sutures should be the same.
- Once all sutures have been placed, the prosthesis is snugged up to the abdominal wall. If the prosthesis is placed intraperitoneally, the prosthesis is carefully examined to make certain no intraabdominal contents have slipped between the sutures; this is done repeatedly as the sutures are pulled up and tied.
- The fascia is then approximated in the midline using a running horizontal mattress suture; we prefer a no. 1 looped polydioxanone suture for this step. Bites are taken after medializing the anterior rectus sheath (**FIG 13**); they should reapproximate the rolled-over edges of the anterior rectus fascia in the midline. When completed, very near normal anatomy is restored, although the rectus muscles will not be approximated (**FIG 13**).

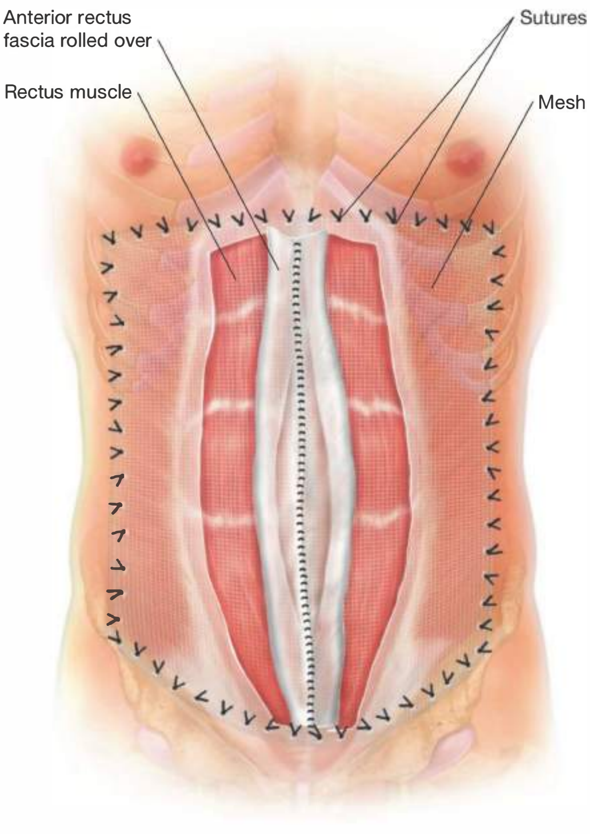


FIG 13 ● Completed intraperitoneal sublay with anterior rectus rollover fascial closure. Note medial edges of rectus muscles not approximated.

FLANK HERNIAS

General Considerations

- Flank hernias (after a flank incision, such as kidney/ureter or anterior spinal access procedures) are different functionally from most incisional hernias, as they have higher recurrence rates. Flank pseudohernias are bulges in the musculofascial components of the lateral abdominal wall secondary to denervation and should be noted prior to operation with a CT because surgical bolstering of pseudohernia have not yielded satisfactory results.
- Repair of a flank hernia is not as straightforward as repair of midline incisional hernias; the points of fixation of the prosthesis are not as reliable. Although onlays and sublays (intramural or intraperitoneal) have been described, we believe strongly that for these difficult hernias, an intramural, synthetic mesh-based repair is best because it provides the most durable and reliable fixation of the prosthesis.

Step 1: Patient Positioning

- If the hernia is located more medially and does not extend past the anterior axillary line, the patient is placed in a "modified lateral" position with the ipsilateral side rotated medially to allow free access to as far posteriorly as the posterior axillary line (**FIG 14A**).
- If the hernia extends further laterally, then a full lateral position (**FIG 14B**) is necessary to allow access to the posterior midclavicular line posteriorly.

Step 2: Development of Intramural Space

- The prior skin incision should be excised down to the hernia sac. Unless necessary, try to stay extraperitoneal.
- Next, a plane is developed posterior to the internal oblique muscle but anterior to the transversalis muscle (**FIG 15**). Attempts to stay in the preperitoneal space cranially can be difficult; caudally, this space is much easier to develop. The goal is to create a space with a large surface area in which to place a synthetic, meshed prosthesis. The space is mobilized to the costal margin cranially, as far laterally as possible (posterior axillary line), to the anterior superior iliac crest caudally and to the lateral edge of the rectus muscle medially.
- If the hernia extends to the lateral edge of the rectus muscle, then the retrorectus space can be entered and mobilized to the midline. The prosthesis lies between the very vascular internal oblique and transversalis muscles to maximize transgrowth. This space is better vascularized than the preperitoneal space.

Step 3: Fixation of Prosthesis

- Once the intramural space has been mobilized with at least a 7- to 10-cm margins from the hernia defect, the

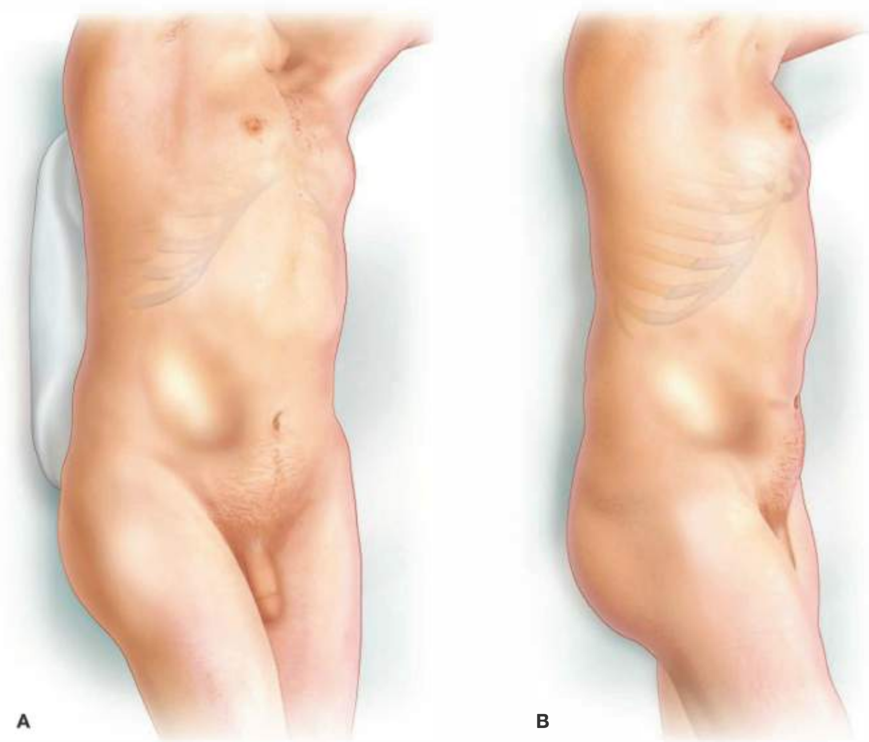


FIG 14 ● Positioning of patient for a flank herniorrhaphy. **A.** When the hernia/bulge does not extend lateral to the anterior axillary line, the patient is placed in a "sloppy" lateral position allowing access to the posterior axillary line. **B.** For defects extending to the midaxillary line, a true lateral position is necessary to allow access to the posterior midclavicular line.

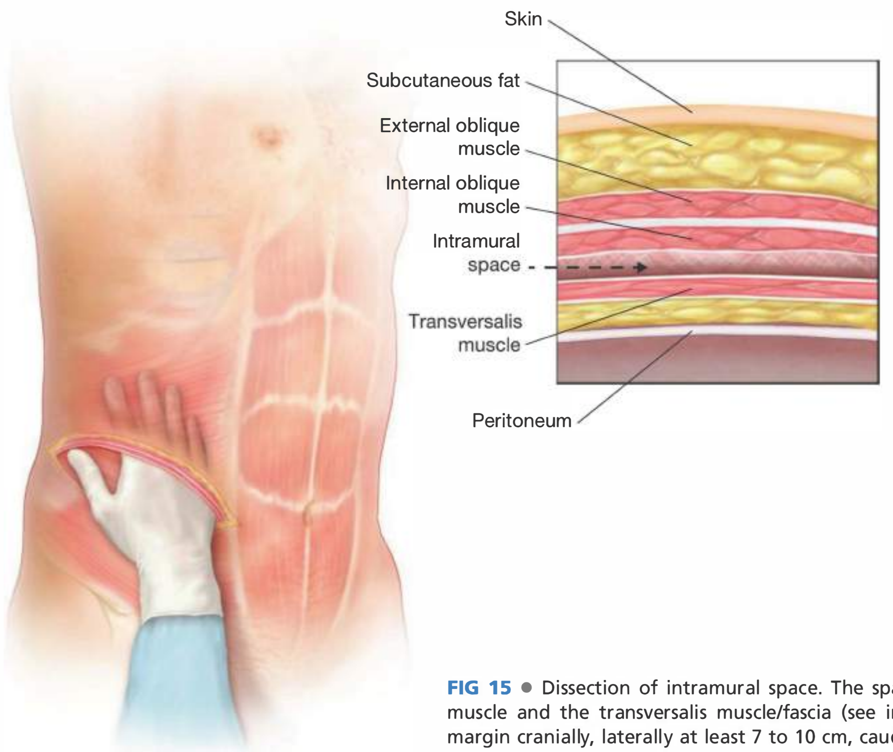


FIG 15 ● Dissection of intramural space. The space between the internal oblique muscle and the transversalis muscle/fascia (see insert) is created up to the costal margin cranially, laterally at least 7 to 10 cm, caudally to iliac crest, and medially to lateral border of the rectus muscle.

meshed prosthesis is fixed with transmural sutures. As described for ventral incisional hernia repairs previously, multiple horizontal sutures of no. 1 polydioxanone are placed along the edge of the prosthesis. Stab wounds are positioned at the extent of the space mobilized (**FIG 15**). Using a suture passer, the ends of the sutures are separately grasped and tied down onto the surface of the abdominal wall fascia. Because the mesh is placed intramurally, there is no concern for bowel becoming entrapped between these sutures, thus the number of sutures should be determined by the quality of the tissue. If the anterior fascia is weak or attenuated, the space needs to be developed further (see later "Special Situations").

Step 4: Closure of the Wound

- A closed suction drain is placed anterior to the mesh brought out cranially.
- The muscle and/or weakened fascial layers anterior to the mesh are reapproximated with a running absorbable suture; the subcutaneous tissue and skin incision are closed with absorbable suture. All the stab wounds can be glued with Dermabond™ (Ethicon, Inc).

Special Situations

- *Fixation to costal margin*: When the musculofascial tissue cranial to the defect is attenuated or the overlap is not at least 5 to 7 cm, the prosthesis can be sewn to the costal margin (**FIG 16**). We use no. 1 polypropylene sutures through and not around the rib; this provides a stable cranial fixation.
- *Fixation to iliac wing*: A more common problem is when the musculofascial tissue caudal to the defect is attenuated or retracted such that the overlap is inadequate; in this situation, we sew the edge of the prosthesis to the anterior iliac spine and the more medial "wing" of iliac bone with no. 1 polypropylene sutures; these sutures pass through the bone and not just in the periosteum (**FIG 16**). The sutures can be placed from within the space created for the prosthesis; but this maneuver takes a bit of force. For very young or large men, we have made an incision in the skin directly over the anterior iliac spine, dissected down to the bone, and used a bone drill through this bone and into the intramural space.
- *Inadequate tissue medially and caudally*: Often, the area medial to the anterior iliac spine is very attenuated. In this situation, we will dissect into the preperitoneal space down to Cooper's ligament and the pubic tubercle behind the inguinal canal. These bony areas can serve as very stable points of medial and caudal fixation of the prosthesis, again with no. 1 polypropylene sutures into and through the bone (**FIG 16**).

FIG 16 ● Fixation of prosthesis. The prosthesis is fixed to the anterior fascia at the edges of the intramural space created, again using multiple stab wounds and a suture passer. The prosthesis can also be sewn to the costal margin cranially and the iliac crest caudally for a more secure fixation. For large flank hernias extending medial to the lateral edge of the rectus muscles, the retrorectus space can be opened to communicate with the intramural space created laterally. The cranial and caudal edges of the fascial defect are then sewn together to cover the prosthesis.

PEARLS AND PITFALLS

Indications	■ Despite lack of systemic symptoms, an acute, nonreducible, incarcerated incisional hernia is an indication for urgent exploration/repair. ■ Review all previous operative notes—surprises in the operating room (OR) are usually not welcome. ■ When repairing a flank hernia, warn the patient that there may still be a bulge. Even with a "successful" repair, these patients can be the least happy postoperatively of all patients after repair of an incisional hernia. ■ Heavy laborers or high-performance athletes will do better with abdominal wall reconstruction (restoration of musculofascial continuity) rather than a laparoscopic patch repair. ■ For patients with lung disease or those with a history of pain intolerance, consider postoperative epidural analgesia or a "one-shot" intrathecal analgesia.
Choice of prosthetic	■ Currently, there are no biologic prosthetics that provide as good a long-term outcome as a synthetic prosthetic. ■ Large pore/lightweight, small pore/heavy weight, and ePTFE all have their advantages/disadvantages. There is little, if any, role for ePTFE for onlay or Rives-Stoppa sublay repair. A protected or "covered" meshed prosthesis of polypropylene, Dacron, or polyester with a layer of either a rapidly absorbable biologic barrier substance (to prevent visceral adherence) or ePTFE facing the viscera for an intraperitoneal repair is preferable to a pure ePTFE because there is no functional ingrowth into ePTFE. The classic role for ePTFE is when the prosthesis needs to be watertight—for example, in the very rare patient with ascites. ■ For laborers or serious athletes, the small-pore/heavyweight prostheses will give more support, but plan for 25%–30% shrinkage in size of the mesh. ■ If the patient has developed suture granulomas in the past to permanent sutures, avoid their use—suture granulomas predispose to superinfection.

Exploration of hernia defect	■ When an unexpected suture granuloma is encountered during the incision, consider aborting the procedure for worry of indolent, inactive bacterial colonization unless you can excise the entire area (i.e., the suture, the associated biofilm, and the cavity/wall are intact). Remove all foreign sutures, culture the area, and use a 2-week course of focused antibiotics postoperatively—we acknowledge that we have no evidence that this treatment is effective. ■ Always look for a Swiss cheese defect along the prior fascial incision distant from the presumed "isolated" hernia defect. ■ When performing a Rives-Stoppa, retrorectus sublay repair in a patient who has had a prior enterostomal takedown (e.g., after takedown of a Hartmann procedure), be aware that a knuckle of bowel may protrude through a defect in the posterior rectus fascia. ■ If the patient has had a recent history of recurrent partial small bowel obstruction, consider an intraperitoneal adhesiolysis in addition to the hernia repair. ■ Weeks to several months after a prior incisional herniorrhaphy, point tenderness laterally may be secondary to a suture granuloma at a fixation point. If possible, inject a local anesthetic to "buy time" and wait for the suture to be reabsorbed. If symptoms persist, locally explore that area and remove the suture.
Early postoperative seroma	■ Should a symptomatic seroma develop within the first postoperative month, repeated percutaneous aspiration may prevent rupture through the incision and subsequent risk of superinfection of the prosthesis. If the seroma persists, then consider a percutaneous drain. Nonresolving "seromas" usually represent the development of a pseudobursa lined with mesothelial cells that produce fluid—if large and symptomatic, these require operative excision of the entire lining. If the seroma is asymptomatic, consider not intervening. ■ When placing lateral fixation sutures, it is possible to encircle a somatic nerve—the resulting early (1 day postoperatively) and persistent pain will follow the dermatome or the distribution of the nerve—for example, intercostal, genitofemoral, or circumflex iliac nerve—and may require early removal of the offending suture, even prior to discharge.
Placement of fixation sutures	■ For intraperitoneal sublay repairs, the surgeon should ALWAYS have his/her hand between the posterior surface of the prosthesis and the abdominal viscera when the sutures are tied. Likewise, there should be NO laxity or space between fixation sutures or tacks.

POSTOPERATIVE CARE

- Most patients will not need a nasogastric tube, but in extended complex repairs, especially with an accompanying adhesiolysis, gastric decompression may be advisable.
- The timing of removal of subcutaneous drains is controversial—drains serve as sites of potential bacterial contamination, yet drains may minimize formation of seromas/pseudobursa. When placed intraperitoneally on the anterior surface of prosthesis or in the retrorectus space, they should be removed early (1st postoperative day). When placed subcutaneously after an extensive, subcutaneous flap mobilization, one must weigh the risk of infection versus that of seroma when deciding to remove the drains. No evidence-based suggestions can be offered.

OUTCOMES

- Recurrence rates with these types of elective repair for anterior abdominal wall hernias (midline or transverse incisions) should be less than 10% to 15% range. Many factors adversely affect recurrence rates, such as multiple prior repairs, hernia size, impaired healing (steroid use, active smoking, chemotherapeutic agents, obesity, etc). "Recurrences" for flank hernias are greater—note the recurrence to the patient may be a "bulge" rather than a true musculofascial/prosthetic defect—preoperative counseling of this possibility and intraoperative planning of the appropriate tension and secure placement of fixation of the prosthesis will minimize this possibility.
- Early or late (even years later) infection of the prosthesis occurs in ~3% of patients. Prior wound infections, usually with *Staphylococcus* species and especially methicillin-resistant *Staphylococcus aureus* (MRSA), appear to increase the risk of prosthetic infection. Whether preoperative clearance of nasal, vaginal, and rectal MRSA colonization is effective is unproven.
- Postoperative, subcutaneous wound infections require immediate, aggressive treatment to prevent underlying infection of the prosthesis, even if there is autogenous tissue between the prosthesis and the subcutaneous space.
- A nonreducible bulge/mass that develops directly under the incision with the first 6 weeks is likely a seroma and often does not require further investigation; ultrasonography will differentiate seroma from recurrence. Not all seromas require intervention, and many will reabsorb over time. Cognizance of this possibility will prevent unnecessary aspiration or especially placement of a drain, both of which can introduce bacteria and secondary infection. Fever, pain, increase in size, or nonresolution warrant aspiration.

COMPLICATIONS

- Bleeding/hematoma—usually contained
- Seroma—appears within first several weeks postoperatively; if persistent for weeks or months, suspect formation of a mesothelial-lined pseudobursa. These are more common with an onlay prosthesis, especially ePTFE or when the herniorrhaphy is combined with an abdominoplasty.

- Subcutaneous wound infection—~2% to 5% but depends on extent of lateral dissection
- Skin necrosis at medial edge of incision after wide lateral mobilization of a skin/subcutaneous flap; with an abdominoplasty, minor wound problems may approach 40%.
- Prosthetic infection, both early (first 2 months) or late (months to years later)—3%
- Recurrence—approximately 10% to 15%; often, the recurrence is at the cranial or caudal end of the prior hernia defect
- Radiculopathy from a somatic nerve trapped by a fixation suture, though rare, can complicate an abdominal wall reconstruction.
- Suture granuloma at fixation site
- Small bowel obstruction from the intraperitoneal part of the hernia mobilization and prosthetic placement of the prosthesis; the obstruction is either related to adhesions or rarely between adjacent fixation points if the space left was too large or too loose. In theory, the fixation suture can trap a loop of bowel within the suture—this should lead to a very early obstruction 1 or 2 days postoperatively.
- Unrecognized enterotomy at the time of hernia repair

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Chapter 4

Incisional Hernia: Laparoscopic Approaches

Todd Heniford Kristopher Williams

DEFINITION

- Incisional hernia is defined as any abdominal wall defect occurring at the site of previous operation or scar. Laparoscopic incisional hernia repair uses prosthetic mesh reinforcement, much like as originally described by Stoppa,[1] applied through minimally invasive operative techniques with reliable success.[2]
- Incidence of incisional hernia following laparotomy exceeds 20% with over 2 million laparotomies performed in the United States annually, a factor contributing to the estimated 348,000 ventral hernia repairs in 2006.[3,4]
- Recurrence rates for primary suture hernia repair have been reported to be as high as 54%,[5] which have been reduced by more than half with the use of mesh reinforcement.[6,7]

DIFFERENTIAL DIAGNOSIS

- Diastasis recti
- Seroma
- Hematoma
- Abdominal wall abscess
- Hypertrophic scar
- Desmoid
- Abdominal scar endometrioma (at sites of previous cesarean or hysterectomy incisions)
- Soft tissue sarcoma

PATIENT HISTORY AND PHYSICAL FINDINGS

- A detailed general health history should be obtained including past medical history, current medications, allergies, social habits (alcohol, illicit drug use, smoking history) as well as previous adjuvant treatments, which may impact any attempt at operative repair (e.g., previous pelvic or abdominal radiation). Consideration of other common abdominal pathology, such as symptomatic cholelithiasis or colon cancer, may need evaluation prior to hernia repair and results should be documented.
- A detailed history regarding obstructive symptomology (nausea, vomiting, passage of flatus, bowel frequency, abdominal pain) the patient may have experienced in the recent or distant past should be recorded.
- For all patients undergoing evaluation of incisional hernia, medical records should be obtained and reviewed, emphasizing surgical history and operative reports from previous pertinent surgeries and hernia repairs. Attention should be directed toward specifics of previous abdominal operations, especially hernia repairs: anatomic location of initial hernia defect, previous attempts at hernia repair, presence and type of previously placed mesh, location of any previously placed mesh (intraperitoneal, preperitoneal, retrorectus, fascial onlay, etc.), method of mesh fixation, and previous operative complications. Also, the extent of previous skin and subcutaneous dissection and the presence and extent of a components separation can be very helpful.
- The presence of comorbidities known to be associated with increased risk of postoperative wound complications or recurrence (current or smoking history, obesity, diabetes, immunocompromised status, cirrhosis, chronic obstructive pulmonary disease [COPD], current or chronic infections such as urinary or pulmonary infection, history of previous mesh or other methicillin-resistant *Staphylococcus aureus* [MRSA] infections), as well as any history of previous or current wound infections and any current abdominal wall wound issues should be noted.
- A complete physical exam should be performed paying particular attention to the existence and location of abdominal scarring, nonhealing wounds, erythema that may indicate deeper pathology, identification of any abdominal wall defects (either incisional or primary), presence and nature of hernia contents within defects, reducibility of hernia contents, and tenderness to palpation of noted defects. Fascial defect size should be estimated to aid in preoperative planning.
- Other physical findings or review of symptoms points may alert a surgeon to medical issues that require workup prior to surgery, such as heart failure, COPD, vascular disease, liver or kidney disease.
- A thorough examination should be performed looking for the existence of other potential hernia sites (umbilical, inguinal, femoral, parastomal, etc.), which may be addressed at the time of surgery. By neglecting other potential hernias, the opportunity to repair them at the same time as the primary hernia may be lost.
- The presence of a gastrointestinal stoma, active wound infection, or chronic draining sinus tracts should also be taken into account, as these situations influence operative planning, risk counseling, and may influence an open versus a laparoscopic repair. A laparoscopic repair with synthetic mesh placement is not appropriate for an actively infected field.
- The presence of peritoneal signs (abdominal rigidity, guarding, rebound tenderness) should alert the surgeon to the likelihood of intraabdominal issues and may mandate an emergent laparotomy.

IMAGING AND OTHER DIAGNOSTIC STUDIES

- Although physical exam is the gold standard of diagnosis, obese body habitus, abdominal scarring, and the presence of previously placed mesh may preclude physical diagnosis of an incisional hernia. For these reasons, computed tomography (CT) is a valuable tool for diagnosis and operative planning in cases of a suspected incisional hernia (**FIG 1**).

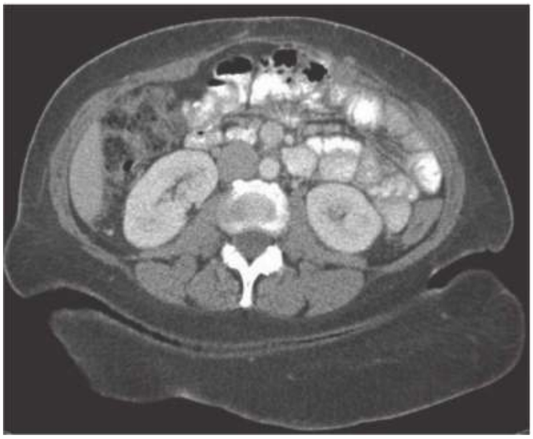


FIG 1 ● CT incisional hernia. A 51-year-old female with multiple gastric revisions since undergoing original gastric bypass, eventually resulting in completion gastrectomy. CT shows 7-cm incisional hernia defect containing normal-caliber small bowel with intraluminal contrast.

- Advantages of CT imaging for the evaluation of incisional hernias are multifactorial: accurate diagnosis in cases of obscure or small defects; proper identification of hernia contents (small bowel, colon, solid organs, omentum, etc.); definition of defect size; location of previously placed mesh; distinction from other or concomitant potential diagnoses (seroma, abscess, hematoma, etc.); identification of bowel incarceration; obstruction or possible ischemia, necrosis, or perforation; and planning of where to enter the abdomen safely.
- When feasible, it is helpful for the operating surgeon to review the actual CT images, as the information discussed earlier may not be included in a radiologist's reading of the films. It is also helpful to have CT images available to be viewed intraoperatively as they can serve as a reference during the operative procedure.
- Colon cancer screening with colonoscopy or other appropriate means is often considered for those patients who have reached appropriate age for screening, have a significant family history, or other colonic symptoms prior to hernia repair.

SURGICAL MANAGEMENT

Preoperative Planning

- For elective procedures, in the weeks leading up to repair, attempts should be made at optimization of preoperative patient factors associated with increased risk of postoperative wound complications: smoking cessation, evaluation and maximization of nutrition status, tight blood glucose control, weight loss in the obese, or elimination of open wounds through local wound care.[8]
- Appropriate intravenous antibiotic prophylaxis should be administered prior to incision and repeated as needed to provide adequate prophylactic coverage depending on length of procedure and drug half-life.[9]
- Venous thromboembolism prophylaxis should be provided, such as lower extremity serial compression devices or subcutaneous prophylactic dose heparin prior to induction of anesthesia, assuming no contraindications.[9]
- Following induction of anesthesia, the abdominal wall is reexamined to confirm the borders of the defect in question and to identify the presence or location of previous mesh, signs of infection, or other issues.
- Intraoperative urinary and gastric decompression are recommended.
- Iodophor-impregnated adhesive skin drape may be used to minimize mesh contact with skin surfaces and therefore reduce the risk of mesh infection, although this has not been proven in randomized clinical trials.

Positioning

- The patient should be positioned supine with arms adducted and tucked at sides of body with adequate padding of pressure points to avoid neurologic pressure injury. This allows movement of the surgeon and the assistant on each side of the table during the operation (**FIG 2**).
- Semilateral or lateral decubitus position may be favored for repair of flank or lumbar hernias.
- The patient should be secured to the operating table to allow steep positioning or rolling of the table as required during the procedure.
- Laparoscopic monitors should be positioned over the working space to allow direct vision by both the primary surgeon and assistant.

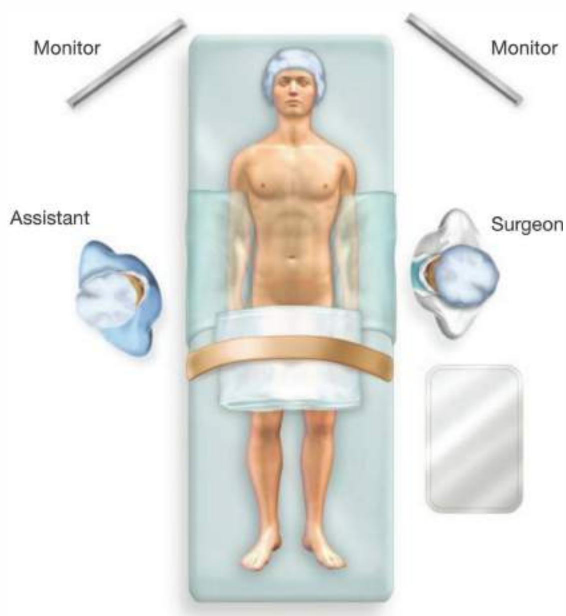


FIG 2 ● Patient positioning. The patient is placed supine on the operating table with arms adducted and monitors positioned toward the head of the table. The surgeon stands on either side of the patient, depending on hernia location, with the assistant directly opposite.

INITIAL ACCESS

- A safe window of intraperitoneal access is usually available in areas distant from site(s) of previous surgery, although an open, "cut-down" technique can be performed near or within a hernia if the surgeon prefers.
- Often, safe entry is found just inferior to the tip of the 11th rib, between midclavicular and anterior axillary lines (**FIG 3**).
- Open cut-down technique is most often performed with identification of individual abdominal wall layers as each is entered, but some surgeons use a port that allows visualization of the abdominal wall layers with the laparoscope as the trocar is slowly advanced into the abdomen.
- Pneumoperitoneum is established at 12 to 15 mmHg.

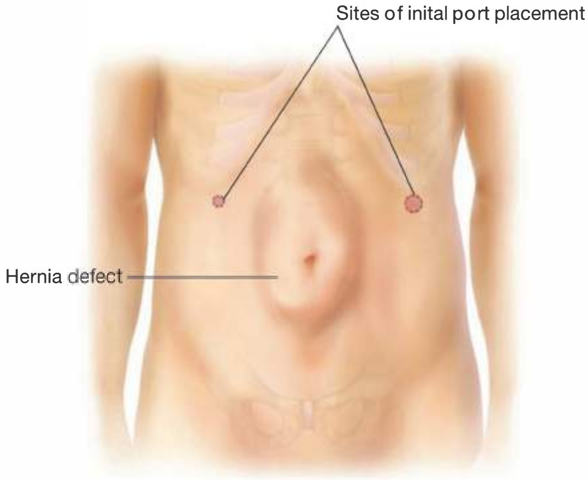


FIG 3 ● Initial port placement. Safe areas of initial trocar placement via the cutdown technique are often found just inferior to the 11th rib between the midclavicular line and the anterior axillary line.

PLACEMENT OF WORKING PORTS

- Using an angled (30- or 45-degree) scope, a brief general inspection of the abdominal cavity checking for organ injury, which may have occurred during initial access, is performed.
- Working port placement is based on target defect location, optimization of working space, and triangulation of working instruments, if possible. Ports that are too far caudal or cephalad may limit freedom of motion of the port due to the hip or rib cage (**FIG 4**).
- Ideal port placement allows sufficient working space between ports and target defect. The distance between individual ports should allow a range of motion that prevents ports from colliding or limiting motion. Ports should not be too close to the hernia defect as this limits visualization for mesh placement or mesh fixation.
- Additional 5-mm trocars are placed under direct visualization (**FIG 5**).
- Often, two 5-mm trocars are placed laterally on same side as initial access port, usually between anterior and midaxillary lines.
- One or two 5-mm trocars can be placed on the contralateral side of initial access port for adhesiolysis or to facilitate mesh fixation.

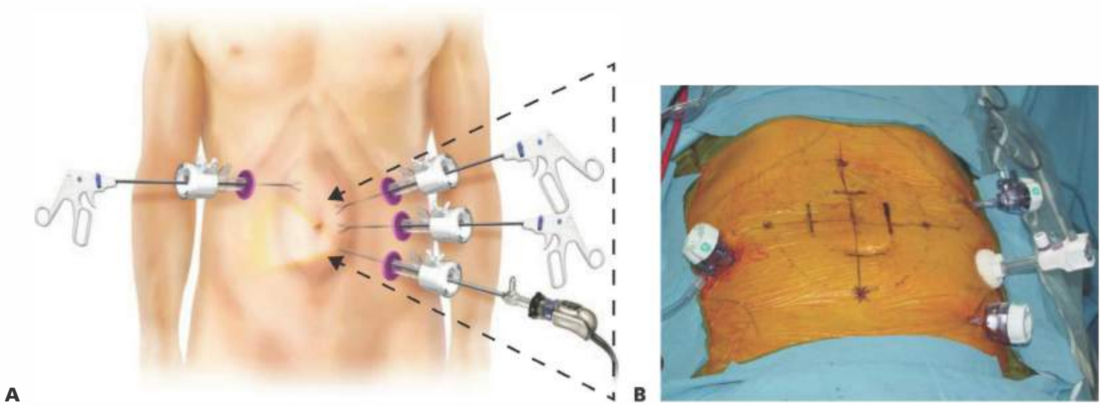


FIG 4 ● Working port triangulation. Figure **A** shows diagrammatic representation of working triangulation to target defect. Figure **B** is an intraoperative view of working ports.

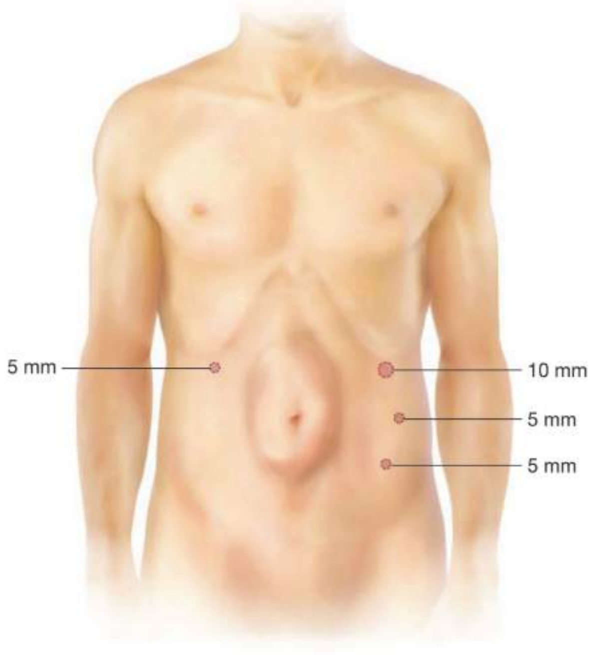


FIG 5 ● Port sizes and position. Positioning of initial 10-mm port and 5-mm working ports for midline periumbilical incisional hernia. Two 5-mm ports are placed on the ipsilateral side of initial access and a single 5-mm port is placed on the contralateral side.

LYSIS OF ADHESIONS AND DEFINITION OF HERNIA DEFECT

- Pneumoperitoneum assists in dissection as countertraction is provided by weight of dependent omentum and bowel to expose safe tissues planes (**FIG 6**).
- Meticulous lysis of adhesions is performed using sharp dissection with minimal judicious electrocautery to avoid thermal spread and bowel injury (**FIG 7**).
- The majority of operative time is often spent performing the adhesiolysis. An enterotomy can increase the risk of mesh infection and, in cases of gross spillage, placement of prosthetic mesh is contraindicated. A bowel injury may result in the need for conversion to an open procedure, may necessitate the use biologic mesh or hernia closure without mesh, or the need for staged repair.
- Freeing the adhesions along the entire length of incision often allows the surgeons to identify all defects

FIG 6 ● Lysis of adhesions. Pneumoperitoneum assists in dissection.

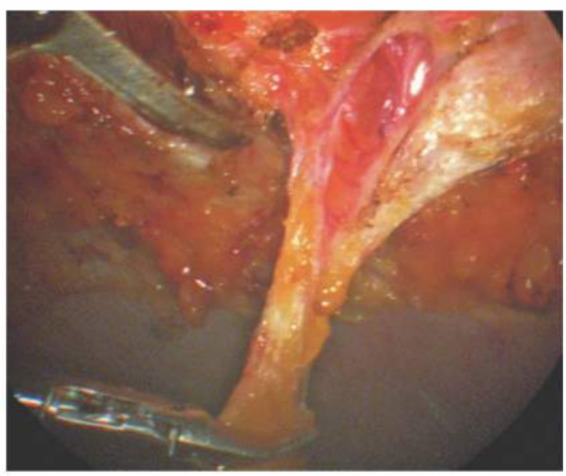


FIG 7 ● Lysis of adhesions. Meticulous adhesiolysis performed to expose entire length of incision.

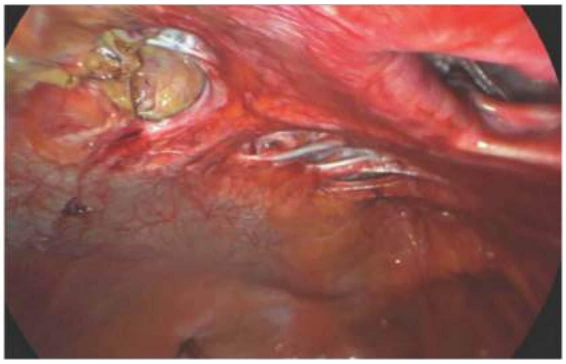


FIG 8 ● Swiss cheese defect. Multiple defects can be seen following complete exposure of incision length.

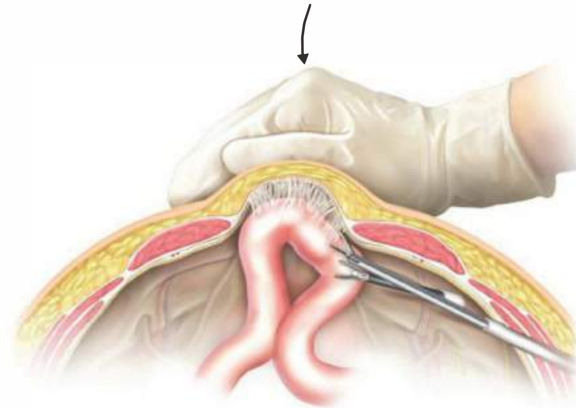
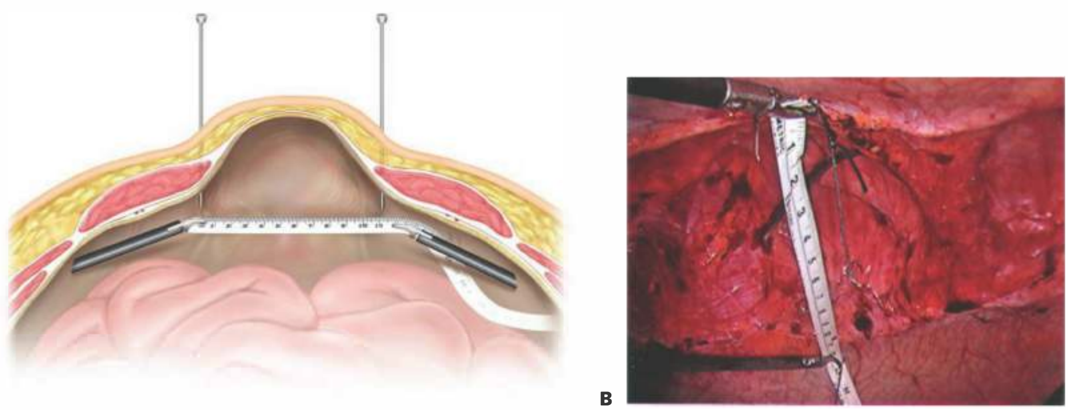


FIG 9 ● External manual reduction. External pressure applied to abdominal wall can aid in intraoperative reduction of hernia contents.

("Swiss cheese" or buttonhole abdominal wall defects), which otherwise may have gone unnoticed and therefore unrepaired (**FIG 8**).

- Hernia contents can be reduced by applying gentle traction using nontraumatic graspers.
- Simultaneous external manual compression of the hernia sac is helpful in reducing contents (**FIG 9**).
- The hernia sac is left in situ.
- The hernia defect edges are measured externally and marked on patient's skin.
- Length and width of the abdominal wall defect is precisely measured intraabdominally using a narrow plastic disposable ruler introduced through a port.
- A spinal needle is used to penetrate the abdominal wall along the internally visualized defect edges to accurately define boundaries (**FIG 10**).
- The falciform ligament and umbilical ligaments may be taken down to allow flush placement of mesh against anterior abdominal wall.



A B

FIG 10 ● Measurement of defect. Figure **A** shows diagrammatic representation of defect measurement using a narrow disposable ruler and spinal needles to define exact borders. Figure **B** shows intraoperative defect measurement.

MESH PREPARATION AND INTRAPERITONEAL INTRODUCTION

- An appropriately sized sheet of mesh is chosen and tailored to overlap defect edges by minimum of 4 to 6 cm circumferentially. Proper mesh to fascia overlap allows for even distribution of intraabdominal forces across peritoneal surface of the mesh and aids in holding the mesh in place according to Laplace's law (**FIG 11**).[10]
- Use of a mesh product constructed with a visceral adhesion barrier to prevent the formation of future adhesions is highly recommended.

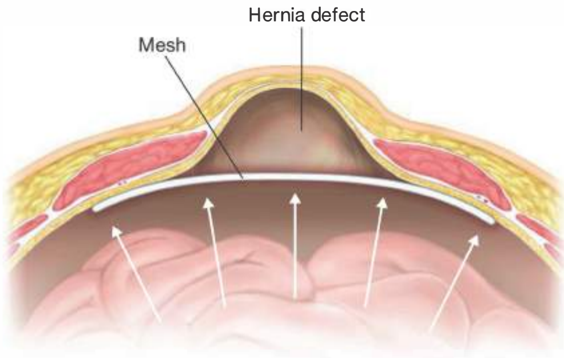


FIG 11 ● Intraabdominal forces on mesh. The intraperitoneal mesh is held in place by the intraabdominal forces acting to push the mesh against the abdominal wall as long as sufficient mesh/defect overlap of 4 to 6 cm is obtained.

- For large single defects, greater mesh to fascia overlap is recommended to resist intraabdominal forces acting to push the mesh through the defect.
- It may be necessary to sew multiple sheets of mesh together in order to fashion a single sheet large enough to provide adequate defect coverage (**FIG 12A**).
- Size 0 or 1 permanent, monofilament sutures are placed at the midpoints of each side of the tailored mesh (**FIG 12B**).
- Corresponding points of reference are marked on the external abdominal wall to allow proper orientation once the mesh is placed intraabdominally (**FIG 13**).

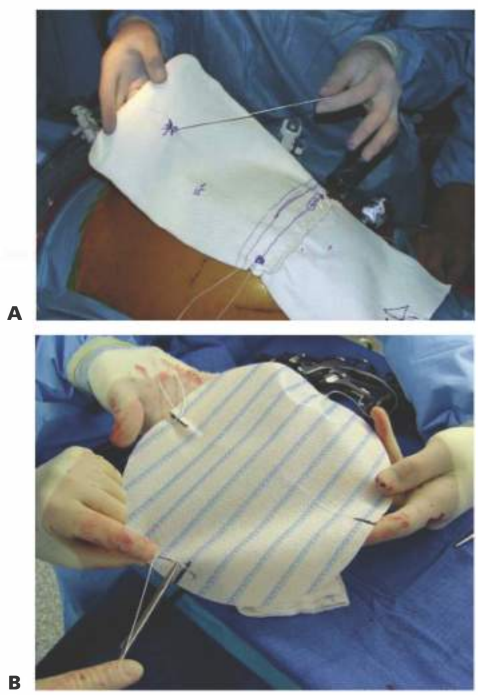


FIG 12 ● Tailoring of mesh. Mesh is fashioned to provide 4 to 5 cm of mesh/defect overlap and permanent sutures are placed at the midpoints of mesh edges. Multiple pieces of mesh may be stitched together to obtain a final mesh of sufficient size as seen in Figure **A**. Figure **B** shows the placement of midpoint sutures along the edges of the mesh.

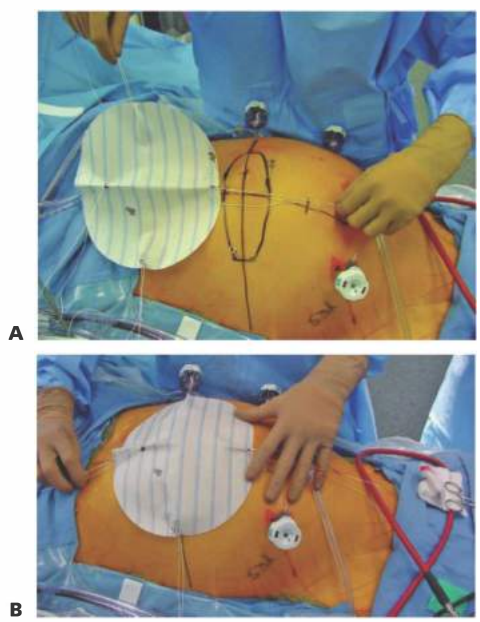


FIG 13 ● Orientation of mesh. Figure **A** shows how the external abdominal wall is marked to ensure proper orientation of mesh placed inside the abdominal cavity. Figure **B** shows the mesh overlying the marked external abdominal surface.

FIG 14 ● Rolling of mesh. Mesh is rolled in a scroll-like fashion from opposite sides inward to allow passage through trocar site.

- Mesh is then rolled from opposing edges in scroll-like fashion (which facilitates intraabdominal unfolding) and compressed to allow passage through trocar site (FIG 14).
- Using a grasper from the contralateral port site, the rolled, compressed mesh can then be pulled intraabdominally (FIG 15).
- Using two graspers, the mesh is unfurled within the peritoneal cavity. This is simplified by holding the center of the mesh with one grasper while pushing the rolled edge with second grasper.

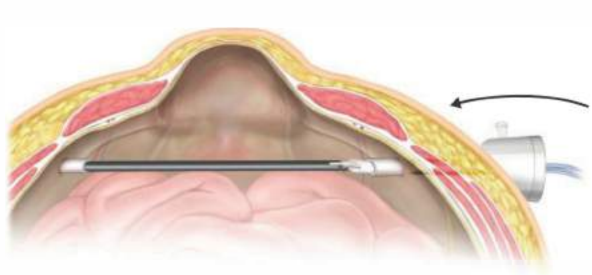


FIG 15 ● Introduction of mesh. Rolled mesh can be pulled intraabdominally from the contralateral 5-mm port site.

FIXATION OF MESH

- The mesh is properly oriented based on previously marked points of reference.
- Previously placed sutures (at midpoints along edges of mesh) are brought through the abdominal wall using a suture passer device under direct laparoscopic vision. Through the same skin incision, the suture passer enters the fascia in two locations a centimeter apart to create a fascial bridge between the tails of suture resulting in a full-thickness abdominal wall "bite" (FIG 16).
- It is recommended that the first suture to be passed transfascially be the one closest to a structure of potential concern (xiphoid, pubis, iliac crest, costal margin, stoma, etc.) to allow for optimal view of the structure(s) in question.
- Each suture is passed with identical technique.
- The transfascial sutures are pulled taut to confirm accurate mesh positioning, defect coverage, and to ensure that the mesh is taut against the abdominal wall at the time of fixation. Repositioning of previously marked reference points may be required to ensure proper mesh placement. It is very important that the mesh be tightly stretched across the abdominal wall; if the mesh is loosely applied, it will balloon out into the defect and result in the appearance of a recurrence.
- The initial two transfascial sutures are tied.
- The position of the mesh is rechecked prior to tying the remaining sutures.
- Using a 5-mm laparoscopic tacking device, the mesh perimeter is stretched out and secured into place by placing

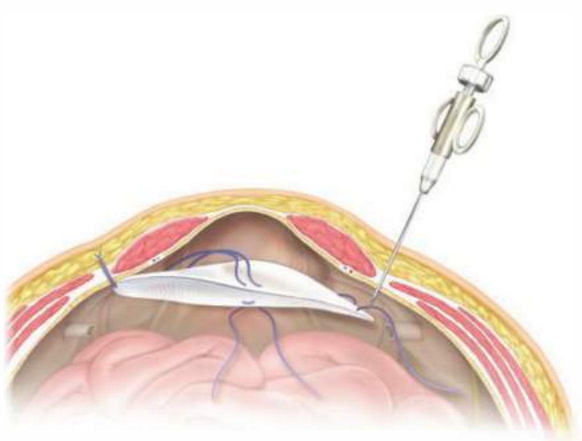
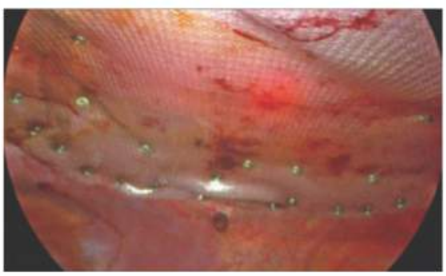


FIG 16 ● Suture passer technique. Previously placed permanent sutures along the mesh edges are brought through the abdominal wall using a suture passer device.

tacks no further than 1 cm apart to prevent bowel herniation between the mesh and abdominal wall. The tacks are also close enough to the mesh edge to prevent folding of the mesh. Placement of tacks is facilitated by external manual palpation of the tip of the tacking device (**FIG 17A**).

- A second row of tacks placed just inside the first row ("double crown" technique) is used by some surgeons to ensure there is no sagging of the mesh and to eliminate "dead space" between the mesh and abdominal wall (**FIG 17B**).

A



B

FIG 17 ● Tacking technique. Accurate placement of tacks is facilitated by external palpation of the tacker tip as seen in Figure **A**. Figure **B** shows completed defect coverage with two rows of tacks in place to eliminate sagging of the mesh.

- Additional full-thickness 0-0 transfascial sutures are placed every 4 to 8 cm circumferentially using the suture passer device (**FIG 18**). Larger defects require additional suture fixation to limit the mesh from eventrating into the fascial defect.
- After individual sutures are tied, the subcutaneous tissues and skin overlying the transfascial suture knots should be released using upward traction with a hemostatic clamp to avoid dimpling of the skin.
- Laparoscopic inspection of the abdominal cavity is performed to ensure adequate defect coverage (proper mesh position, attachment, and mesh/fascia overlap), hemostasis at areas of adhesiolysis, and that no bowel injury occurred.

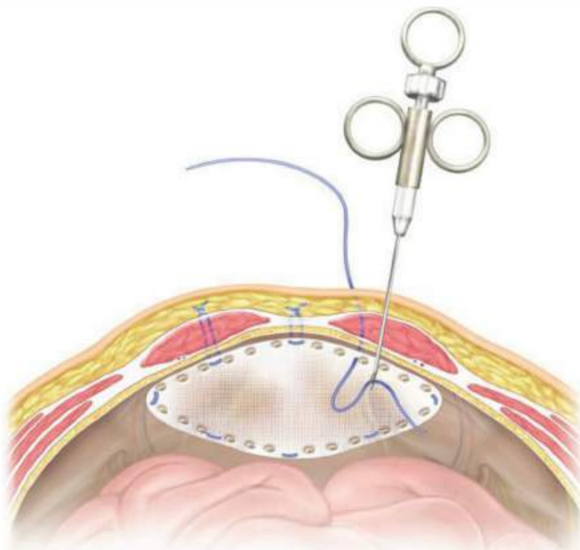


FIG 18 ● Full-thickness suture technique. Additional full-thickness transabdominal sutures are placed every 4 to 6 cm along the edge of the mesh using the suture passer device.

CLOSURE

- Fascia for all size 10-mm or larger port sites is closed with an adequate absorbable suture either externally or by using the suture passer device and laparoscopic visualization.
- Skin incisions overlying all port sites are often closed with size 4-0 absorbable suture and covered with sterile dressings or skin adhesive.

PEARLS AND PITFALLS

Preoperative imaging	■ Preoperatively, review CT images as available. ■ Images should be available for reference during procedure.
Port placement	■ Improper triangulation of working ports to target defect leads to inefficient working space and increases level of procedural difficulty. ■ Placing ports too close to the hernia leads to added difficulty in mesh placement and may result in mesh covering working ports.

Bowel injury during procedure	■ Gross contamination or large enterotomies likely requires conversion to open procedure and possibly the need for a staged repair or the use of biologic or biosynthetic mesh. ■ If little or no contamination is present and the enterotomy is small, primary laparoscopic repair may be acceptable with either immediate (no contamination) or delayed (significant contamination) herniorrhaphy.
Mesh placement	■ Inadequate fixation of mesh edges risks folding of mesh and subsequent recurrence. ■ Insufficient mesh/defect overlap (4 to 5 cm) or lack of appropriate fixation may lead to repair failure. ■ Not fixating the mesh so that it is taut across the abdominal wall risks eventration of mesh into the hernia sac after desufflation.
Unrecognized bowel injury	■ Examination of patients to diagnose an unrecognized bowel injury early in the post-operative course
Failure to close larger port sites (10 mm or greater)	■ Risks future port site hernia and possible bowel incarceration

POSTOPERATIVE CARE

- Patients are monitored postoperatively as for standard laparoscopic procedures and either discharged same day or admitted, depending on presence of significant comorbidities, recovery from anesthesia, and adequate pain control.
- Pain control measures should be initiated in the immediate postoperative period and continued 1 to 4 weeks following surgery as dictated by clinical assessment during follow-up.

OUTCOMES

- In a large series of 850 laparoscopic ventral hernia repairs performed spanning 9 years and an average of 20.2 months of follow-up, an overall complication rate (13.2%) was observed; the most common of which being prolonged ileus (3%) and seroma (2.6%). A recurrence rate of 4.7% was seen and was associated with large defect size, obesity, previous open repairs, and postoperative complications.[2]
- In the largest quality-of-life outcomes study to date comparing laparoscopic and open ventral hernia repairs from a multinational, prospective, self-reported database at 1-, 6-, and 12-month follow-up, laparoscopic repair was associated with decreased quality of life (pain and movement limitation) in the short term (1-month follow-up) but was equivalent to open repair at 6 and 12 months. An overall recurrence rate of 5.7% was observed at 1 year; 5.2% recurrence for laparoscopic versus 6.0% for open. There was also no difference in overall complications (deep venous thrombosis [DVT], ileus, urinary problems, pneumonia, fistula formation, and reoperation). However, laparoscopic ventral hernia repair was associated with decreased hospital length of stay of almost 2 days and fewer surgical site infections compared to open repairs (0.3% for laparoscopic versus 3.0% for open).[11]
- Laparoscopic incisional hernia repair has proven to be a safe and effective option for hernia repair and may actually be favored in certain patient populations, such as the morbidly obese, due to decreased rates of wound complications as compared to open ventral hernia repair.[12]

COMPLICATIONS

- Prolonged postoperative ileus
- Seroma
- Hematoma
- Prolonged transfascial suture site pain
- Mesh infection
- Bowel or bladder injury
- Recurrence
- DVT
- Cardiac or pulmonary problems
- Anesthesia complications

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Chapter 5 Incisional Hernia Repair: Abdominal Wall Reconstruction Options

Michael J. Rosen

DEFINITION

- The field of abdominal wall reconstruction has seen significant advances in the past decade. A resurgence in the concept of recreating a functional dynamic abdominal wall through reconstructing the linea alba and restoring normal anatomy of the abdominal wall unit has fostered several innovative techniques to achieve these goals. The foundation for much of our understanding of abdominal wall reconstruction can be linked to pioneering surgeons such as Oscar Ramirez, Renee Stoppa, and Jean Rives. These reconstructive surgeons brought forth the concepts of performing fascial releases of the anterior abdominal wall compartments to provide advancement of the midline fascia. Although each of these surgeons and several of the newer techniques that will be described in this chapter differ in the exact mechanism in which fascial advancement is obtained, the underlying concept of achieving fascial advancement to reconstruct the midline is a constant.
- When considering which approach is indicated for reconstructing the abdominal defect that the surgeon is faced with, it is helpful to provide general categories of the various abdominal wall reconstructive techniques. In the authors' opinion, the most clinically relevant classification scheme is based on preservation of the anterior abdominal wall neurovascular blood supply and the need to raise large lipocutaneous flaps to gain access to the lateral abdominal wall. In general, minimally invasive approaches preserve the abdominal wall blood supply and avoid large skin flaps. Examples of such techniques include endoscopic component separation, posterior component separation, and periumbilical perforator sparing approaches, whereas, the standard open approach does not typically preserve the anterior abdominal wall blood supply.
- This chapter will focus on some of the more advanced reconstructive techniques to repair large abdominal wall defects. Prior to discussing each of these approaches, it is imperative to understand that not all ventral hernia repairs will require these approaches. In fact, most abdominal wall defects less than 10 to 15 cm in maximal width can be repaired using a standard Rives-Stoppa-Wantz approach. This technique will be described in detail in another chapter in this textbook. In the authors' opinion, this approach should always be initially considered prior to moving on to more advanced techniques.

DIFFERENTIAL DIAGNOSIS

- When planning an abdominal wall reconstruction, the most important first step is to clarify patient's expectations for a successful outcome as well as the surgeon's. Not all defects, particularly in the setting of contamination or infection, can or should be repaired in a single setting. Often, the initial attempt at clearing the infectious source or reconstructing the gastrointestinal (GI) tract takes precedence and formal reconstruction should be delayed. In these cases, the patient should understand that they will likely have a ventral hernia at the end of the procedure that eventually will need to be repaired.

PATIENT HISTORY AND PHYSICAL FINDINGS

- Basic cardiac and pulmonary risk stratification are essential.
- Skin preparation is critical, and an experienced wound care nurse is invaluable. Treating any subcutaneous cellulitis or breakdown can significantly improve soft tissue coverage at the time of formal reconstruction.
- Optimization of nutritional status is also important. This can include supplemental, enteral, or parenteral feeding when necessary. It is also important to point out that patients with an ongoing infectious nidus, particularly infected synthetic mesh, can be very difficult to obtain a positive nitrogen balance.
- Many patients with large ventral hernias also suffer from morbid obesity. The ideal approach to managing obesity in the setting of a complex ventral hernia is challenging. No doubt, substantial weight loss prior to surgical intervention is optimal. However, the best approach is unclear, but options include medically supervised weight loss or bariatric surgery. This can be particularly challenging in symptomatic incarcerated hernias in which there is little time to achieve or obtain clearance for weight loss surgery.
- Preoperative smoking cessation is mandatory in our practice prior to complex abdominal wall reconstruction. Smoking has been clearly linked to impaired wound healing and in the author's opinion is an absolute contraindication to complex abdominal wall reconstruction.
- Obtaining and reviewing all old operative records is extremely important. Understanding what type of mesh and in what layer in the abdominal wall it was placed can help guide your approach. In addition, it is important to clarify if one of the lateral abdominal wall muscles were already released because it can lead to lateral abdominal wall laxity if it is rereleased. Likewise, the surgeon might choose another muscle to release to access an undissected plane.

IMAGING AND OTHER DIAGNOSTIC STUDIES

- Routine radiologic imaging with an abdominal–pelvic computed axial tomography (CAT) scan is particularly useful in complex ventral hernia repairs. These scans can provide valuable information as to the size of the defect and presence of loss of domain, the absence or destruction of important components of the abdominal wall, and the presence of remnant prosthetic materials.

- More advanced radiologic imaging such as magnetic resonance imaging (MRI) or angiogram to look for periumbilical perforator vessels is not routinely performed in our practice.
- Preoperative antibiotic and deep venous thrombosis prophylaxis is routinely given. Typically, a first-generation cephalosporin will suffice, but in cases of prior or active methicillin-resistant *Staphylococcus aureus* (MRSA) infection, Vancomycin is added.
- Nasogastric tube decompression and Foley catheters are routinely inserted.
- Perioperative anesthesia management is critical to success in large abdominal wall reconstructions. It is important that the patient remains completely relaxed during the procedure as this greatly improves exposure of the abdominal wall. In addition, in larger abdominal wall reconstruction, there is often some level of compartment syndrome at the conclusion of the procedure. It is important to keep these patients intubated for a 24- to 48-hour period until their airway pressures normalize.

SURGICAL MANAGEMENT

- As with any hernia repair, it is critically important that the surgeon has a firm understanding of the anatomy of the abdominal wall prior to manipulation. The abdominal wall is basically composed of the two rectus muscles running longitudinally and the three lateral muscles on each side of the abdominal wall. Each performs a valuable function for the abdominal wall, and any disruption can cause impairment in core physiology. Understanding the neurovascular anatomy of the anterior abdominal wall is particularly important for optimizing the results of each of these approaches. The rectus muscle receives its innervation from the T7–T11 intercostal nerve routes. These nerves run above the transversus abdominis and below the internal oblique muscles in the lateral abdominal wall. They penetrate the linea semilunaris and segmentally innervate the rectus muscle. It is very important to preserve these nerves in any reconstruction; otherwise, the rectus muscle will atrophy and prevent any hope for a functional abdominal wall (**FIG 1**). One important consideration for a posterior component separation is that the transversus abdominis muscle actually forms the posterior sheath of the rectus muscle in the upper two-thirds of the abdomen.
- The blood supply of the anterior abdominal wall is slightly more complex (**FIG 2**). The rectus muscle receives its blood supply both laterally from the intercostal vessels and from a superior and inferior branch of the inferior epigastric vessel. The blood

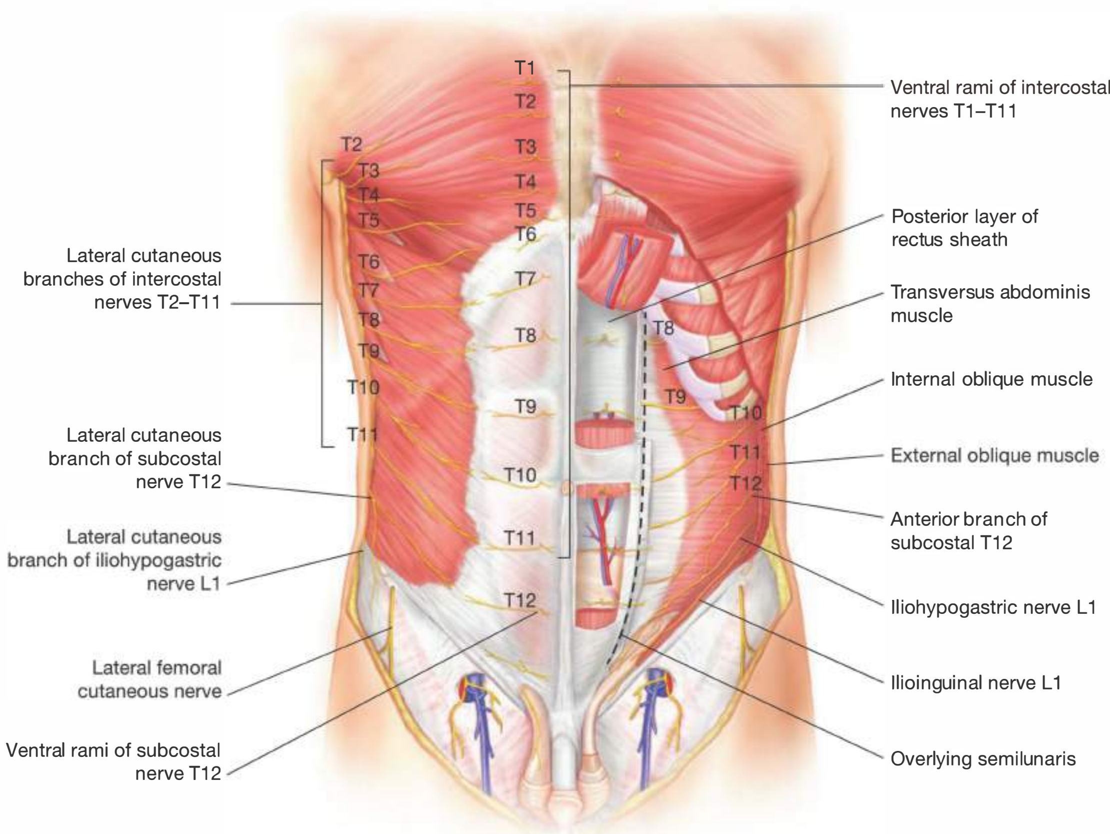

FIG 1 ● Innervation of the anterior abdominal wall. Note the intercostal nerves run in the lateral abdominal wall in between the internal oblique and transversus abdominis muscle.

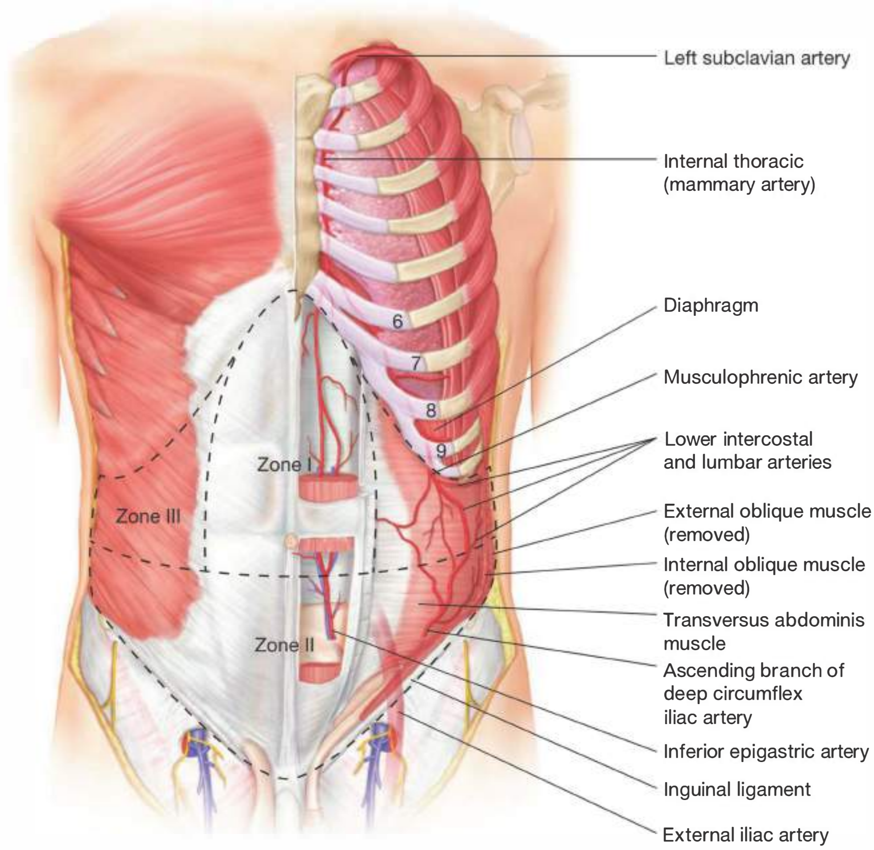

FIG 2 ● Blood supply to the anterior abdominal wall. Note location of the medial row of perforators off the inferior epigastric providing blood supply to the medial aspect of the skin.

supply to the skin and subcutaneous tissues of the midline is also important to understand to limit ischemic problems during reconstruction. The skin does receive some limited supply from the lateral intercostal vessels, but the majority comes from deep inferior epigastric perforator vessels. These vessels typically lie within 5 cm cephalad and caudad to the umbilicus. This relationship is particularly useful when performing a periumbilical perforator sparing component separation.

Positioning

- Regardless of the abdominal wall reconstructive technique chosen, some basic technical aspects remain constant. A wide surgical preparation including the entire abdomen, lower chest, and upper legs is performed with a chlorhexidine solution. All stoma sites are oversewn to minimize spillage. An iodine-impregnated dressing is routinely applied to cover the entire abdominal wall.

TECHNIQUES

INCISION

- The surgical incision is typically performed in a midline fashion and all other old scars or skin ulcerations are completely excised.

ADHESIOLYSIS

- The abdominal cavity is entered and a complete adhesiolysis is performed to free up the entire abdominal wall all the way to the gutters. This step is critical, as the abdominal wall will be limited in its mobility if it remains fixated to the viscera.

CONCOMITANT PROCEDURES AND REMOVAL OF ALL FOREIGN MATERIAL

- Any concomitant GI surgery is completed and all prior synthetic material is removed from the abdominal wall. In our opinion, removing prior synthetic material allows the new prosthetic to actually grow into the abdominal wall and reduces seromas and mesh infections. After the intraperitoneal portion of the procedure is completed, a countable towel is placed over the abdominal viscera to prevent inadvertent injury during dissection of the abdominal wall.

POSTERIOR COMPONENT SEPARATION TECHNIQUE

- A posterior component separation is basically an extension of the standard Rives-Stoppa-Wantz repair.
- The initial procedure begins in a similar fashion. The linea alba is identified and grasped with Kocher clamps. To avoid confusion and misidentification of appropriate planes, the clamps must be placed on the medial edge of the rectus muscle and not on the hernia sac. If the clamps are on the hernia sac, the dissection will proceed in a subcutaneous plane. Next, an incision of the posterior sheath is made approximately 1 cm off the linea alba. It is important to identify the rectus muscle, which will avoid creating a subcutaneous or preperitoneal plane of dissection (**FIG 3**).
- The posterior rectus sheath is then separated off the rectus muscle using electrocautery, carefully preserving the inferior epigastric vessel. This dissection plane is facilitated by placing upward traction on the rectus muscle and medial traction on the posterior sheath with Kocher clamps. Typically, small posterior branches off the epigastric vessels can be coagulated.
- The lateral extent of this dissection continues until the perforating intercostal nerves and vessels are identified. These nerves as mentioned are critical to preserve to maintain a functional innervated rectus muscle. They also are the landmark of the linea semilunaris, that is, the lateral extent of the rectus muscle. In a standard Rives-Stoppa-Wantz repair, the dissection is completed at this point (**FIG 4**).
- If more advancement is needed to provide mobilization for the posterior sheath or anterior sheath, or provide a larger compartment for an adequate-sized piece of mesh, then a posterior component separation is performed.
- This dissection is usually started in the upper third of the abdomen. In this location, the transversus abdominis muscle actually forms the posterior sheath and does extend medial to the linea semilunaris. The incision is begun approximately 0.5 cm medial to the intercostal nerves. The initial incision should involve the fascial covering of the muscle, and it is extended throughout the length of the posterior rectus sheath. When performing this release, it is always important to confirm that it is not disrupting the intercostal nerves.
- Next, the transversus abdominis muscle is released medial to the linea semilunaris. This is facilitated by the use of a right-angle clamp in the upper third of the abdomen under the muscle (**FIG 5**). Below this muscle is the peritoneum and can be quite thin on the medial side.
- As the dissection continues caudally, the muscle belly of the transversus abdominis is replaced with a fascial layer. This layer is also incised, leaving the transversalis fascia and peritoneum in the lower third of the abdomen (**FIG 6**).
- Once the entire transversus abdominis is released, the dissection is continued laterally. Again, this dissection plane is below the transversus abdominis muscle and above the peritoneum/retroperitoneum. The lateral extent of this

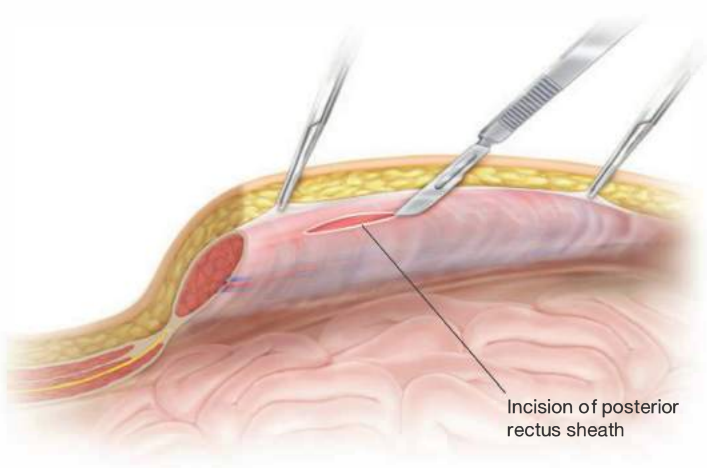

FIG 3 ● The posterior rectus sheath is incised 1 cm lateral to the linea alba to gain access to the retrorectus space.

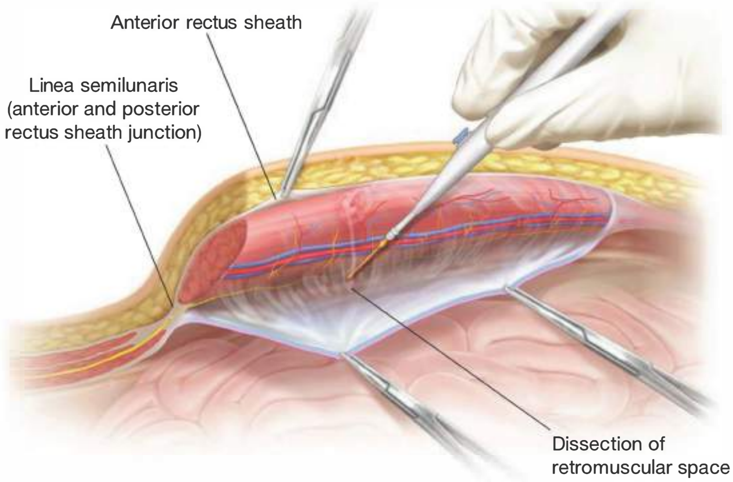

FIG 4 ● The posterior rectus sheath is separated off the rectus muscle until the lateral edge of the rectus is identified by the presence of the perforating intercostal nerves.

dissection is the lateral edge of the psoas muscle. This plane can be extended cephalad to the costal margin, sweeping the peritoneum off the diaphragm.

- The posterior sheath is incised at its insertion into the linea alba to connect each side of the abdomen. This is continued at least 5 cm above the incision and typically can be performed to the xiphoid process. In upper abdominal hernias, the insertion of the posterior sheath is released from the xiphoid, and the dissection is continued to the fatty triangle underneath the sternum and toward the central tendon of the diaphragm.
- Inferiorly, the bladder is separated off the anterior abdominal wall. In suprapubic hernias, the pelvis is exposed, including the pubis, Cooper's ligaments, and the space of Retzius.
- The posterior sheath, peritoneum, and transversalis fascia are reapproximated in the midline, completely excluding the mesh from the bowel. Any fenestrations are sutured closed. In cases of large defects of the posterior sheath, Vicryl mesh can be used.
- It is very important that the posterior sheath is closed safely because bowel can herniate through the posterior closure and become incarcerated below the mesh.
- A large sheet of unprotected medium-weight large-pore polypropylene mesh is typically placed in the retrorectus space.
- Several transfascial sutures are placed at the lateral edge of the mesh. The sutures are placed under tension so as to allow the midline closure to be off weighted. These sutures also set the tension on the mesh that prevents buckling when the midline is closed over the mesh (**FIG 7**).
- Drains are placed over the mesh and below the rectus muscle and removed when less than 30 mL per day of output.
- The midline fascia is reapproximated with running or interrupted slowly absorbable monofilament sutures. The skin is closed in layers.

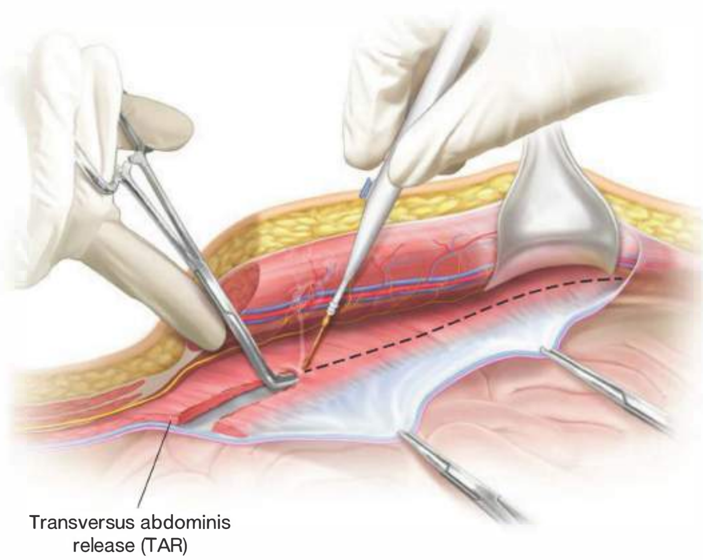

FIG 5 ● The transversus abdominis muscle is incised to expose the peritoneum below. Note the intercostal nerves are preserved as this release occurs medially.

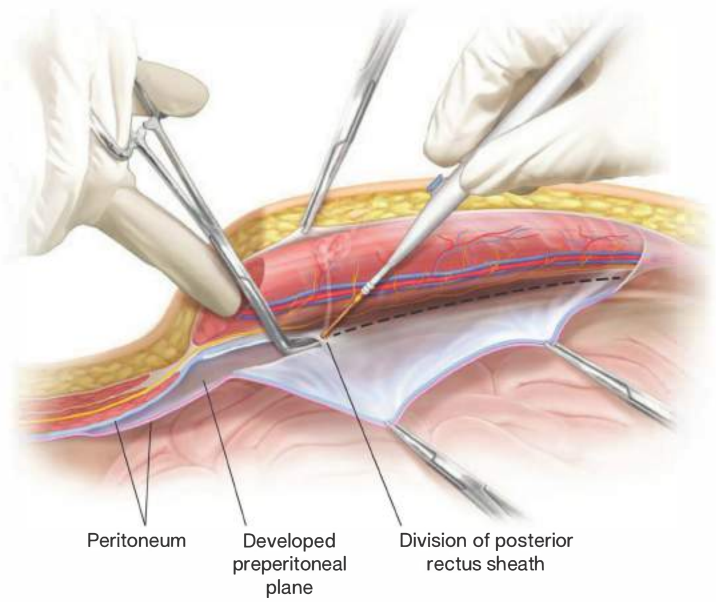

FIG 6 ● In the lower third of the abdomen, the transversus abdominis is mainly fascia and is released to expose the peritoneum.

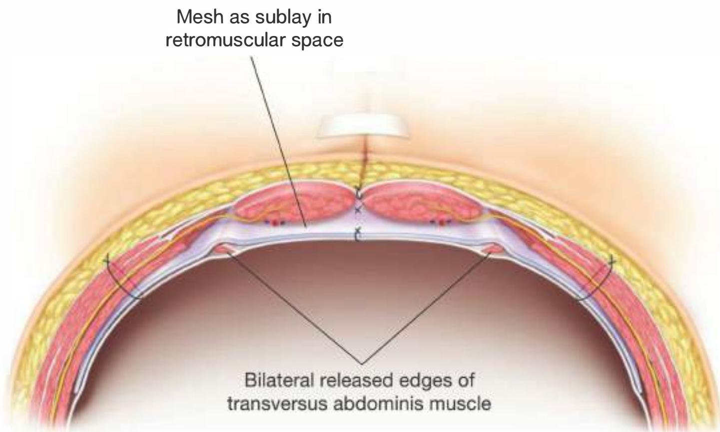

FIG 7 ● Mesh is placed as a sublay with lateral transfascial sutures and the midline closed without buckling of the mesh.

COMPONENT SEPARATION TECHNIQUE

- Anterior component separation is typically performed if the skin will require undermining to gain advancement for closure. In addition, if the retrorectus space or the preperitoneal or retroperitoneal space cannot be accessed, an anterior component separation can be performed with intraperitoneal mesh placement.
- Placing Kocher clamps on the linea alba provides medial retraction, whereas rake retractors are placed on the dermis and retracted superiorly. Using electrocautery, the subcutaneous tissues are undermined to the lateral abdominal wall.
- These lipocutaneous flaps are created to the inguinal ligament and several centimeters above the costal margin. In a standard open component separation, all of the medial row perforator vessels are sacrificed. Therefore, the skin flap is supplied by the intercostal vessels approaching laterally.
- The release is performed by incising the external oblique muscle. It is imperative that this incision does not violate the linea semilunaris. This can occur if the release is begun too medially and will result in a full-thickness defect in the lateral abdominal wall, which is very challenging to repair. There are no clear anterior anatomic landmarks to define the linea semilunaris or the external oblique. It is helpful to grip the rectus muscle in between the thumb and fingers and feel the indentation at the lateral extent of the rectus muscle (**FIG 8**). The incision in the external oblique should be placed approximately 2 cm lateral to the identified linea semilunaris.
- A 1-cm incision is made parallel to the linea semilunaris. The orientation of the muscle fibers below should be confirmed. If the fibers are oriented in a vertical direction, it is likely that the anterior rectus sheath has been incised.

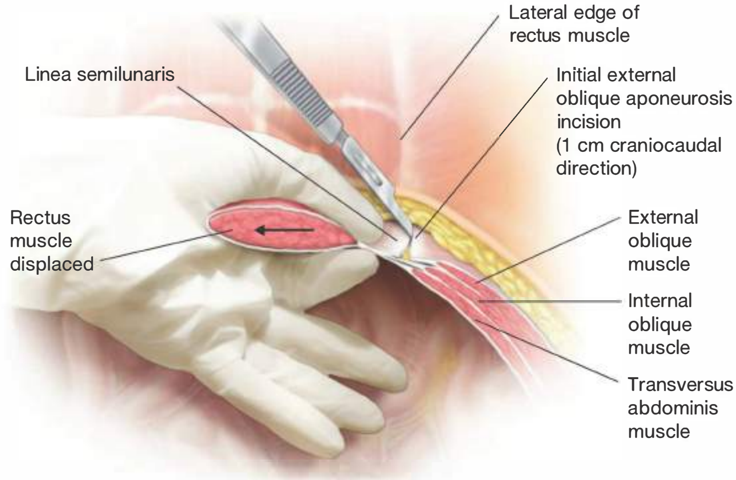

FIG 8 ● Bimanual palpation to confirm the linea semilunaris location.

To confirm, a right-angle clamp can be placed below the external oblique muscle and passed medially. If in the correct plane, the tip of the instrument will not be able to traverse the linea semilunaris. If the incision was erroneously placed on the anterior rectus sheath, the clamp will not meet resistance, and the incision should be closed and the dissection continued laterally.

- The external oblique is then released from the inguinal ligament to 3 to 4 cm above the costal margin. This can typically be performed with electrocautery (**FIG 9**). It is important to avoid injuring the internal oblique fascia or muscle complex below to avoid bulging and herniation.
- A component separation is more than a fasciotomy of the external oblique muscle. After the muscle is released, the external oblique muscle is dissected in the avascular plane in between the external and internal oblique to the posterior axillary line. This dissection allows the rectus complex to slide medially.
- A component separation should typically be performed bilaterally to allow for equal redistribution of forces on the eventual repair. In certain circumstances, such the presence of a stoma or a prior transverse incision, unilateral releases can be performed.
- If further advancement is necessary, the posterior rectus sheath can be separated off the rectus muscle. This incision is made approximately 1 cm lateral to the linea alba on the posterior rectus sheath. The posterior rectus sheath can be separated off the rectus muscle to the linea semilunaris if necessary.
- An appropriately sized mesh is placed as a sublay. Typically, this is placed in the intraperitoneal position. Depending on the indications of the case, a synthetic or biologic mesh might be appropriate.
- One of the major drawbacks of the anterior component separation is skin flap ischemia and wound breakdown. There are several techniques to minimize this risk. First, the skin flap should only be created as far lateral as needed to access the external oblique release and not all the way to the posterior axillary line. Second, redundant skin should be readily excised. This will limit the dead space and remove the most ischemic area. In certain cases, this can require a formal panniculectomy. However, most cases can just be performed using a vertically oriented elliptical incision. Some authors have advocated quilting sutures, securing the flaps to the anterior abdominal wall.

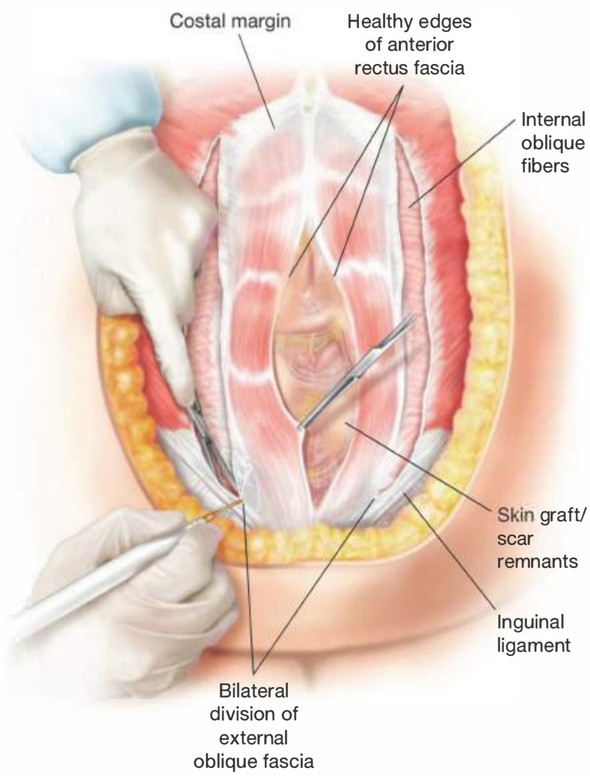

FIG 9 ● Bilateral open component separation procedure completed.

PERIUMBILICAL PERFORATOR SPARING COMPONENT SEPARATION

- The rationale for preserving the periumbilical perforator vessels is to decrease the risk of skin flap necrosis, infection, and dehiscence. This technique takes advantage of the fact that the majority of the perforator vessels supplying the medial aspect of the skin originate within 5 cm of the umbilicus. This approach might be particularly useful in high-risk patients such as those with obesity, diabetes, or concomitant stomas.
- The periumbilical approach is indicated in any patient undergoing a component separation. However, in cases that require extensive subcutaneous skin dissection, it is often not feasible to perform. When removing an infected onlay mesh, or if significant skin advancement is necessary, a standard anterior open component separation as previously described is indicated.
- The periumbilical component separation technique is performed by creating subcutaneous tunnels to access the anterior aspect of the external oblique muscle.
- The dissection is begun in the epigastric area. A lighted retractor can be very helpful to minimize the size of the tunnel while providing exposure (**FIG 10**). The skin and subcutaneous tissues are dissected off the anterior rectus sheath to a point 2 cm lateral to the linea semilunaris. This can be confirmed by manual palpation as described in the anterior open release. Once this lateral point is reached, the dissection continues inferiorly. The dissection should extend to a point several centimeters above the umbilicus.
- The suprapubic dissection is carried out in a similar fashion. Once the lateral extent is reached, the tunnels are connected in the lateral abdominal wall.
- It is important to understand that there is a fairly large amount of subcutaneous tissue that remains attached to the midline (**FIG 11**). If the periumbilical perforator vessels are skeletonized, they often will thrombose.
- Once the tunnels are connected and the external oblique identified, it is incised similar to a standard open component separation. It is also separated off the underlying internal oblique muscle.
- Additional advancement can be obtained from division of the posterior rectus sheath. If feasible, the mesh can be placed in this retrorectus space, with the lateral limit being the linea semilunaris.
- If not feasible, an appropriately sized mesh can be placed intraperitoneally.
- The midline fascia is then reapproximated and the skin closed. Drains should be placed in the lateral tunnels.

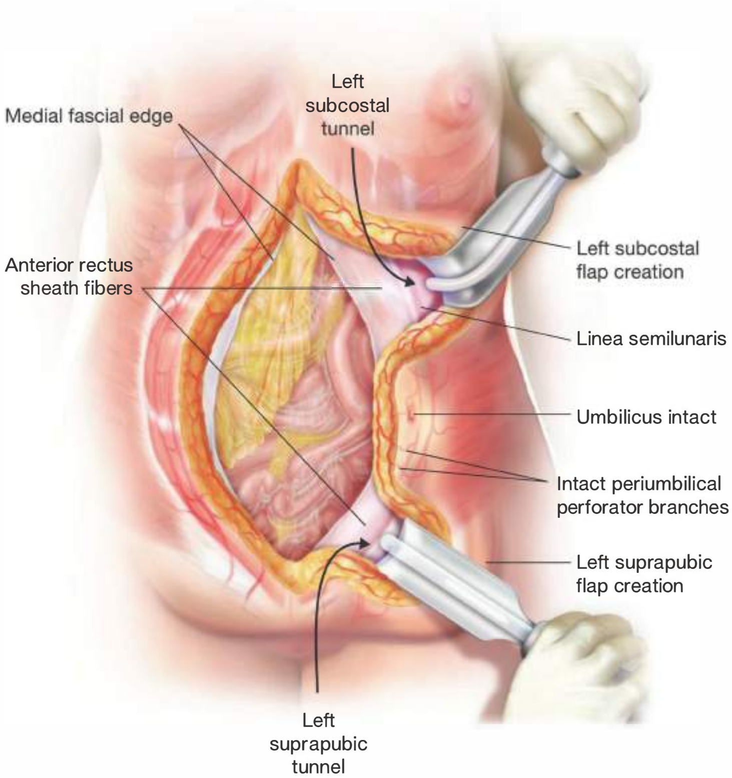

FIG 10 ● Use of lighted retractor to begin tunnel to the lateral abdominal wall while preserving the periumbilical perforator vessels.

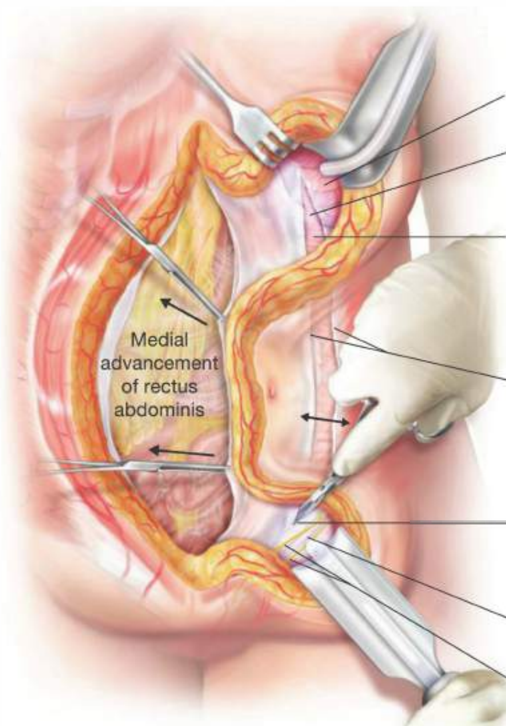

FIG 11 ● Completed periumbilical release with intact medial row of perforator vessels.

PEARLS AND PITFALLS

Operative planning	■ One of the most common pitfalls associated with abdominal wall reconstruction is underestimating the limitations of what each of these procedures can accomplish. In patients with massively large defects more than 30 cm in width and damaged, fibrotic, fixed abdominal walls, there is little hope for a definitive repair. It is critically important that both the patient and the surgeon have reasonable expectations as to what abdominal wall reconstruction procedures can actually achieve. ■ Preoperative optimization of the patient is one of the most important steps in predicting a successful outcome. Weight loss is encouraged; optimization of diabetes control and smoking cessation are mandatory.
Difficult anatomy	■ The xiphoid and suprapubic region can be difficult to achieve maximal advancement and should be avoided early in one's experience. ■ In many cases of complex abdominal wall reconstruction, the umbilicus must be resected. Patients must be aware of this issue preoperatively.
Avoid denervation	■ Understanding the anatomy of the anterior abdominal wall is very important to ensure a successful outcome. Special consideration should always be given to the innervation and blood supply to the abdominal wall musculature and skin during manipulation.
Inability to reapproximate the midline	■ Although it is always optimal to bring the midline together and reconstruct the linea alba, it is not always safe or feasible. If excessive tension results and the patient manifest hemodynamic instability or respiratory embarrassment, the closure should be aborted and a bridged repair is appropriate. ■ These advanced reconstructive procedures are not simply fasciotomies. Much of the advancement achieved is a result of separating the muscle layers from each other to provide advancement.

POSTOPERATIVE CARE

- Abdominal wall reconstruction is a major surgical procedure that results in a significant physiologic impairment to the patient. Because many patients undergoing abdominal wall reconstruction have multiple comorbidities, careful perioperative management is important to maximize outcomes.
- Reestablishing the midline in a large defect can have early consequences to respiratory mechanics. If the plateau pressures rise by greater than 6 mmHg after fascial closure, patients remain intubated overnight. Airway pressures are reassessed in the morning to plan for extubation.
- Epidural catheters are routinely used in patients undergoing major abdominal wall reconstruction. These catheters are typically maintained for up to 5 days, depending on return of bowel function and level of pain.
- Early resumption of oral intake is highly discouraged in this patient population. Because most of these patients have increased intraabdominal pressure after the reconstruction, some form of ileus is common. To avoid retching and potential breakdown of the repair, we avoid initiating a diet until the return of flatus. However, routine nasogastric tube decompression is not necessary.
- Most patients undergoing complex abdominal wall reconstruction are hospitalized for 5 to 7 days. Depending on the complexity of the procedures, some patients remain in the intensive care unit for several days.
- Patients are encouraged to ambulate early.
- Because these procedures create significant dead space, drains are placed. Drains should be removed when the output is less than 30 mL per day. In patients with subcutaneous drains, these may remain for several weeks.
- Perioperative antibiotics are continued for up to 24 hours, unless otherwise indicated.
- Most patients are allowed to return to activity within 6 weeks of surgery and unrestricted activity at 3 to 6 months, depending on the case. Abdominal binders are continued for the first 6 weeks and then as needed for comfort.

OUTCOMES

- There are very little comparative studies evaluating the outcomes of each of these approaches head-to-head. In fact, it is likely that these studies will never be completed, as the heterogeneous nature of the patients who develop incisional hernias precludes any one approach ever being ideal. Most series are from single centers with high-volume abdominal wall reconstructive practices. In the selected references, each article provides reasonable outcomes as to the expectations for each procedure.

COMPLICATIONS

- Wound morbidity is common after complex abdominal wall reconstruction.
- Wound cellulitis should initially be treated with broad-spectrum antibiotics. In most cases, the skin does not need to be opened. If the erythema does not improve within 24 to 48 hours, the incision should be opened, cultured, and drained. In cases with clinical signs of sepsis, the surgeon should have a low threshold to perform an abdominal pelvic computed tomography (CT) scan.
- Skin necrosis should be treated with early debridement and wound care. In certain cases, delayed primary closure can be performed.
- Seromas are very common after abdominal wall reconstruction and most do not require any intervention. If they are symptomatic, they can be drained under sterile conditions.

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Chapter 6

Parastomal Hernia

Melissa M. Alvarez-Downing   Susan M. Cera

DEFINITION

- Parastomal hernia is defined as an incisional hernia which occurs at the site of or immediately adjacent to an existing ostomy.

DIFFERENTIAL DIAGNOSIS

- Abdominal wall mass (tumor, hematoma, abscess)
- Eventration of the abdominal wall

PATIENT HISTORY AND PHYSICAL FINDINGS

- A thorough history should be obtained to determine the time frame of onset, severity of symptoms, and degree of size change. Patients should also be questioned about their satisfaction with stoma site location because relocation is an option for repair of parastomal hernia.
- The most common symptoms associated with an uncomplicated parastomal hernia include bulging near the stoma that worsens with activity and difficulty of adherence of the stoma wafer due to irregularities and bulging of the skin surface. The result is frequent leakages and skin excoriation. In addition, patients complain of the associated expense of increased appliance/wafer usage. Occasionally, wafer leakage may be the presenting complaint and parastomal hernia should be included in the differential diagnosis.
- Other symptoms associated with a complication of the parastomal hernia (obstruction, incarceration, and strangulation) include abdominal pain, decreased ostomy output, cramping, nausea, or vomiting.
- Characteristic findings on physical exam will render the diagnosis of parastomal hernia in most patients. Examination should be performed with the stoma wafer off with the patient in both the supine and standing position. The patient should be asked to perform a Valsalva maneuver. A characteristic bulge adjacent to the stoma site will be present and confirmed with digital palpation (**FIG 1**). A search for concomitant hernias should be undertaken, especially at previous laparotomy scars, because these can occur in up to 41% of patients.[1]
- Abdominal tenderness or skin discoloration associated with a nonreducible hernia is indicative of incarceration and/or strangulation and requires urgent/emergent intervention.

IMAGING AND OTHER DIAGNOSTIC STUDIES

- Computed tomography (CT) scan of the abdomen and pelvis performed with intravenous (IV) and oral contrast can confirm the presence of a hernia and help guide operative intervention (**FIG 2A,B**). Having the patient perform Valsalva during the CT may unmask a hernia and/or reveal the true extent of the hernia. The use of oral contrast will assist in identification of partial or complete obstruction associated with the hernia. The CT scan will also aid in the identification of other associated hernias, that is, at the site of previous laparotomy scars. The size of the neck of the hernia is important and is especially useful in determining the size of the mesh needed in cases where it will be used in the repair. Knowing the contents of the hernia sac (omentum, small bowel, large bowel) preoperatively aids in minimizing bowel injury during surgery because the peritoneum of the hernia sac and bowel serosa can appear similar during dissection. In addition, the planes between the hernia sac and intestine are often distorted by adhesions.
- If the stoma was created for inflammatory bowel disease, thorough evaluation of the entire gastrointestinal (GI) tract to evaluate for active disease that may necessitate surgical intervention at the time of the hernia repair is warranted. In addition to endoscopic exams (see below), radiologic testing may include barium small bowel follow-through and capsule endoscopy.

A

B

FIG 1 • **A,B.** Characteristic parastomal bulge seen on physical exam in a patient with a parastomal hernia.

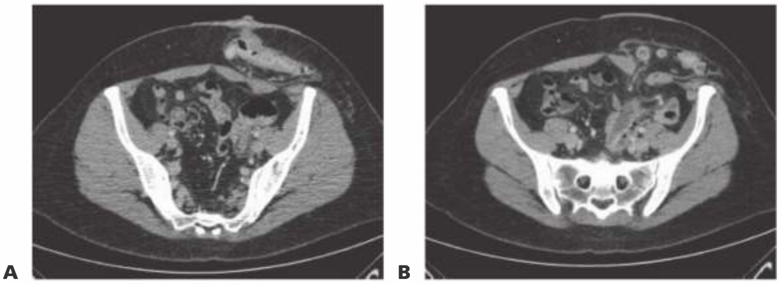


FIG 2 ● **A,B.** CT images demonstrating a parastomal hernia with bowel present in the hernia sac at and below the level of the colostomy.

SURGICAL MANAGEMENT

Preoperative Planning

- Patients should be counseled that parastomal hernia is the most frequent complication following the construction of a stoma and can occur in up to 50% of patients because the stoma itself creates a weakened area in the abdominal wall.[2]
- Patients should also be counseled on the various techniques/options available for treatment. Nonsurgical options are appropriate for asymptomatic patients and include use of a hernia belt (secured to the stoma wafer) or an abdominal binder. Surgical intervention is reserved for an enlarging hernia or those associated with symptoms or decreased quality of life because of inadequate stoma pouching. If surgical intervention is considered, the choice of procedure should be tailored to the individuals' life expectancy, operative risk/benefit analysis, degree of physiologic function (which often corresponds to the degree of weakness of the abdominal wall and ability to successfully sustain repair), and risk of recurrence.
- Type of surgical technique chosen is based on patient factors, surgeon experience, and safety of laparoscopic approach.
- Risk of initial occurrence and recurrence after repair is associated with obesity and/or weight gain, smoking, emergent intervention, poor nutritional status, immunosuppression, infection, and persistent underlying malignancy or inflammatory bowel disease.
- Informed consent should include a possibility of conversion to open in laparoscopic procedures and possible placement of a mesh, particularly in large hernia repairs.
- If stoma relocation is planned, preoperative stoma marking for a new stoma site is an important step. Consultation with a stoma nurse is advised. Stoma relocation may include placing the stoma in either of the upper quadrants as opposed to the lower quadrants because less tangential pressure is generated in the upper abdominal wall. This type of placement is also beneficial in morbidly obese patients with a large abdominal wall pannus. Additionally, it is important to explain to patients that the new ostomy site is associated with the same risk of hernia formation.[3]
- In morbidly obese patients, preoperative weight loss can assist with durability of parastomal hernia repair.
- Colonoscopy/ileoscopy should be performed to ensure no concomitant lesions are present, which would require simultaneous surgical resection. This can be performed the day prior to planned hernia repair so that the patient can undergo a single bowel preparation.
- After obtaining appropriate preoperative medical clearance, a standard bowel preparation with an isoosmotic lavage (polyethylene glycol solution) and oral antibiotics is used for parastomal hernias associated with colostomy. Bowel preparation is not needed for paraileostomy hernias. These patients are instructed to take a liquid diet the day prior to surgery. As with all abdominal surgery, perioperative IV antibiotics should be administered within 1 hour prior to incision and routine venous thromboprophylaxis should be instituted.

Positioning

- The patient is placed in a modified lithotomy position (**FIG 3**) for all cases whether open or laparoscopic because of the possibility of encountering extensive adhesions, which may require surgeon repositioning between the patient's legs. The arm on the working side (opposite the stoma and hernia) should be abducted. Securing the patient to the operative table with use of a bean bag and safety strap or silk tape across the chest is recommended to allow for rotational

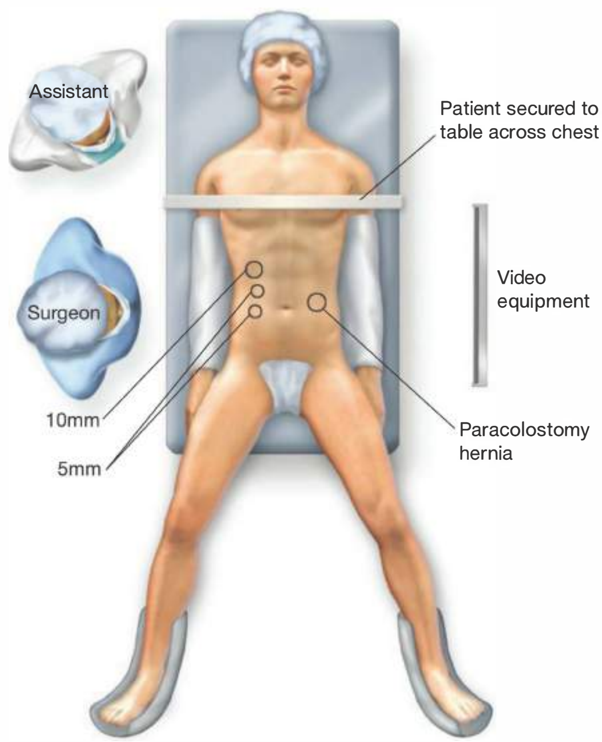


FIG 3 ● Lithotomy position and positioning of surgeon and assistant.

adjustment during the procedure if laparoscopic approach is planned.

- After induction of general anesthesia, a nasogastric and sterile indwelling bladder catheter are placed. A nasogastric tube (NGT) and inpatient hospitalization is advocated for larger hernia repairs to prevent postoperative vomiting that may result in immediate postoperative disruption of the repair.

TECHNIQUES

STOMA RELOCATION

Existing Ostomy

- The new planned stoma site is marked prior to the procedure either during consultation with a stoma nurse or with a pen in the preoperative holding area and an 18-gauge needle after induction of anesthesia.
- A circumferential parastomal incision is made to isolate the stoma from the skin and subcutaneous tissue.
- Dissection is then carried down to the fascia identifying the hernia, reducing its contents, and excising the hernia sac. The bowel is placed into the abdomen using a marking stitch to easily retrieve it when necessary.

Division of Adhesions

- Lysis of adhesions is performed through the stoma site circumferentially and under direct vision. Placement of a wound protector and use of a headlight will facilitate visualization and adhesiolysis.

Relocation of the Ostomy

- Two fingers are now placed into the wound and underneath the abdominal wall to the new stoma site. A disk of skin is removed at the new stoma site. The anterior fascia and rectus muscle is divided vertically, directly over the fingers underneath the abdominal wall. The ostomy site is dilated two fingerbreadths. Using a Babcock clamp, the previously mobilized stoma is passed via the abdominal cavity and brought up through the new fascial opening. Care should be taken to ensure there is no twisting, rotation, or undue tension of the bowel mesentery.
- If extensive adhesions are found or the bowel does not reach the new stoma site, exploratory laparotomy may be necessary.
- A Babcock clamp should be left on the bowel at the new stoma site to prevent it from slipping back into the abdominal cavity until stoma maturation (final step).

Hernia Repair

- The hernia at the old stoma site is repaired by approximating the fascial edges with interrupted nonabsorbable sutures (0 Ethibond). Use of a prosthetic or biologic mesh should be done to ensure adequate closure, especially for fascial defects greater than 4 cm due to the high failure rate with primary repair.[3]

Closure

- If a midline laparotomy was made, it is closed with running 0 polydioxanone (PDS) sutures.
- The skin edges are reapproximated with running 4-0 Monocryl sutures or skin staples.
- The new stoma is matured with interrupted 3-0 chromic sutures and a stoma appliance is placed.

OPEN UNDERLAY TECHNIQUE (MODIFIED SUGARBAKER TECHNIQUE)

Exploratory Laparotomy and Lysis of Adhesions

- The abdomen is prepped, and a sterile 4 × 4 gauze is placed over the existing stoma. Ioban is included in the draping to keep the stoma covered but in the operative field.
- A midline incision is made and lysis of adhesions is performed. Caution should be used when dissecting in the vicinity of the stoma (which is why it is visually kept in the operative field).
- The stoma itself is not typically mobilized for this procedure unless the patient is unsatisfied with the extent of the brooking. In this case, the stoma can be mobilized and rebrooked, and the hernia repair should be performed with a biologic mesh to reduce mesh infection.

Hernia Repair

- Once the proximal bowel of the stoma is freed from surrounding adhesions, the hernia sac is resected and the hernia contents are reduced.
- A dual-sided expanded polytetrafluoroethylene (ePTFE, Gore-Tex DualMesh Biomaterial, WL Grove Associates, Newark, DE, USA) or biologic mesh is selected based on the size of the fascial defect, ensuring there is at least 4 cm additional reach on all sides.
- A precise keyhole incision is made in the mesh, making certain the central opening is small enough to only allow passage of the bowel to the stoma. The mesh is placed around the stoma on the undersurface of the abdominal wall and the ends secured to itself (**FIG 4**). Placement of mesh above the fascia (onlay technique) or into the abdominal wall defect (inlay technique) have been abandoned because of high failure rates.[4]
- The mesh is sutured to the anterior abdominal wall using interrupted 0-Vicryl sutures. Additional sutures made of 2-0 Prolene may be passed through the entire abdominal wall ensuring no migration of the mesh, although this is not necessary because the stoma itself anchors it in place.

Closure

- The midline fascia is closed using running 0-PDS suture.
- The skin edges are reapproximated with running 4-0 Monocryl sutures or skin staples.

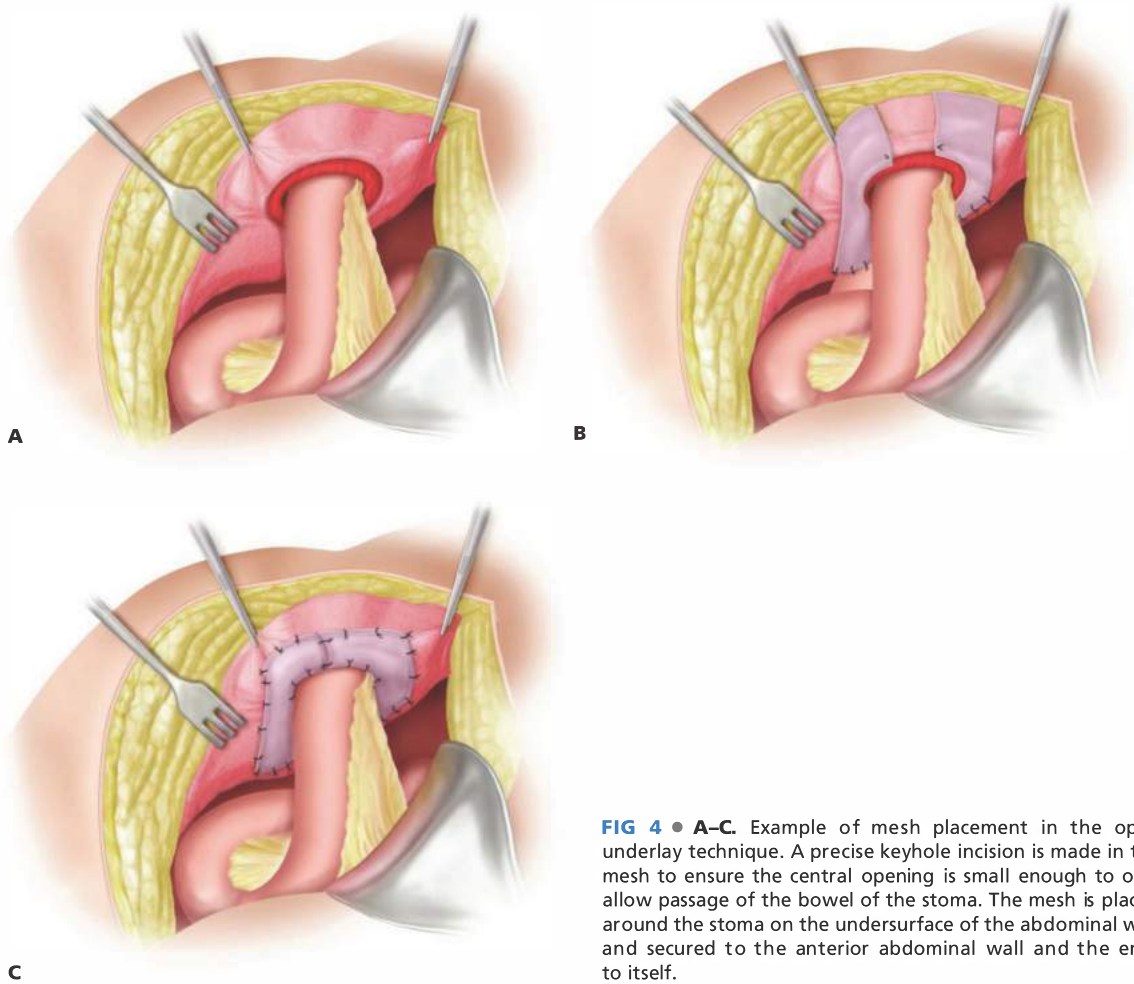


FIG 4 ● **A–C.** Example of mesh placement in the open underlay technique. A precise keyhole incision is made in the mesh to ensure the central opening is small enough to only allow passage of the bowel of the stoma. The mesh is placed around the stoma on the undersurface of the abdominal wall and secured to the anterior abdominal wall and the ends to itself.

LAPAROSCOPIC MESH UNDERLAY TECHNIQUE

Entering the Abdominal Cavity

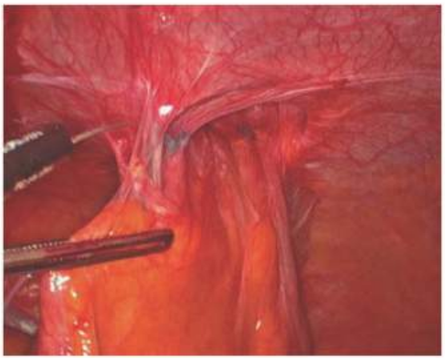
- A 10-mm subcostal incision is made on the side opposite of the stoma. Direct access is gained and a port is placed into the abdominal cavity. Pneumoperitoneum is achieved, and inspection of the abdominal cavity is performed to assess if a laparoscopic approach is both feasible and safe.
- Two additional 5-mm ports are placed under direct visualization laterally according to **FIG 3**.

Lysis of Adhesions

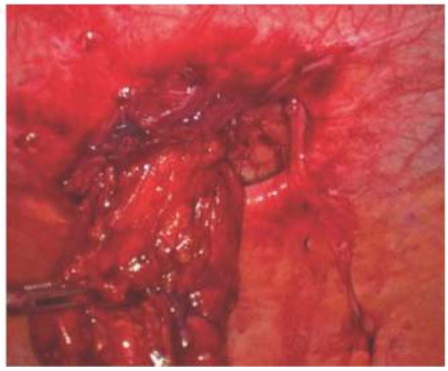
- Laparoscopic lysis of adhesions and reduction of the hernia sac and contents is performed (**FIG 5**). Careful dissection should be performed sharply with gentle countertraction to ensure no injury occurs to the bowel.

Hernia Repair

- The fascial defect is measured using a spinal needle passed intraabdominally and by marking the external abdomen appropriately.
- An ePTFE or synthetic mesh is selected based on the size of the fascial defect, ensuring there is 4-cm additional reach on all sides. Permanent 0-0 sutures are placed on all four sides and the mesh is rolled up and introduced into the abdomen via the 10-mm port. A 5-mm camera should be used in an ipsilateral port to insert the mesh under direct visualization.
- The mesh is unrolled in the abdominal cavity ensuring correct orientation. The previously placed sutures are brought



A



B

FIG 5 ● **A.** Laparoscopic lysis of adhesions to reduce the contents of the parastomal hernia sac and define the size of the fascial defect. **B.** Careful sharp dissection is performed with gentle countertraction to ensure no injury occurs to the bowel wall.

through the abdominal wall using stab incisions and a suture passer.

- A mechanical fixation device, for example, ProTack (Covidien, Mansfield, MA, USA), is used to place tacks around the circumference of the mesh to ensure no bowel can herniate between the mesh and the abdominal wall (**FIG 6**). Additional Prolene sutures are placed 2 cm apart through the abdominal wall around the mesh, except for the side of the mesh through which the bowel to the stoma passes.

Closure

- Once the mesh has been secured in place, the ports are removed under direct visualization and pneumoperitoneum is released. A 0-Vicryl suture is used to close the fascia of the 10-mm port site. 4-0 Monocryl sutures are used to close the skin at all port sites. Adhesive tape or glue can be used on the skin of the small stab incisions created to pass the sutures.

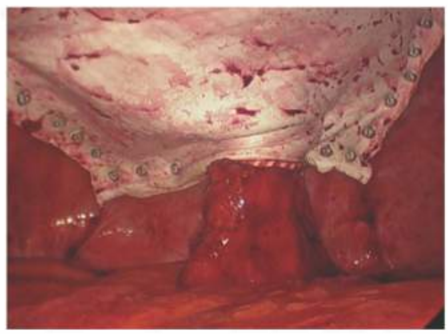


FIG 6 ● Underlay mesh (ePTFE) secured to the anterior abdominal wall with tackers placed using a mechanical fixation device in a laparoscopic approach. The existing ostomy is visible exiting the lateral border of the mesh.

PEARLS AND PITFALLS

Indications	■ Parastomal hernia repair should be undertaken only in patients who are symptomatic and/or with quality of life issues. Relocation is reserved for those who wish more desirable stoma location.
Preoperative planning	■ Preoperative imaging is important to assess the extent of the parastomal hernia as well as address any confounding factors. ■ When considering relocating a stoma, preoperative stoma marking is essential.
Type of hernia repair	■ Open vs. laparoscopic approach without stoma relocation is based on surgeon experience and comfort with laparotomy. Minimally invasive approach offers faster recovery and less pain.
Lysis of adhesions	■ When performing lysis of adhesions, it is important to take extra caution around the stoma.
Hernia repair	■ Primary closure of the hernia site should only be undertaken in hernias <4 cm in size. In patients with larger hernias, use of a mesh for repair will improve success rates. ■ It is important to ensure the keyhole incision made in the mesh is exact to only allow passage of the stoma, therefore preventing future herniation at this site.

POSTOPERATIVE CARE

- Perioperative antibiotics can be administered during the first 24 hours after surgery.
- For small hernia repairs, diet can be resumed and the patient discharged after the recovery room. In most cases, however, the extent of the lysis of adhesions dictates at minimal inpatient observation and possibly an NGT until the ileus resolves.
- Patients should be encouraged to avoid heavy lifting and strenuous activity for 4 weeks following surgery.

OUTCOMES

- Long-term durability of parastomal hernia repair is variable, with recurrence rates reported in up to 50% of patients.[5] Although some studies have suggested that stoma relocation is superior to fascial repair, both approaches carry a high recurrence rate (33% vs. 75%) because neither addresses the underlying pathophysiology driving hernia formation.[3] To address this, use of a mesh to aid in repair has been employed and dramatically reduces hernia recurrence rate to 16%, with no difference between synthetic or biologic mesh.[6,7] Additionally, mesh infection rates are similar, therefore making the less expensive synthetic mesh a more favorable option.[7]
- Mesh repair performed in a laparoscopic approach offers the best results, with a low recurrence rate of 6.6% and an ability to identify additional hernias not evident clinically.[1,6,8]
- Addressing patient risk factors such as obesity, nutritional status, immunosuppression, and comorbid conditions can aid in overall repair success.

COMPLICATIONS

- Postoperative wound infection
- Ileus
- Enterotomy
- Obstruction
- Recurrent hernia

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Chapter 7

Umbilical, Epigastric, Spigelian, and Lumbar Hernias

Filip Muysoms

DEFINITION

- A primary ventral hernia is an abnormal protrusion of the contents of the abdominal cavity or of preperitoneal fat through a defect in the abdominal wall that developed spontaneously without trauma to the abdominal wall or prior surgery as the cause of the hernia.[1]
- An umbilical hernia is a primary ventral hernia with its center at the umbilicus.
- An epigastric hernia is a primary ventral hernia in the midline between the umbilicus and the xiphoid.
- A spigelian hernia is a primary ventral hernia in the area of the fascia spigelian aponeurosis.
- A lumbar hernia is a primary ventral hernia in the lumbar area.
- In contrast to umbilical and epigastric hernias, the hernia sac of a spigelian hernia or lumbar hernia is covered with an intact layer of abdominal wall muscle. For spigelian hernias, this is the external oblique muscle (**FIG 1**), and for lumbar hernias, the latissimus dorsi muscle.
- Primary ventral hernias are classified according to the diameter of the hernia defect as shown in Table 1.[2]

DIFFERENTIAL DIAGNOSIS

- Subcutaneous lesions at the site where primary ventral hernias occur, like lipoma, sebaceous cysts, metastatic lesions, and trocar site metastasis.
- Caveat: Epigastric lipoma: In a patient with a clinical subcutaneous lipoma near the midline above the umbilicus, an epigastric hernia should always be suspected.
- Abdominal wall tumors: desmoid tumors (or fibromatosis), soft tissue sarcoma, metastatic lesions.
- Caveat: A "Sister Joseph's nodule" is an umbilical swelling that might be mistaken for an umbilical hernia but is the manifestation of intraperitoneal carcinomatosis.
- Secondary ventral hernias: incisional hernia, trocar site hernia, and recurrent ventral hernias after previous repair.

PATIENT HISTORY AND PHYSICAL FINDINGS

- Symptoms can range from an asymptomatic presentation to acute incarceration with bowel obstruction and/or strangulation.
- Many small umbilical or epigastric hernias are asymptomatic, and often, the patient is not even aware of having a small abdominal wall defect.
- A swelling at the hernia site is often the first sign of a hernia. This swelling is usually present for a long time period and gradually increases in size (**FIG 2**).
- The presence of a reducible swelling, enlarging when straining (Valsalva maneuver), is pathognomonic for an abdominal wall hernia, but not all hernias are reducible and can hinder the clinical diagnosis in those hernias.
- The swelling of an epigastric hernia is often mistaken for a subcutaneous lipoma (**FIG 3**).
- Pain intensity is not always correlated with the size of the hernia defect. Small hernias can cause a sharp pain, whereas umbilical hernias can be quite large without significant pain. The pain is caused by herniation of abdominal contents or of preperitoneal fat through the defect.
- For some hernias that are not palpable, such as spigelian hernias, abdominal wall pain can be the first presenting symptom and diagnosis might only be possible by imaging.
- Acute pain due to incarceration of intestines or omentum is very intense and sharp. Incarceration can be intermittent and resolve by lying down and manual compression of the hernia sac. Reduction of an incarcerated hernia allows the patient to be operated on electively after appropriate preoperative workup. If manual reduction is not possible, an emergency operation to reduce the hernia is indicated.
- Intestinal obstruction and vomiting due to incarcerated small bowel sometimes is the primary presentation in patients who have a subclinical hernia. In obese patients and for spigelian or lumbar hernias, the incarcerated hernia is sometimes not clinically visible or palpable.

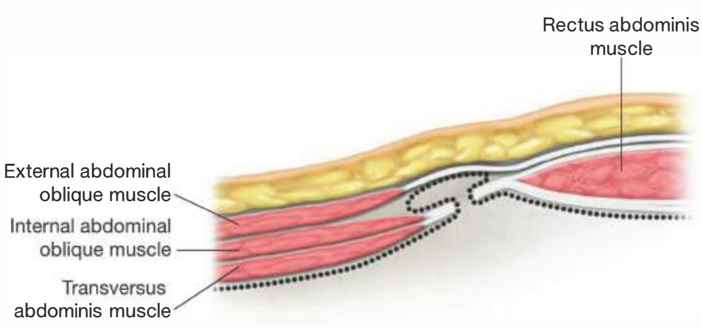


FIG 1 • Spigelian hernias are defects of the insertion of the transversus abdominis muscle and/or internal oblique muscle to the lateral border of the rectus muscle sheath (the spigelian aponeurosis). The external oblique muscle covers the hernia sac superficially.

Table 1: Classification of Primary Ventral Hernias According to the European Hernia Society Classification

EHS Primary Abdominal Wall Hernia Classification		Diameter cm	Small <2cm	Medium ≥2–4cm	Large ≥4cm
Midline	Epigastric				
	Umbilical				
Lateral	Spigelian				
	Lumbar				

Reprinted from Muysoms FE, Miserez M, Berrevoet F, et al. Classification of primary and incisional abdominal wall hernias. Hernia. *2009;13:407–414.*

- Late presentation of an incarcerated hernia includes sepsis from bowel ischemia and intestinal perforation. This can evolve into peritonitis or enterocutaneous fistula.

IMAGING AND OTHER DIAGNOSTIC STUDIES

- For diagnosis of an umbilical or epigastric hernia, clinical examination is sufficient for the majority of patients. Imaging is rarely needed for most patients.
- Imaging with ultrasound or computed tomography (CT) scan can be helpful to measure the hernia defect size in irreducible hernias or obese patients. Sometimes the size of the hernia defect will influence the therapeutic approach, for example, open or laparoscopic technique.
- For spigelian and lumbar hernias, imaging with ultrasound or CT scan is often needed to make the diagnosis: spigelian hernia (**FIG 4**), lumbar hernia (**FIG 5**).
- CT scan imaging of the abdominal wall allows sizing the defect to see the hernia sac contents and to detect signs of intestinal obstruction.

SURGICAL MANAGEMENT

- Small primary umbilical, epigastric, or lumbar hernias do not require an operation, unless they are painful, increase in size, or cosmetic considerations are present. For spigelian hernias, a surgical repair is indicated even for asymptomatic patients because they hold an increased risk of incarceration compared to the other primary ventral hernias.
- There is no consensus whether a suture repair for small primary hernias is sufficient or if every primary ventral hernia should be treated by mesh reinforcement.[3] For inguinal hernias and incisional hernias, the current recommendation is to use mesh in all patients because of the proven decrease in recurrences. Therefore, recurrent umbilical or epigastric hernias should be repaired using a mesh prosthesis, as they are considered to be incisional hernias. Most surgeons agree

FIG 2 ● Typical clinical presentation of an umbilical hernia with an umbilical swelling increasing in standing position and while straining (Valsalva maneuver).

FIG 3 ● This patient not only has an umbilical hernia but also a supraumbilical swelling from a concomitant epigastric hernia.

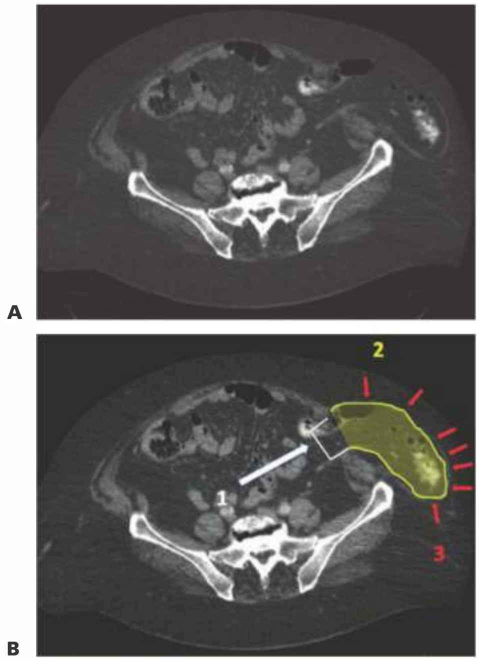


FIG 4 ● **A.** CT of a patient with a left-sided spigelian hernia. The hernia defect is located lateral to the rectus sheath. The hernia sac contains a loop of the sigmoid colon. The external oblique muscle covers the hernia sac. **B.** *1 (white)* The hernia defect in the abdominal wall muscles just lateral to the recuts sheath. *2 (yellow)* The hernia sac with a sigmoid colon loop *3 (red)* the intact external oblique muscle covers the hernia sac.

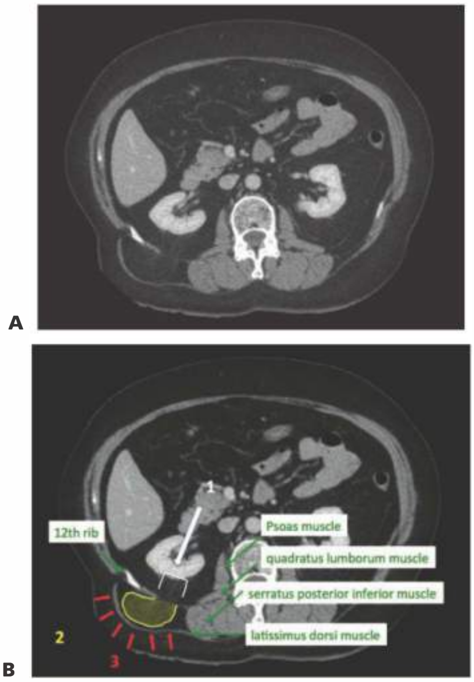


FIG 5 • **A.** CT of a patient with a right-sided lumbar hernia. The hernia defect is located lateral to the quadratus lumborum muscle. The hernia contains some retroperitoneal fat. The latissimus dorsi muscle covers the hernia sac. **B.** *1 (white)* The hernia defect in the abdominal wall muscles just lateral to the quadratus lumborum muscle. *2 (yellow)* The hernia sac with retroperitoneal fatty tissue. *3 (red)* The intact latissimus dorsi muscle covers the hernia sac. *Green arrows*: the names of the different muscle involved.

that only small (<2 cm) primary ventral hernias should be repaired without mesh reinforcement.

- The mesh used to repair abdominal wall hernias can be placed at different positions in relation to the abdominal wall layers. Five positions can be defined: onlay, inlay, retromuscular, preperitoneal, and intraperitoneal (**FIG 6**).[1]
- Laparoscopic repair of ventral hernias is a technique with promising short-term results.[4] The technique is safe but long-term follow-up is needed in order to elucidate whether laparoscopic repair of ventral hernia is efficacious.[4]

Preoperative Planning

- Based on the size and the localization of the hernia, a decision will be made about the preferred approach in the individual patient: mesh or primary repair/open or laparoscopic technique.
- Although some centers perform the repair of small umbilical or epigastric hernias under local anesthesia as a routine, most centers prefer a general anesthesia for the comfort of the patient and the surgeon. Regional anesthesia through a sensory blocking of the anterior abdominal wall, by a transversus abdominis plane block (TAP block), is another less practiced option for postoperative pain control.
- For incarcerated hernias with bowel obstruction, adequate preoperative measures with nasogastric tube suction and rapid "sequence intubation" should be considered to minimize aspiration risk.

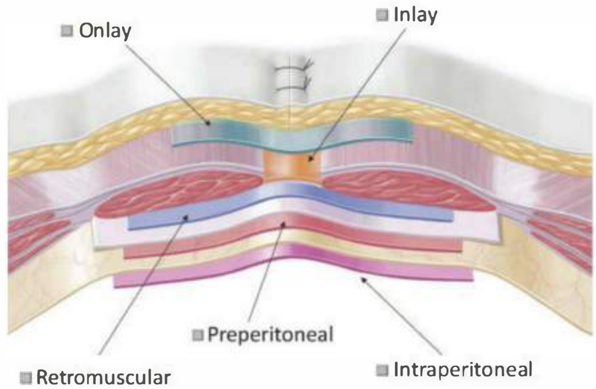


FIG 6 • Different positions of the mesh in relation to the abdominal wall layers to repair a ventral hernia by mesh reinforcement. (From: Winkler MS, Gerharz E, Dietz UA. Narbenhernienchirurgie. Übersicht und aktuelle Trends. *Urologe.* 2008;47:740–747, with permission.)

- Preoperative cleaning and disinfection of the umbilicus is helpful in decreasing the bacterial load during the operation.
- Antibiotic prophylaxis as a routine is not indicated for most hernia repairs because they are clean operations with a low risk of wound infection. In the presence of risk factors for wound infection, antibiotic prophylaxis at induction of anesthesia should be considered.

Positioning

- Patients treated for primary ventral hernias are usually positioned in a dorsal decubitus. Lumbar hernias are positioned in a 90-degree or 45-degree lateral decubitus to expose the lumbar region (**FIG 7**).
- For laparoscopic approach of ventral hernias, the position of the surgeon and the video equipment is determined by the localization of the hernia. It is important to have a wide lateral accessibility of the abdominal wall, because the trocars are placed very laterally to obtain access to hernias on the midline.

FIG 7 • Intraoperative positioning of a patient with a 45-degree lateral decubitus for open approach of a left-sided lumbar hernia.

SUTURE REPAIR

Incision

- For umbilical hernias, the incision of the skin for primary repair can be within the umbilical rim, thus leaving a nearly invisible scar postoperatively. The incision can be placed either cranial or caudal, depending on the site of the hernia sac. It is recommended not to incise the umbilical rim for more than 180 degrees because of the increased risk of devascularization of the umbilical skin after further dissection of the hernia sac, leading to skin necrosis and wound infection.
- For epigastric, spigelian, or lumbar hernias, the incision will be directly above the hernia.
- The skin is retracted with small Volkmann retractors and the subcutaneous layer incised down to the fascia, exposing one side, cranial or caudal of the hernia defect (**FIG 8A**).

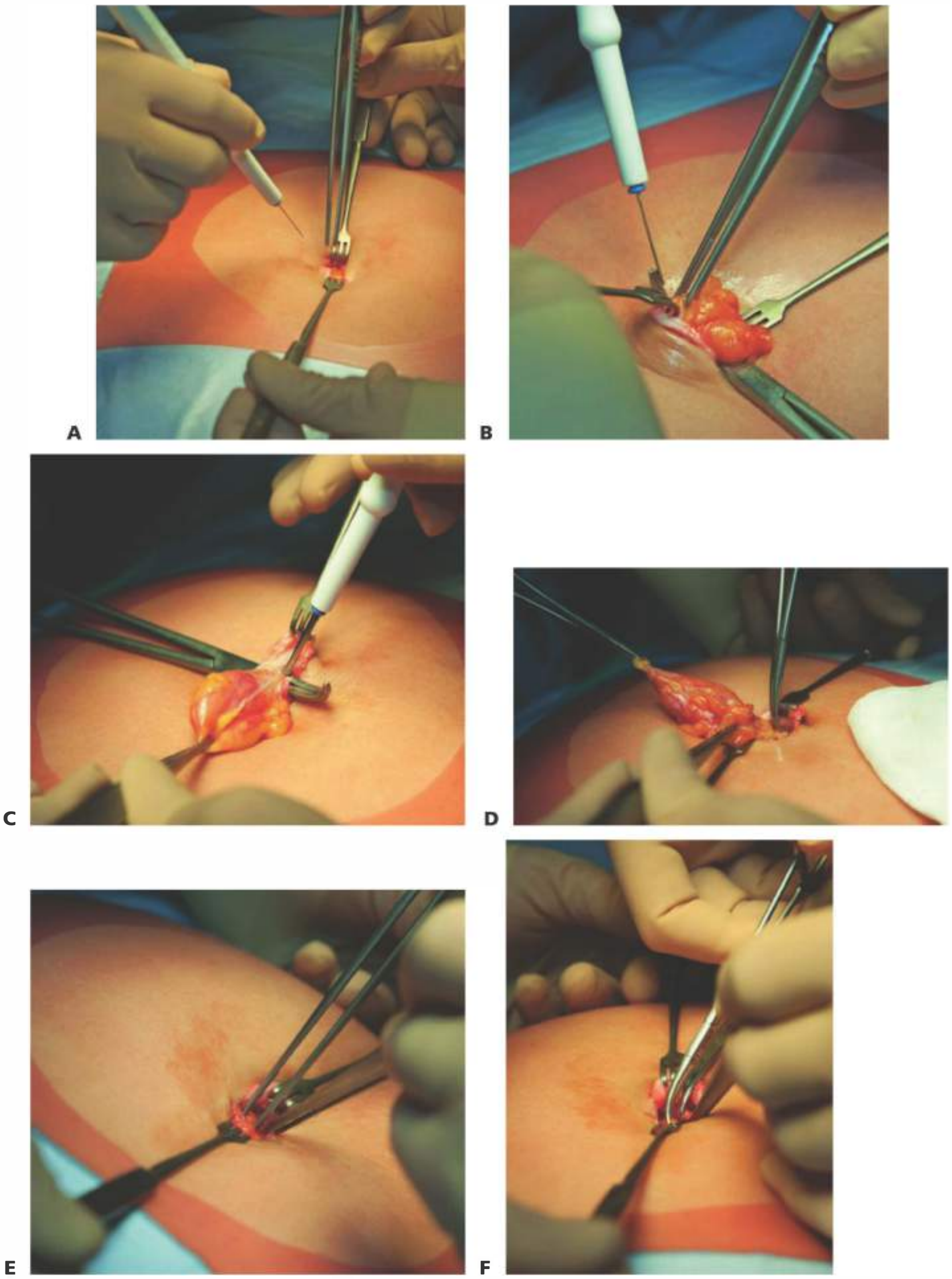


FIG 8 ● **A–F.** Intraoperative pictures of an umbilical hernia repair by open approach.

Dissection of the Hernia Sac

- Starting at the lateral side of the hernia defect, the hernia sac, usually containing preperitoneal fat and/or omentum, is encircled using a curved hemostat clamp. The clamp is pushed through to the other side of the hernia defect (**FIG 8B**).
- The top of the hernia sac is dissected of the umbilical skin, taking care not to injure the skin (**FIG 8C**). This will expose the opposite side of the hernia defect (**FIG 8D**).

Reduction of the Hernia Sac

- The hernia sac and its contents are reduced through the hernia defect behind the abdominal wall muscles (**FIG 8E**). Careful control of hemostasis of the preperitoneal region is performed.
- Sometimes, the contents of the hernia sac are too voluminous to be reduced through the hernia defect. This is often the case in umbilical hernias with herniation of omental fatty tissue and in epigastric hernias with preperitoneal fat. In these patients, we can either resect the herniated fatty tissue or we can enlarge the hernia defect.
- In patients with acute incarcerated hernias, the hernia sac should be opened and the herniated bowel inspected for viability. In case of doubt, a bowel resection should be considered.

Closure of the Hernia Defect by Primary Closure

- The fascial edges of the defect are identified and isolated from the subcutaneous tissue and from the preperitoneal tissue for 5 to 10 mm (**FIG 8F**).
- We close the umbilical and epigastric hernias in a horizontal line. Several options for suturing technique (separate sutures, running suture, or "vest-over-pants" plication sutures) (**FIG 9A–C**) and materials (monofilament vs. braided sutures; nonabsorbable, slowly absorbable, rapid absorbable) are available.
- Similar to the recommendations to close midline laparotomies, we recommend a running suture with small bites (5 mm from the fascial edge and 5 mm between stitches) using a long-term absorbable monofilament suture (**FIG 9B**).

Closure of the Skin

- The skin is sutured either subcutaneously or with separate superficial sutures.

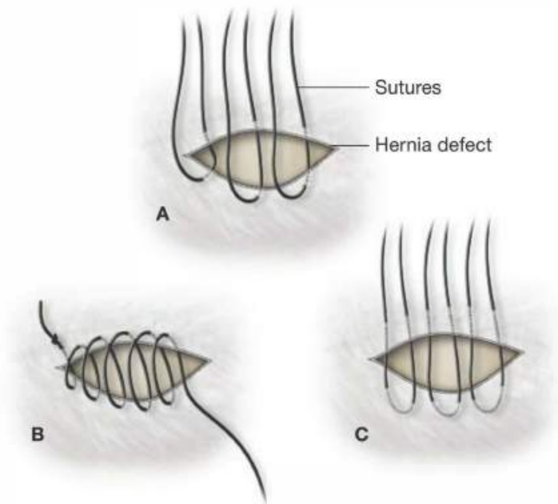


FIG 9 ● Several techniques are available for closure of the hernia defect. **A.** Closure with separate sutures. **B.** Closure with running sutures. **C.** Closure with a vest-over-pants plication, commonly known as the Mayo Clinic technique.

OPEN MESH REPAIR WITH A FLAT MESH

Incision

- This depends on the localization of the hernia. For umbilical hernias, placing a flat mesh will require an incision that is larger than the incision needed for primary closure or for placement of an umbilical ventral patch. Often, a horizontal omega incision (Ω) is chosen. For epigastric, spigelian, or lumbar hernias, the incision is directly over the hernia sac (**FIG 10**).

Dissection of the Hernia Sac and the Hernia Defect

- For umbilical and epigastric hernias, this is similar as for primary hernia repair (**FIG 8B–E**).
- For spigelian and lumbar hernias, an intact muscle layer covers the hernia sac. This is why these hernias can become quite large before they become clinically evident. For a spigelian hernia, the overlying external oblique muscle has to be opened to access the hernia sac. The muscle fascia is split in the direction of its fibers, which is from lateral downward in a ±45-degree angle toward the midline. The hernia sac is thus exposed and contains preperitoneal fat. The sac is reduced underneath the other abdominal wall muscles and the defect is measured.

Closure of the Hernia Defect and Mesh Augmentation

- Usually in open surgery, the mesh is used to augment the primary fascial closure of the hernia defect. There are several options for positioning the mesh in relation to the abdominal wall as shown in **FIG 6**.[1]
- *Onlay position*: The mesh is positioned on top of the fascia underneath the subcutaneous tissue. After closure of the hernia defect, a dissection of the subcutaneous plane is performed for several centimeters around the defect to allow enough overlap of the mesh beyond the margins of the defect.
- *Inlay position*: The mesh is placed inside the hernia defect, which is not closed, and the mesh is sutured to the

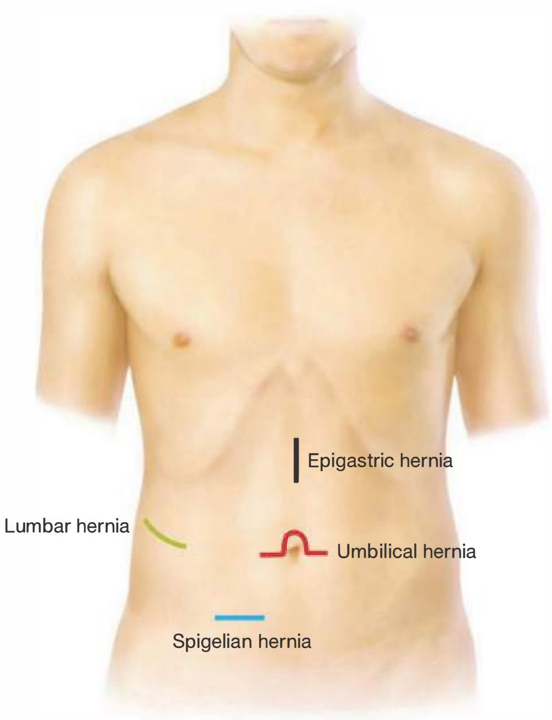


FIG 10 ● Incisions to perform an open primary ventral hernia repair will depend on the localization of the hernia.

margin of the defect. There is a large consensus amongst surgeons that this is not a good way to perform a mesh repair because of the lack of overlap between the mesh and the defect. The amount of overlap is considered to be critical to diminish the risk for recurrence.

- *Retromuscular position for midline hernias*: For umbilical and epigastric hernias, the mesh will be placed behind the rectus abdominis muscle and in front of the posterior rectus fascia. To get enough overlap, a dissection in this plane is needed in all directions for several centimeters. In the cranial and caudal direction, this dissection involves incision of the posterior rectus fascia to allow placement of the mesh behind an intact linea alba. The posterior layer of the rectus fascia is closed. The flat mesh is placed in the dissected retromuscular plane. The anterior rectus fascia is closed in front of the mesh.
- *Retromuscular position for lateral hernias*: For spigelian and lumbar hernias, the mesh is placed behind the intact superficial muscle layer, the external oblique muscle or the latissimus dorsi muscle, respectively. The mesh is placed on top of the closed hernia defect, on the internal oblique muscle or on the quadratum lumborum muscle, respectively.
- *Preperitoneal position*: Another option is to place the mesh behind the posterior rectus fascia, or for lateral hernias, behind the transversus abdominis muscle. The preperitoneal space has to be created by dissecting the peritoneum of the fascia of the deepest abdominal muscle. It is not always easy to develop this plane without creating holes or tears in the peritoneum. These have to be closed if a regular mesh without a protective antiadhesive layer is used.
- *Intraperitoneal position*: There is a consensus that if we want to place a mesh in the intraperitoneal position, thus in contact with the intestines, we have to use a mesh with a protective antiadhesive layer. Unprotected polypropylene or polyester meshes holds an increased risk of causing adhesions and complications such as bowel obstructions, bowel erosions, and fistula.

Fixation of the Mesh

- Several options for fixation of the mesh are available, depending on the mesh positioning.
- For meshes in an intraperitoneal or preperitoneal position, transabdominal sutures can be used. These sutures will fixate the mesh underneath the abdominal wall muscles.
- Suturing the mesh to the posterior fascia or muscular layer can hold the meshes in a retromuscular position. Avoiding transabdominal sutures will avoid the pain related to these sutures.
- For a mesh in the onlay position, sutures can be placed of the mesh to the anterior fascia.
- Fixation with glue applied to the surface of the mesh is a first alternative to the use of sutures.
- Another alternative to the sutures are self-fixating meshes. These meshes have a mechanical fixation either with small gripping hooks or by glue impregnated in the mesh, which becomes active in contact with the moisture of the tissues.
- The size of the mesh and the overlap of the mesh beyond the hernia defect are of critical importance to avoid recurrences.

Closure of the Hernia Defect

- It is recommended that the fascia defect be closed if possible, which is usually the case in primary ventral hernias. A mesh augmentation rather than a bridging of the hernia defect by the mesh is preferred.
- The anterior fascia is closed over the mesh in all repairs except an onlay mesh. In the onlay position, the hernia defect is closed before placing the mesh.

Closure of the Skin

- The skin is sutured either subcutaneously or with separate superficial sutures.

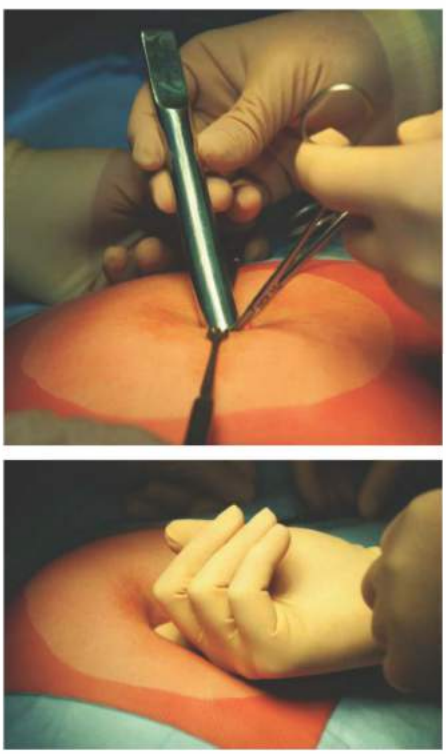
OPEN MESH REPAIR WITH A VENTRAL PATCH

Incision

- The incision needed for repair with a ventral patch is smaller than the incision to place a flat mesh. It is similar to the incision for suture repair. It is recommended not to incise the umbilical rim for more than 180 degrees because of the increased risk of devascularization of the umbilical skin after further dissection of the hernia sac, leading to skin necrosis and wound infection.
- The skin is retracted with small Volkmann retractors and the subcutaneous layer incised down to the fascia, exposing one side, cranial or caudal of the hernia defect (**FIG 8A**).
- The dissection of the hernia sac and reduction of contents is the same as the open primary repair technique.

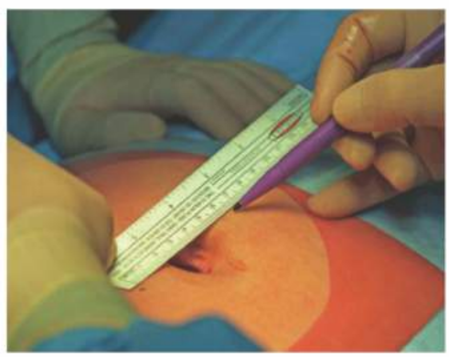
Dissection of the Plane to Position the Mesh Device

- The mesh devices have an antiadhesive layer similar to the meshes used in an intraperitoneal position. Thus, the *intraperitoneal placement* is considered to be safe. If this is done, we consider it of utmost importance that the preperitoneal fat around the hernia is dissected from the abdominal wall around the hernia defect to allow contact between the mesh and the muscular fascia. This is most important cranial to the umbilical hernia, where the round ligament of the liver and its fatty tissue will hinder a correct flat placement of the mesh.
- Alternatively, it is possible in most patients to develop the plane behind the posterior rectus fascia without major damage to the peritoneum. The development of the preperitoneal plane is done through the hernia defect. This allows placement of the mesh device in *a preperitoneal position* and may allow for better contact between mesh and fascia, resulting in better ingrowth while avoiding the possible disadvantages of an intraperitoneal mesh. When using a mesh device, I (*personal opinion of the author*) always try the preperitoneal placement. Only in cases of failure to develop the preperitoneal plane an intraperitoneal position is done.
- The hernia defect can be measured using Hegar dilators to correctly evaluate the size of the defect and classify the hernia accordingly. Because the diameter of the mesh devices does not allow a large overlap beyond the hernia defect, we recommend limiting the repair of ventral hernias with mesh devices to small hernias not larger than 2 cm (**FIG 11A**).
- Isolate the fascia margin from its underlying peritoneum, grasping the fascia edge with the small Volkmann retractors.
- Develop the preperitoneal plane by blunt dissection with the finger if the hernia defect is large enough to allow this (**FIG 11B**). Sometimes, slightly enlarging the hernia defect is needed to allow introducing a digit.



A

B



C

FIG 11 ● **A–K.** An umbilical hernia is repaired using a round mesh device (Proceed Ventral Patch™, Ethicon, Johnson & Johnson) of 6.4-cm diameter. We preferably place the mesh in a preperitoneal position if possible. The mesh is fixed with sutures to the hernia defect, using two central fixation strips, and we usually close the hernia defect on top of the mesh.
*Note: **FIG 11C** and **11D**—In this patient, a mesh of 6.4-cm diameter will be placed. To illustrate the size of dissection needed underneath the posterior rectus fascia, we have measured and drawn a circle of 6.4-cm diameter. (continued)*

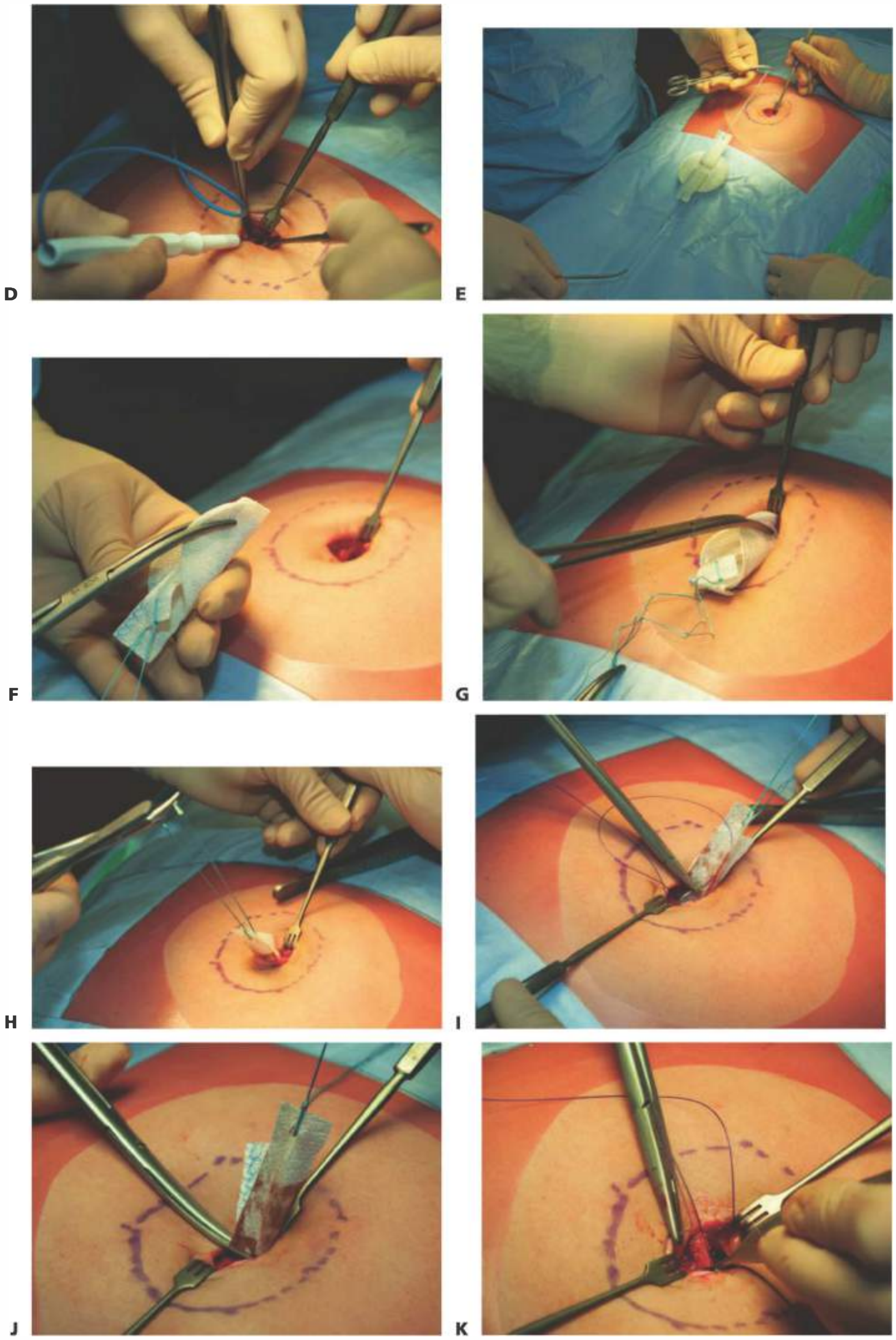


FIG 11 ● *(continued)*

- The dissection of the preperitoneal plane is helped by introducing a gauze in the space created.
- The preperitoneal dissection should be extended far enough to allow easy and flat application of the mesh (**FIG 11C,D**).
- It is important to perform a good hemostatic control of the dissection plane to avoid postoperative hematoma around the mesh.

Introduction of the Mesh Device

- The mesh device is removed from the package after changing surgical gloves.
- The mesh device is 6.4 cm in diameter and has two central strips allowing the mesh to be pulled against the abdominal wall and fixed to the hernia defect (**FIG 11E**).
- The mesh is folded in a manner not to break the internal memory ring at the margin of the mesh and grasped with a clamp (**FIG 11F**).
- While lifting the cranial fascia edge with the retractor, the mesh is pushed in the preperitoneal plane through the hernia defect (**FIG 11G**).
- With two nontraumatic forceps, the mesh is unfolded and checked for a correct flat position.
- The mesh is pulled against the abdominal wall by the central strips, controlling for a correct flat positioning of the mesh (**FIG 11H**).

Fixation of the Mesh Device

- Most round mesh devices for the treatment of small ventral hernias have two central fixation strips to fix the device to the margins of the hernia defect. The caudal strip is fixed to the lower margin of the hernia defect with a U-shaped suture of a slowly absorbable monofilament suture (**FIG 11I**).
- The strip is cut directly above the suture, leaving no mesh material above the fascia (**FIG 11J**).
- The same is done with the cranial strip that is sutured to the upper margin of the hernia defect.

Closure of the Hernia Defect

- Closure of the hernia defect is recommended. It separates the mesh device in the intraperitoneal or preperitoneal position from possible postoperative wound infections.
- As for the primary hernia repair, several options for suturing technique and materials are available: separate sutures, running suture, or vest-over-pants plication sutures (**FIGS 9A–C** and **11K**).

Closure of the Skin

- The skin is sutured either subcutaneously or with separate superficial sutures. A sterile bandage is placed.

LAPAROSCOPIC MESH REPAIR

Creation of the Pneumoperitoneum and Trocar Placement

- The surgical field should be prepped and draped widely, with good exposure of the lateral parts of the abdomen. The trocars are placed very laterally to allow for a good view of the anterior abdominal wall and optimal angles when placing the tacks to fixate the mesh (**FIG 12**). For a midline hernia or for a right spigelian hernia, the trocars will be placed on the left side. For a left-sided spigelian hernia, the trocars are placed on the right side.
- The pneumoperitoneum is created with the use of a Veress needle placed subcostally. Alternatively, an open access can be performed with placement of a blunt trocar.
- Three trocars are placed in the flank on the anterior axillary line (**FIG 12**). When a large mesh is used, fixation on the surgeon's side will need an extra contralateral trocar to allow the tacks to be applied. For most primary ventral hernias, three trocars on one side are sufficient.

Adhesiolysis, Hernia Reduction, and Preconditioning of the Abdominal Wall

- Adhesiolysis, which is sometimes very difficult and time-consuming in laparoscopic incisional hernia repair, is usually not a major issue in primary ventral hernias. If any adhesions are present, they are most often between the omentum and the hernia sac. Adhesiolysis has to be performed carefully, avoiding the use of cautery or other energy sources to minimize the risk of an inadvertent bowel injury.
- The peritoneum of the hernia sac is reduced. Care is taken not to injure the overlying skin while dissecting the sac. The skin above an umbilical hernia may be very thin.
- It is important to precondition or prepare the area of the anterior abdominal wall that will be in contact with the intraperitoneal mesh. This is a part of the operation called "preparing the landing zone" and involves the removal of the fatty tissue and peritoneum around the hernia defect.[5] Above the umbilicus, the falciform ligament of the liver will be removed from the abdominal wall. Below the umbilicus, the fat between the plica umbilicalis mediana of both sides will be dissected down from the abdominal wall, thus exposing the posterior part of the rectus muscles.
- The defect of the hernia can be left open (i.e., bridging technique: the defect is covered and "bridged" by the intraperitoneal mesh) or can be closed (i.e., mesh augmentation: the intraperitoneal mesh is covering the closed hernia defect). *(See video 1: closure and video 2: defect left open in the accompanying eBook.)* There is no consensus whether closure of the hernia defect has advantages to the bridging of the defect.

Mesh Placement and Fixation of the Mesh

- The mesh used during laparoscopic ventral hernia repair needs an antiadhesive side that will be in contact with the viscera. Many different meshes are available for this purpose.[5]
- It is mandatory to have a good overlap of the mesh beyond the hernia defect. An overlap of at least 5 cm in all directions is considered a minimum (**FIG 13**). This is

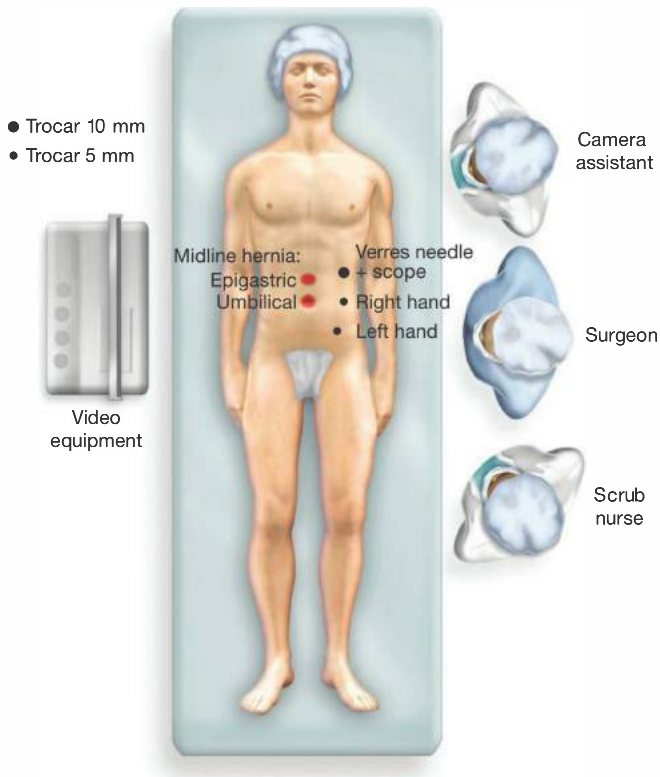


FIG 12 ● Drawing of the intraoperative setting and trocar positions for a laparoscopic ventral hernia repair.

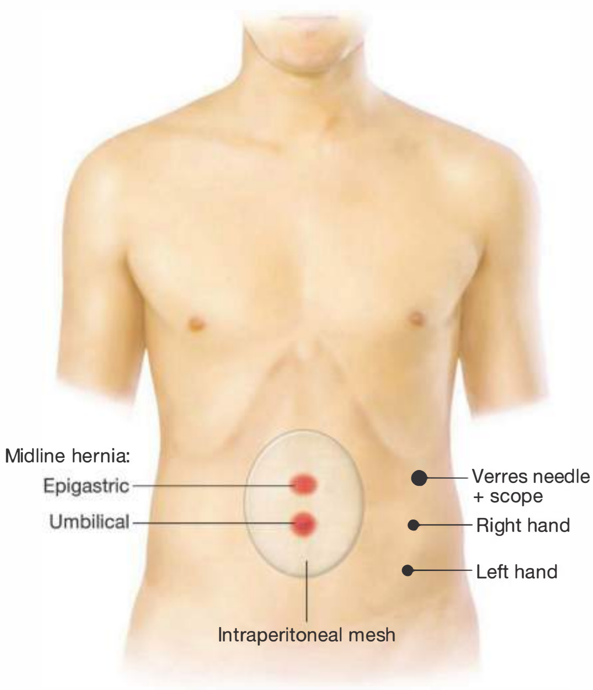


FIG 13 ● A good symmetrical positioning of the mesh with ample overlap beyond the hernia defect is needed.

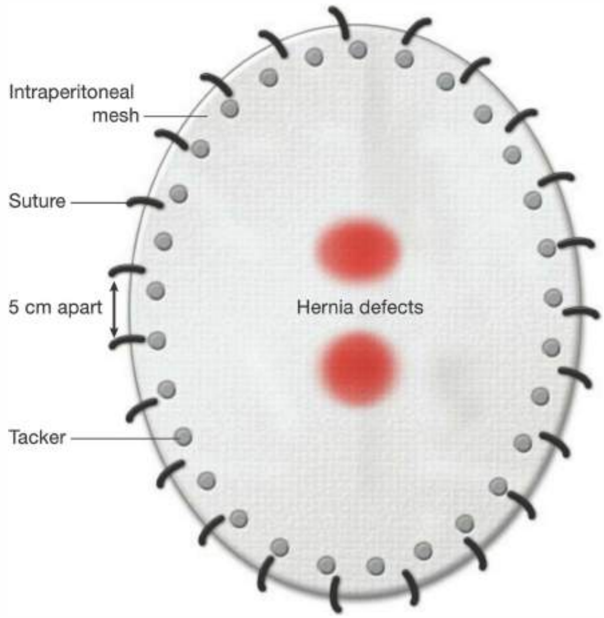


FIG 14 ● Fixation with sutures and tackers during laparoscopic ventral hernia repair.

necessary because all meshes shrink over time. Moreover, it is important to position the mesh symmetrically around the hernia defect. Because of the sharp angle between the abdominal wall and the tacker device, there is a tendency to push the mesh away from the surgeon's side, resulting in an asymmetric mesh placement.

- Several devices are available for the fixation of the mesh.[5] Some of the tackers are absorbable. There is no consensus if the mesh can be adequately fixed with tackers alone or if the addition of transabdominal sutures is needed. Most reported techniques involve a combination of sutures and tackers ("suture and tackers technique") (**FIG 14**) or the use of a double row of tackers ("double crown technique") (**FIG 15**). During the initial experience, the use of four cardinal sutures to orient and position the mesh is very helpful (**FIG 16**).

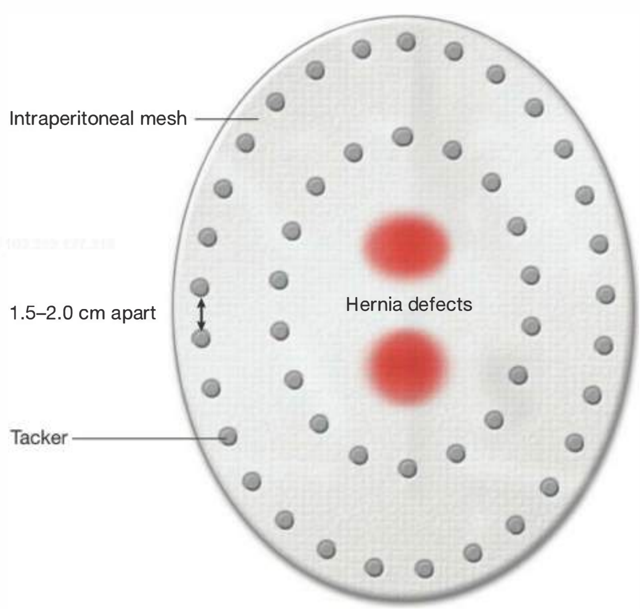


FIG 15 ● "Double crown" fixation during laparoscopic ventral hernia repair.

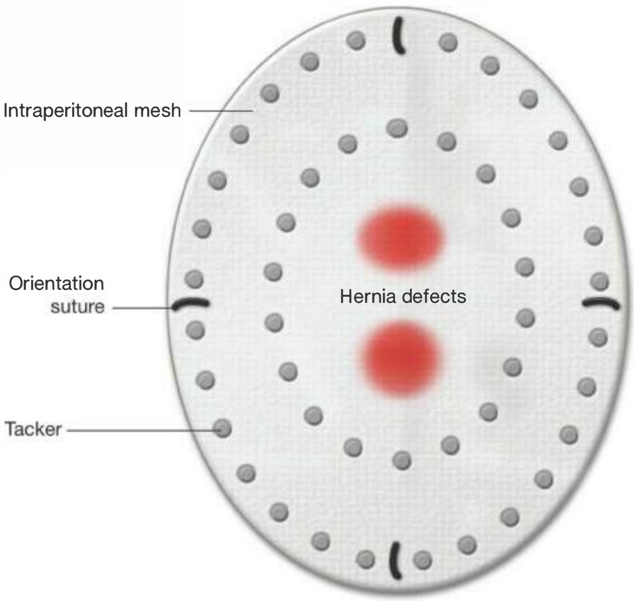


FIG 16 ● Double crown fixation with four cardinal sutures orientation for laparoscopic ventral hernia repair.

PEARLS AND PITFALLS

Indications	■ Small asymptomatic umbilical, epigastric, or lumbar hernias do not need repair and a "watchful waiting" policy can be proposed. ■ Spigelian hernias need surgical treatment because they hold an increased risk of incarceration. ■ Incarcerated hernias should be operated in emergency.
Medical imaging	■ For most umbilical and epigastric hernias, medical imaging is not necessary for diagnosis and treatment planning. ■ Spigelian and lumbar hernias can often only be diagnosed with medical imaging, if they are clinically not palpable.
Mesh repair	■ Suture repair is only applicable in small ventral hernias. ■ A mesh repair will decrease the risk for recurrent ventral hernia. ■ Several mesh positions and surgical approaches are possible. ■ A good overlap of the mesh beyond the hernia defect margin is important to compensate for mesh shrinkage.
Laparoscopic repair	■ A mesh with antiadhesive properties has to be used for intraperitoneal placement. ■ Flat and symmetric positioning of the mesh around the hernia defect is the goal. ■ The abdominal wall around the hernia in contact with the mesh should be adequately prepared and fatty tissue removed. ■ Several mesh fixation alternatives exist, without a clear consensus on the optimal approach. ■ Closure of the hernia defect is optional during laparoscopic ventral hernia repair.

POSTOPERATIVE CARE

- Repair of primary ventral hernias can most often be performed in an ambulatory setting. Restriction of lifting heavy weight and intense sporting activities for 2 weeks is advocated. An abdominal binder to support the hernia repair can have a positive impact on early ambulation and pain control.

OUTCOMES

- Nationwide Danish follow-up data 41 months after surgery show a reoperation rate for recurrence of 4% and a total clinical recurrence rate of 15%.[6]
- From the same Danish database, we know that umbilical and epigastric hernia repair has a low morbidity and mortality but a high readmission rate mostly because of wound

problems, seroma formation, or pain.[7] Moreover, many patients complained about pain and discomfort 3 years after elective repair of a small umbilical or epigastric hernia.[8]

COMPLICATIONS

- Seroma
- Hematoma
- Surgical site infection
- Mesh infection
- Recurrence
- Chronic pain

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Chapter 8 Vagotomy: Truncal and Highly Selective

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DEFINITION

- Truncal vagotomy is defined as the division of the anterior and posterior vagus nerves, which innervate the stomach and remainder of the gastrointestinal (GI) tract, at the level of the distal esophagus. Vagotomy eliminates cholinergic stimulation to gastric parietal cells and decreases parietal cell response to gastrin and histamine, thereby reducing gastric acid secretion. By transecting at the entrance point into the abdomen, all innervation to the liver, gallbladder, pancreas, and small intestine is also divided. Truncal vagotomy requires a drainage procedure due to the disruption of antral and pyloric muscular innervation.
  - For many years, vagotomy was one of the cornerstones of surgical treatment of ulcers. However, with further understanding of the role of *Helicobacter pylori* in ulcer pathogenesis and advancement in pharmacologic management including proton pump inhibitors (PPIs) and histamine blockers, the role of surgery has changed. Of the classic indications for ulcer, surgery, bleeding, perforation, obstruction, and intractability, vagotomy is only commonly used in those patients who require surgical control of ulcer bleeding.
  - Level one evidence suggests that it is not necessary in the treatment of duodenal perforation in patients who are *H. pylori* positive,[1] and the number of patients requiring operation for gastric outlet obstruction and intractability has declined dramatically with the advent of improved pharmacologic and endoscopic therapy of peptic ulcer disease (PUD). The incidence of definitive acid reduction surgery decreased by more than 50% from 1993 to 2006.[2]
- Highly selective vagotomy (HSV) is defined as the division of the gastric branches of the nerves of Latarjet. The nerves of Latarjet, celiac division of posterior vagus, and hepatic division of anterior vagus are preserved. Therefore, cholinergic stimulation is selectively eliminated to reduce acid secretion by parietal cells in the body and fundus, and the innervation of the antrum and pylorus, biliary tract, and small and large intestines are untouched. A drainage procedure is not required with HSV. This is also known as "parietal cell vagotomy" or "proximal gastric vagotomy."
  - The operation was developed to avoid the need for a gastric drainage procedure, which is required with truncal vagotomy, as up to one-third of patients will develop delayed gastric emptying following this procedure. Despite the elegance of parietal cell vagotomy, it is a technically demanding operation with a higher ulcer recurrence rate and much longer learning curve than truncal vagotomy. In an era when few vagotomies are performed, it has largely fallen out of favor.[3]
- Of historical note, a selective vagotomy sections the anterior vagus just distal to the point where the branch to the gallbladder and liver and the posterior vagus just distal to the branch to the pancreas and small intestines. Although in theory this might reduce the side effects of vagotomy, it is unclear in practice that this had any effect on outcomes.

DIFFERENTIAL DIAGNOSIS

- In a patient with acute severe upper GI bleeding, the differential diagnosis includes a bleeding peptic ulcer, bleeding esophageal or gastric varices secondary to portal hypertension, esophageal mucosal diseases such as severe esophagitis and Mallory-Weiss tears, gastric arteriovenous malformations and Dieulafoy's lesion, and rarely, ulcerated tumors or hemobilia.
- In a patient with acute abdominal pain and free air, the differential diagnosis should include a perforated peptic ulcer, perforated diverticulitis, perforated appendicitis, and small bowel perforation.
- In the patient with gastric outlet obstruction, the differential diagnosis includes PUD, gastric cancer, duodenal web, functional delay in gastric emptying, and chronic ulcer disease related to nonsteroidal antiinflammatory drug (NSAID) or aspirin use.

PATIENT HISTORY AND PHYSICAL FINDINGS

- The majority of operations for PUD performed now are urgent or emergent operations for complicated ulcer disease.
- A thorough history and physical should be obtained with key focus on the duration of symptoms, previous ulcer therapy, NSAID or aspirin use, and smoking history. Consider investigation into hypersecretory and malignant etiologies in patients with refractory ulcer disease.
- Patients should be specifically questioned regarding *H. pylori* status and prior *H. pylori* treatment including a history of eradication. In patients unable to stop antiinflammatory drug use or those with *H. pylori*–negative ulcer disease, it may be reasonable to consider performing an acid-reducing procedure at the time of ulcer repair.
- Bleeding can occur in 15% to 20% of patients with PUD and is the most common ulcer-related complication.[4] The majority will resolve with conservative or endoscopic treatment. In patients undergoing operation for a bleeding duodenal ulcer, the best available evidence suggests that vagotomy should be combined with oversewing of a duodenal ulcer.[5] As such, the patient's *H. pylori* status, history of prior NSAID use, or prior ulcer disease will not affect the use of vagotomy in the management of their bleeding duodenal ulcer
- Perforations occur in up to 10% of ulcer complications.[4] Patients that will most likely to benefit from acid-reducing surgical intervention during repair of a perforation include those that have contraindications to PPI, perforation on PPI, or prior eradication of *H. pylori*.
- Obstruction is the least common complication of ulcer disease at 5% to 8% and occurs as a result of scarring of the pylorus.[4] Endoscopy often delineates location and degree of the obstruction and also allows for therapeutic balloon dilation of the pylorus. Surgery is reserved for failure of less invasive treatments.

- Intractable disease encompasses failure of medical management to heal the ulcer, relapse of disease while on current therapy, or multiple courses of medical therapy. Medical management includes acid suppression, *H. pylori* eradication, and NSAID cessation. Symptoms should be substantiated with endoscopic visualization of a persistent or recurring ulcer.

IMAGING AND OTHER DIAGNOSTIC STUDIES

- In a patient with sudden onset acute abdominal pain and physical exam findings of peritonitis, an upright chest radiograph confirming the finding of free intraperitoneal air is a sufficient workup prior to proceeding to the operating room (OR) for a presumed perforated ulcer.
- In patients with a history and physical consistent with a perforated ulcer, but without free air on radiograph, a computed tomography (CT) scan or upper GI contrast study using water-soluble contrast can help to make the diagnosis.
- Testing for *H. pylori* is used to confirm presence of or gauge the eradication of disease. Antibody testing assesses overall exposure but is not specific for active disease. Urease breath test and stool antigen test can be used to confirm eradication. Full treatment of *H. pylori* should be attempted before definitive acid reduction surgery is considered.
  - Stool antigen testing for *H. pylori* should be performed prior to operation for PUD, as knowledge of *H. pylori* status may help determine the need for vagotomy. As mentioned earlier, it may not be necessary to perform vagotomy for *H. pylori* positive disease, but may be considered in treatment of *H. pylori*-negative ulcer disease.
- Serum gastrin levels should be tested to rule out hypergastrinemic syndromes.
- Endoscopy is part of standard investigation of ulcer disease when symptoms persist despite medical therapy. Endoscopy is also used to assess ulcer healing and perform biopsies to evaluate malignancy, gastritis, and *H. pylori* infection.
- In patients with a bleeding peptic ulcer, the surgeon should be present at the time of upper endoscopy to gain an accurate anatomic understanding of the location of the ulcer. Patients with gastric ulcers not caused by acid, such as ulcers along the lesser curvature proximal to the incisura or near the gastroesophageal (GE) junction, will not require a vagotomy. Patients with duodenal or prepyloric ulcer should undergo vagotomy at the time of their operation for bleeding control.

SURGICAL MANAGEMENT

Preoperative Planning

- Patients undergoing emergency surgery for peptic ulcer bleeding will have a stomach full of blood and are at significant risk of aspiration. A nasogastric tube should be placed prior to induction for all vagotomy procedures, and rapid sequence induction should be used if possible.
- When performing an emergency operation for bleeding, the surgeon should ensure that blood is cross-matched and available.
- For laparoscopic procedures, having the ability to perform intraoperative esophagogastroduodenoscopy (EGD) can facilitate the identification of the ulcer in difficult cases.
- With truncal vagotomy, the gastric antrum and pylorus are denervated and concomitant drainage procedure must be performed.
  - Options include pyloroplasty, gastrojejunostomy, or gastric resection with reconstruction (see Part 2, Chapter 9).
- HSV preserves antral muscular function and the pylorus mechanism. It is not necessary to perform a drainage procedure.
- Transthoracic vagotomy requires double lumen intubation tube and separate lung ventilation; for sufficient exposure to distal esophagus, the left lung must be collapsed.
- Perioperative antibiotics should be administered; cefazolin is standard, clindamycin plus a fluoroquinolone or aminoglycoside for penicillin allergy.

Positioning—Open

- Open approach: Patient is supine with the arms tucked or extended.
  - Space is left on the patient's left side to attach a Bookwalter or Omni retractor to the bed rail.
- Reverse Trendelenburg position of the table will help with exposure of the hiatus.

Positioning—Laparoscopic

- Laparoscopic approach: Patient is supine with right arm tucked. Surgeon stands on patient's right and assistant stands on patient's left.
- Reverse Trendelenburg position of the table will help with exposure of the hiatus.

Positioning—Transthoracic

- Patient is placed in right lateral decubitus position.

TECHNIQUES

TRUNCAL VAGOTOMY—OPEN

Skin Incision and Retractor Positioning

- Use a standard upper midline incision, from just below xiphoid process to level of the umbilicus.
- A body wall retractor blade is placed on either side of the upper half of the incision to facilitate exposure.
- Depending on the size of the left lateral segment of the liver, it may be necessary to divide the avascular portion of the left triangular ligament to allow the left lateral segment to be retracted in order to facilitate visualization of the abdominal esophagus (**FIG 1**).

Exposure of the Esophagus

- The pars flaccida and the phrenoesophageal ligament are divided to expose the right crus and anterior esophageal wall. Take caution to recognize and preserve an accessory left hepatic artery when dividing the pars flaccida. The position of the esophagus can be verified by palpation of the nasogastric tube within the lumen of the esophagus.
- Identify the right crus of the diaphragm; gently dissect to expose the anterior surface of the esophagus. This peritoneal incision should be carried across the

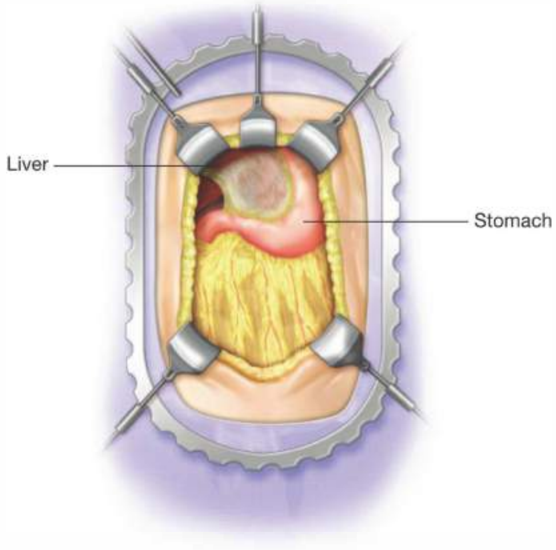


FIG 1 ● A Bookwalter-style self-retaining retractor provides excellent exposure of the stomach and duodenum for drainage procedures. Placement of four abdominal wall blades, two on either side of the upper and lower aspect of the wound will provide the optimum exposure. A Harrington or malleable retractor on the left lobe of the liver can facilitate exposure.

anterior surface of the esophagus and onto the left crus of the diaphragm to expose the anterior surface of the esophagus (**FIG 2A**). By applying downward and rightward traction on the stomach, the surgeon can place the esophagus on tension to enhance exposure (**FIG 2B**).

- Continue to develop a plane between right crus and the esophagus; extend posteriorly to create a retroesophageal window.
- The esophagus is then dissected circumferentially and this, again, can be facilitated by palpating the nasogastric tube in the lumen of the esophagus.
- A Penrose drain is placed around the GE junction to assist with downward traction on the GE junction.

Identification and Division of the Anterior (Left) Vagus Nerve

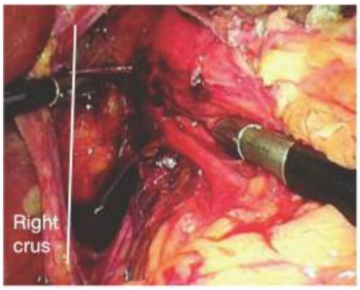
- The vagus nerves rotate counterclockwise at the level of the esophageal hiatus with the right vagus nerve coursing more posterior and the left vagus nerve anterior with respect to the esophagus.
- The left (anterior) vagus nerve is typically anterior and just right of midline at the 1 o'clock to 2 o'clock position. It is often almost within the longitudinal muscle layer (**FIG 3**).
  - Downward traction of the GE junction via the Penrose drain can help tense the nerve like a guitar string to help with palpation.
  - Dissect the nerve off the anterior surface of esophagus using a right angle with sharp dissection, minimal cautery.
  - Any additional anterior vagus nerve should be dissected free of esophagus if present. In about 10% of cases, two or rarely more anterior vagal branches may be found.[6]
- A medium clip is then placed on the nerve(s) at the level of the diaphragm and a second clip is placed on the nerve 3 to 4 cm distal to the first. The segment of nerve(s) between the clips is excised and sent for pathology to verify nervous tissue was excised (**FIG 4**).

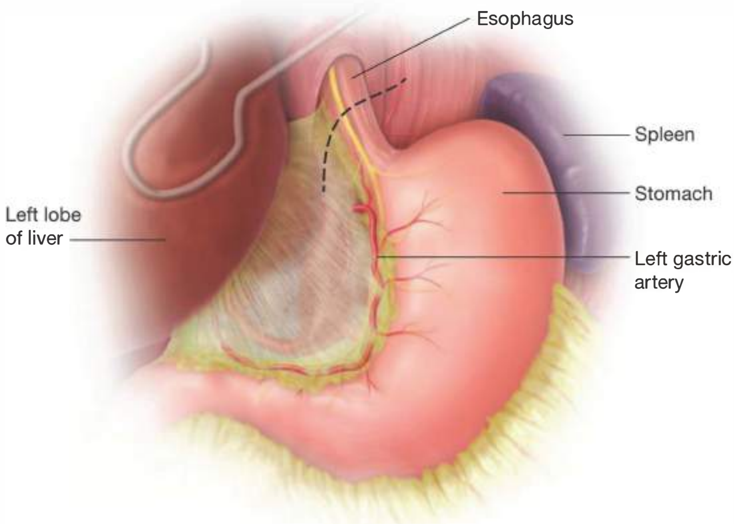
Identification and Division of the Posterior (Right) Vagus Nerve

- The right (posterior) vagus is found at the 7 o'clock position and is often up to a centimeter away from the esophageal wall between the esophagus and the right crus (**FIG 5**).
  - In about 15% of cases, it may be located to the left of midline.[6]
- To identify the posterior vagus trunk(s), the surgeon should again apply downward traction on the Penrose while sweeping the index finger of the right hand posterior to the esophagus from the left crus to the right.
  - The surgeon's finger should be right on the esophageal wall and any tense bands identified should be hooked with a right angle and dissected free from the esophageal wall (**FIG 6**).
- A clip should be placed at the level of the diaphragm and a second clip is placed on the nerve 3 to 4 cm distal. The segment of nerve(s) between the clips is excised and sent for pathology to verify nervous tissue.
- Continue with gastric drainage procedure as indicated: pyloroplasty, gastrojejunostomy, or gastric resection with reconstruction (see Part 2, Chapter 9).

Assessment of Hemostasis and Closure

- After verifying that no additional vagal trunks can be identified, the surgeon should inspect the diaphragmatic hiatus. During blunt mobilization of the GE junction, a hiatal hernia is sometimes created.
  - If the surgeon can insert more than the one finger adjacent to the esophagus through the hiatus, the right and left crura should be reapproximated with one or two 0 braided polyester or silk sutures to prevent the development of a postoperative hiatal hernia.
  - At the completion of the repair, a single finger should be able to be inserted alongside the esophagus to avoid postoperative dysphagia.
- After hemostasis is verified, the midline is closed in usual standard fashion.





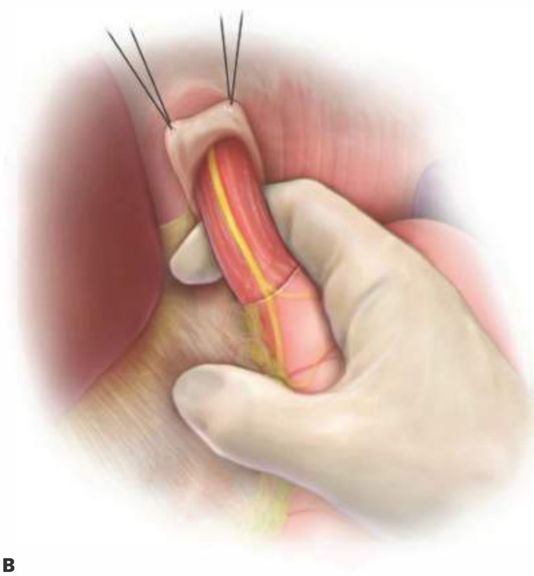


FIG 2 ● **A.** Photo **(left)** and illustrations of the peritoneum of the pars flaccida is incised to expose the right crus of the diaphragm and the esophagus. This peritoneal incision should be carried across the anterior surface of the esophagus and onto the left crus of the diaphragm to expose the anterior surface of the esophagus. **B.** Beginning on the left of the esophagus, blunt dissection with a finger or a Kittner dissector will allow the surgeon to separate the esophagus from the left crus. With gentle blunt dissection, it is possible to encircle the esophagus with the right index finger.

FIG 3 ● As seen in this intraoperative photo, the anterior vagus trunk is a large band intimately associated with the muscular wall of the esophagus and often located on the right anterior surface of the esophagus.

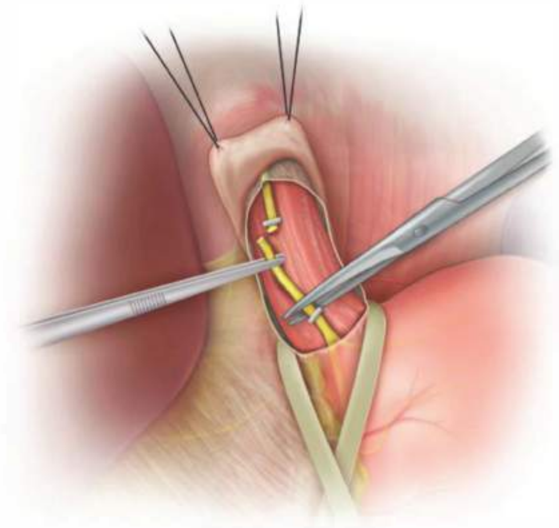


FIG 4 ● The anterior vagus trunk is carefully dissected from the anterior surface of the esophagus, and a medium clip is then placed on the nerve(s) at the level of the diaphragm and a second clip is placed on the nerve 3 to 4 cm distal to the first. The segment of nerve(s) between the clips is excised and sent for pathology to verify nervous tissue was excised.

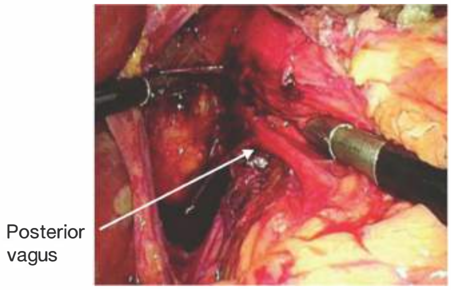


FIG 5 ● As shown in this intraoperative photo, the posterior vagal trunk is less intimately associated with the esophageal musculature.

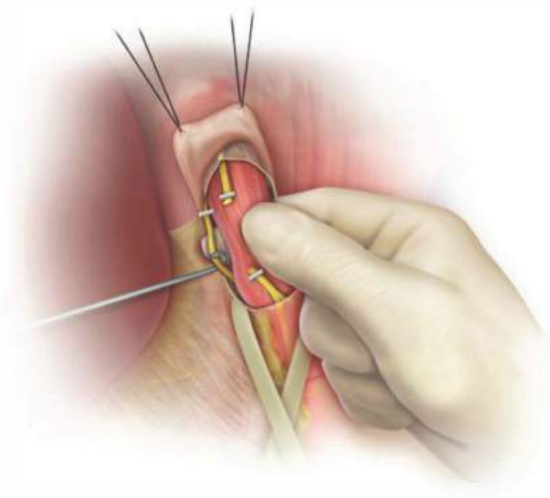


FIG 6 ● To identify the posterior vagus trunk(s), the surgeon should again apply downward traction on the Penrose while sweeping the index finger posterior to the esophagus from the left crus to the right. The surgeon's finger should be right on the esophageal wall and any tense bands identified should be hooked, dissected free from the esophageal wall, and divided between clips.

TECHNIQUES

LAPAROSCOPIC TRUNCAL VAGOTOMY

Port Placement and Liver Retraction

- Port placement (FIG 7)
    - 5-mm periumbilical camera port 2 cm to the left of midline
    - 5-mm subxyphoid trocar for liver retraction
    - 5-mm right midclavicular line, two fingerbreadths below costal margin: left hand working port
    - 5-mm trocar between the right midclavicular line and camera trocar
    - 5-mm left anterior axillary line, below costal margin: stomach retraction
- A Nathanson liver retractor is placed to elevate the left lobe of the liver.
    - The patient is positioned supine with the right arm tucked.
    - The surgeons stands to the patient's right and the assistant to the patient's left.

Exposure of the Esophagus

- The peritoneum of the pars flaccida and the phrenoesophageal ligament is incised with a Harmonic scalpel or bipolar cautery device to expose the right crus of the diaphragm onto the anterior surface of the esophagus and across to the left crus to expose the entire surface of the esophagus.
- The position of the esophagus can be verified by palpation of the nasogastric tube within the lumen of the esophagus or by performing an intraoperative EGD.
- The peritoneum overlying the medial edge of the right crus of the diaphragm is identified and incised, and then, blunt dissection is used to elevate the esophagus off of the right and left crus to make a retroesophageal window.

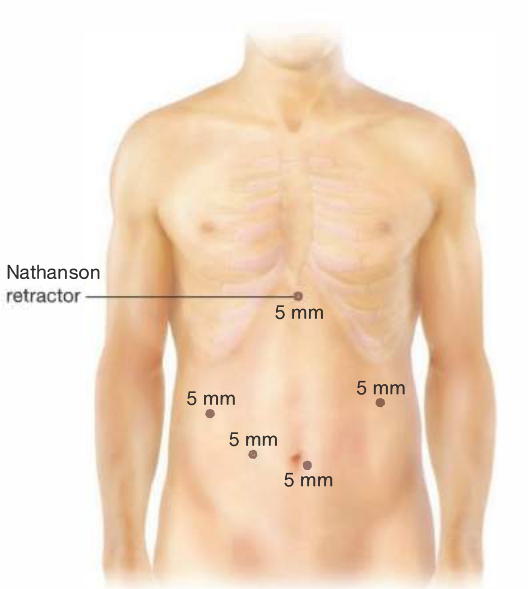


FIG 7 ● Shows the standard port placement used for a laparoscopic vagotomy.

- A grasper is then passed though the window and a Penrose drain is used to encircle the esophagus.

Identification and Division of the Anterior (Left) Vagus Nerve

- With the magnification inherent in laparoscopy, the anterior vagus can often be visualized directly on the anterior surface of the esophagus (FIG 3).
    - If the nerve cannot be easily visualized, downward traction on the GE junction obtained by having the assistant pull down on the Penrose will make the nerve tense like a guitar string and will allow for either visual or tactile identification of the anterior vagus.
- Using a Maryland dissector, the surgeon should carefully dissect the anterior vagus away from the esophageal muscle and elevate the nerve.
- Using sharp dissection with the Harmonic scalpel or bipolar cautery device, the surgeon should free up the vagus to the diaphragmatic hiatus.
- An endoclip should be placed across the nerve at the hiatus and a second clip placed 3 to 4 cm inferior to the first. The portion of the nerve between the clips is then excised and sent to pathology.
- A search for additional anterior trunks should be conducted as discussed previously.

Identification and Division of the Posterior (Right) Vagus Nerve

- The posterior vagus is less closely associated with the esophageal wall.
- To identify the posterior vagus trunk(s), the assistant should apply caudal and leftward traction on the Penrose drain with a grasper inserted through the left upper quadrant port.
    - The posterior vagus should become visible at this point as a tight band traversing between the posterior wall of the esophagus and the right crus of the diaphragm (FIG 5).
    - Many times, the posterior vagal trunk will be encircled within the Penrose drain, and the Penrose will need to be repositioned to allow the dissection of the nerve trunk away from the esophagus.
- Using sharp dissection with the Harmonic scalpel or bipolar cautery device, the surgeon should free up the vagus to the level of the diaphragmatic hiatus
- An endoclip should be placed at the level of the diaphragm and a second clip is placed on the nerve 3 to 4 cm distal. The segment of nerve(s) between the clips is excised and sent for pathology to verify nervous tissue was excised.

Assessment of Hemostasis and Closure

- Again, verify no additional vagal trunks
- Inspect the diaphragmatic hiatus as described earlier and reapproximate if necessary.
- Remove laparoscopic ports under direct vision to ensure hemostasis.
- Close skin in the usual standard fashion, with fascial closure for port sites greater than 5 mm.

TRANSTHORACIC VAGOTOMY

Port Placement

- 10-mm camera port in 7th or 8th intercostal space, posterior axillary line
- 10-mm instrument trocar along anterior axillary line at 6th and 10th intercostal space, forming a semicircle with the camera port
- 5 mm can be placed in 10th or 11th intercostal space along posterior axillary line if needed (**FIG 8**).

Exposure of the Esophagus

- The left lung will need to be collapsed to visualize the distal esophagus.
- Transect the pulmonary ligament with scissors or electrocautery and retract the collapsed lung superiorly (**FIG 9**).
- Incise the mediastinal pleura to expose the esophagus.

Identification and Division of the Anterior (Left) Vagus Nerve

- With the magnification in laparoscopy, the anterior vagus can often be visualized directly on the anterior surface of the esophagus.
- Using a Maryland dissector, the surgeon should carefully dissect the anterior vagus away from the esophageal muscle and elevate the nerve, placing tension by pulling toward the surgeon.

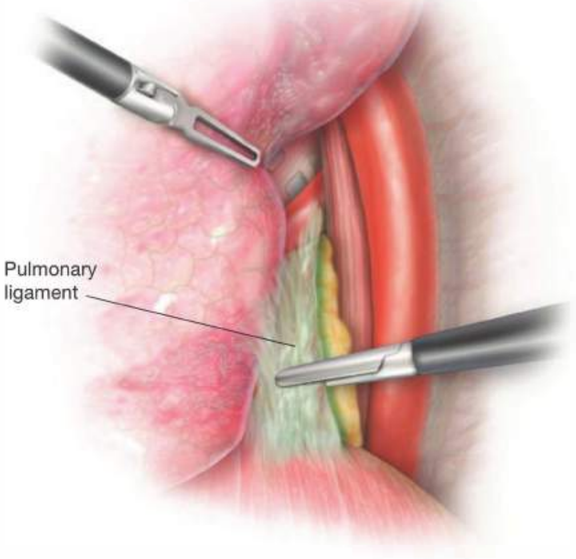


FIG 9 ● To expose the distal esophagus, transect the pulmonary ligament and retract the collapsed left lung superiorly.

- Using sharp dissection with the Harmonic scalpel or bipolar cautery device, the surgeon should free up 3 to 4 cm of the vagus nerve (**FIG 10**).
- An endoclip should be placed across the nerve at the hiatus and a second clip placed 3 to 4 cm inferior to the first. The portion of the nerve between the clips is then excised and sent to pathology.

Identification and Division of the Posterior (Right) Vagus Nerve

- The posterior vagus is less closely associated with the esophageal wall.

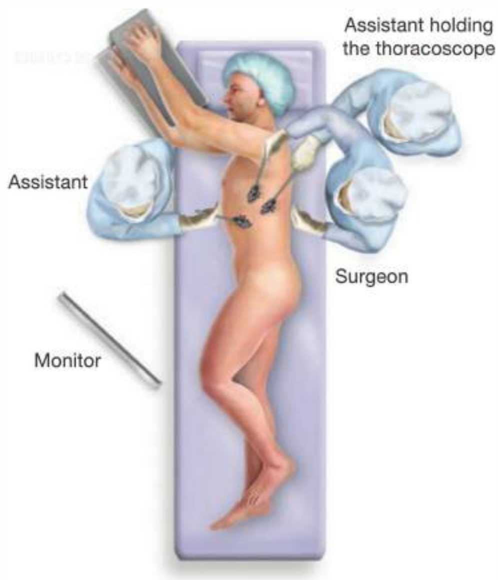


FIG 8 ● Positioning and port placement for the transthoracic vagotomy. Patient is in the right lateral decubitus. Note hand ports are as far away as possible from each other but forming semicircle with video port.

FIG 10 ● Anterior vagus is identified on top of the esophagus. It is carefully dissected by spreading parallel to esophagus and then placed on tension by pulling toward the surgeon. A segment is then clipped for removal and sent to pathology.

- Place gentle upward traction on the esophagus. Using a Maryland dissector, continue to spread parallel to the nerve and esophagus in the retroesophageal plane.
    - Pull vagus again toward the surgeon to tense nerve like a guitar string in order to transect the nerve.
- Using sharp dissection with the Harmonic scalpel or bipolar cautery device, the surgeon should free up 3 to 4 cm of the vagus nerve (**FIG 11**).
- An endoclip should be placed across the nerve at the hiatus and a second clip placed 3 to 4 cm inferior to the first. The portion of the nerve between the clips is then excised and sent to pathology.

Assessment of Hemostasis and Closure

- After hemostasis is ensured, a red rubber should then be inserted through on the camera ports and fed proximally over the lung tissue to act as a chest tube.
- The camera port is then withdrawn and lung reinflated under direct visualization.
- Closure of laparoscopic port sites in usual standard fashion.

FIG 11 ● Gentle traction placed on esophagus to pull anterior in the chest. The posterior vagus nerve is dissected from the tissue below the esophagus. This is again pulled toward surgeon to aid in excision.

HIGHLY SELECTIVE VAGOTOMY

Exposure of Esophagus

- The phrenoesophageal ligament overlying the esophagus is incised and the esophagus is encircled with a Penrose drain.

Exposure of Vagus Nerves, Nerve of Latarjet

- The anterior and posterior vagus nerves are identified and each encircled with a vessel loop. Dissection is carried far enough into the posterior mediastinum to identify main vagal trunks.
- Examine the lesser curvature of the stomach to identify the nerve of Latarjet (**FIG 12**).
- Dissect 6 to 7 cm proximal to the pylorus along the lesser curvature of the stomach at the incisura angularis. It is key to leave the terminal branches of the nerve, referred to as "crow's foot," to maintain innervation to the antrum and pylorus (**FIG 13**).
- Divide the lesser omentum from the lesser curve from the incisura angularis and continue to divide the vagal branches to 6 cm proximal to the GE junction. Stay inside the main vagal braches.
    - Clamp and divide neurovascular branches along the lesser curve as close to the stomach as possible to avoid injury to the nerve of Latarjet (**FIG 14**).
    - There is an anterior and posterior bundle and they should be divided separately.
- Invert the lesser curvature of the stomach with interrupted Lembert sutures.

Hemostasis and Closure

- Midline is closed in usual standard fashion.
- Laparoscopic ports close in usual standard fashion, with fascial closure for port sites greater than 5 mm.

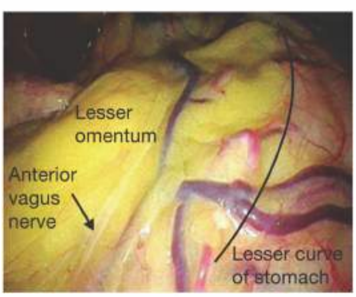


FIG 12 ● Identify the lesser curve of the stomach; see the anterior vagus nerve coursing in on the lesser omentum.

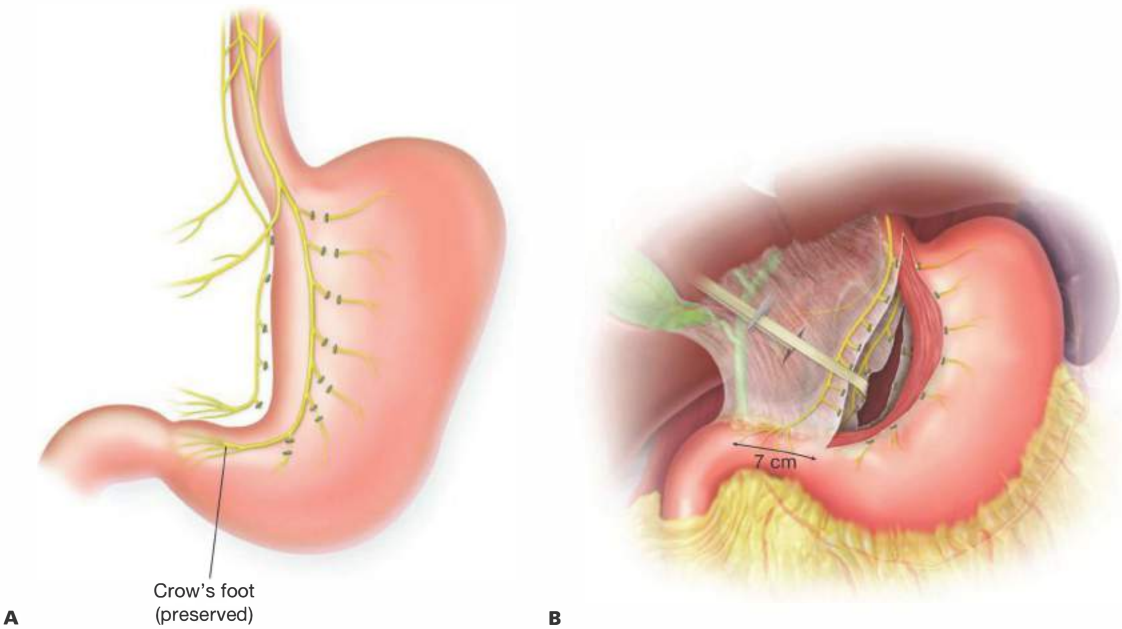


FIG 13 ● **A,B.** Dissection occurs along the lesser curvature of the stomach from proximal to the GE junction to the incisura angularis, 6 to 7 cm proximal to the pylorus. Leave the terminal branches of the nerve, referred to as "crow's foot," to maintain innervation to the antrum and pylorus.

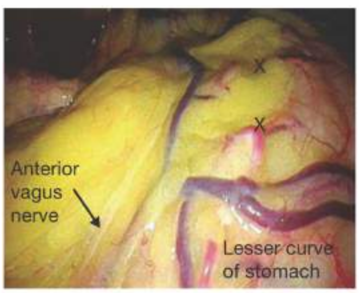


FIG 14 ● Clamp and divide neurovascular branches along the lesser curve as close to the stomach as possible to avoid injury to the nerve of Latarjet. Marked by the *X*. There is an anterior and posterior bundle and they should be divided separately.

PEARLS AND PITFALLS

Indications	■ In patients with evidence of active *H. pylori* infection, treatment of the ulcer complication and antihelicobacter therapy may be sufficient. ■ When the operative indication is GI bleeding, the surgeon should verify if the bleeding source is in a location associated with a high acid state such as the duodenum or prepyloric stomach.
Exposure	■ Take caution when encircling the esophagus and dissecting the vagus off of the esophagus to prevent injury. ■ Avoid the use of cautery when dissecting the vagal fibers away from the esophageal surface.
Vagotomy	■ Ten percent of patients will have more than one anterior or posterior vagal trunks; care must be taken to look for additional fibers after division of the first trunk. ■ Always send a section of the excised vagal trunk to pathology to verify that nervous tissue was excised. ■ Most ulcer reoccurrences result from incomplete vagotomy. ■ Care to resect above the criminal nerve of Grassi (**FIG 15**) ■ Injury to thoracic duct in transthoracic approach

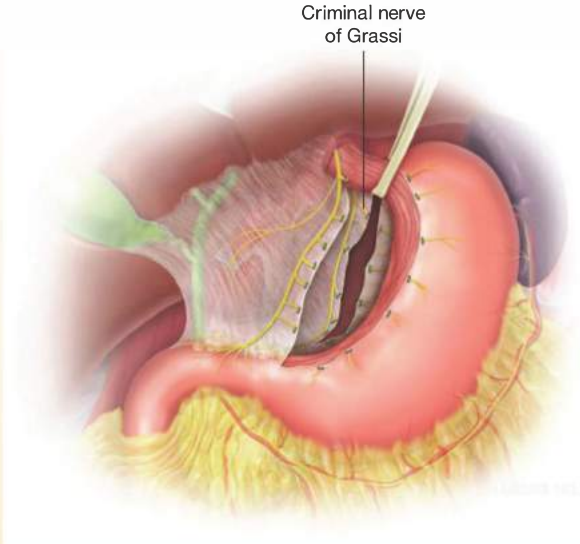


FIG 15 ● Criminal nerve of Grassi—Vagus nerve must be dissected proximal to criminal nerve of Grassi which, if undivided, can keep high acid levels postvagotomy.

Drainage procedure	■ A drainage procedure, a pyloroplasty, gastrojejunostomy, or antrectomy should always be combined with a truncal vagotomy as up to one-third of patients will develop gastric stasis after vagotomy alone.
Paraesophageal herniation	■ Inspect the esophageal hiatus at the conclusion of the procedure to verify that an iatrogenic paraesophageal hernia has not been created.

POSTOPERATIVE CARE

- Nasogastric suction may be used in the early postoperative period. In patient who has undergone gastric drainage procedure or perforation repair, postoperative ileus may last as long as 7 to 10 days.
- Consistent with other foregut surgery, diet advancement is as tolerated.
- Intolerance to diet should prompt investigation for delayed gastric emptying.
- In patients operated on for perforated ulcers, broad-spectrum antibiotic therapy including antifungal agents should be administered postoperatively.
- Patients who are found to be *H. pylori* positive should receive 10 to 14 days of antibiotic therapy directed at *H. pylori* eradication. Eradication should be confirmed by repeat testing.
- Patients operated on for bleeding should be carefully monitored for rebleeding for up to 96 hours.
- Patients chronically using NSAIDS or aspirin products should be counseled to avoid further use of these medications. Patients who are medically unable to discontinue these drugs should be started on a PPI.
- Transthoracic patients should be monitored with daily chest radiographs until the chest tube is removed appropriately.

OUTCOMES

- **Vagotomy**
  - Truncal vagotomy has demonstrated 80% reduction in basal acid secretion.[7]
  - Truncal vagotomy has the lowest reoccurrence rates (1% to 10%) but have the highest morbidity (20% to 25%) and mortality (0.5% to 2%).[8,9] Ulcer recurrence rates also vary based on drainage procedure, with best results from total vagotomy with antrectomy.
  - Common postoperative morbidity includes diarrhea (10% to 25%), dumping syndrome (10% to 20%), and bile reflux gastritis (2%).[8,9]
  - Vagal-mediated receptive relaxation of the stomach is abolished; there may be more rapid emptying of liquids and solids.
- **HSV**
  - Lower mortality and morbidity including diarrhea and dumping syndrome (1% to 5%).[3]
  - Higher ulcer recurrence rates, greater than 10% at 5 years.[3]
  - Vagal-mediated receptive relaxation of the stomach is abolished, and therefore, there is more rapid emptying of liquids. However, with preservation of antrum innervation, emptying of solids is unaffected.

COMPLICATIONS

- Esophageal perforation
- Bleeding
- Incomplete vagotomy—failure to identify accessory vagus nerves. Vagus must be taken proximal to the criminal nerve of Grassi, the first gastric branch of the posterior vagus.
- Delayed gastric emptying
- Dumping syndrome
- Pleural effusion

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Chapter 9

Drainage Procedures: Pyloromyotomy, Pyloroplasty, Gastrojejunostomy

George A. Sarosi, Jr.

DEFINITION

- Drainage procedures, or more properly gastric drainage procedures, are a variety of surgical approaches used to either render incompetent or bypass the pylorus. Drainage procedures are often performed in conjunction with procedures that interrupt vagal innervation of the pylorus, and the purpose is to facilitate gastric drainage. Originally performed in conjunction with a truncal vagotomy for the treatment of peptic ulcer disease, drainage procedures are also performed to facilitate gastric emptying when the stomach is used as an esophageal replacement and occasionally to address poor gastric emptying in patients who have undergone fundoplication or paraesophageal hernia repair. Gastrojejunostomy is also frequently used to treat duodenal or gastric outlet obstruction.

DIFFERENTIAL DIAGNOSIS

- In patients who have undergone prior gastroesophageal (GE) junction surgery, the differential diagnosis for abdominal bloating includes visceral hypersensitivity (irritable bowel syndrome [IBS]), gastroparesis, postsurgical delayed gastric emptying secondary to vagal injury, paraesophageal herniation of the fundoplication or portions of the stomach, and overeating or excess consumption of inappropriate foods such as carbonated beverages.
- In patients who have undergone esophageal replacement with a gastric conduit, the differential diagnosis of dysphagia, early satiety, or regurgitation of undigested foods includes anastomotic structure, an inadequate-sized hiatal opening, torsion of the conduit, paraesophageal hernia, and competent pylorus.

PATIENT HISTORY AND PHYSICAL FINDINGS

- Depending on the indication for a drainage procedure, certain historical elements and physical findings should be sought.
  - For patients with peptic ulcer disease, the duration of symptoms and any prior treatment of peptic ulcer disease should be sought. In addition, knowledge of the patients' *Helicobacter pylori* status and prior *H. pylori* treatment is important. Finally, a history of use of nonsteroidal antiinflammatory drugs (NSAIDs) or aspirin products should be sought.
    - In patients with a prior history of peptic ulcer disease who are undergoing surgical treatment of a bleeding ulcer, a history of prior ulcer disease should alert the surgeon to the possibility of encountering a scarred and possibly fibrotic duodenum.
    - Patients known to be *H. pylori* positive who have not had treatment for their *H. pylori* may not require an acid-reducing procedure at the time of surgical bleeding control. Simple ligation of the bleeding site may be sufficient.
    - Patients with a significant history of NSAID or aspirin product use are at a significant risk of recurrent ulcers and must be counseled to avoid all these products in the future.
  - For patients undergoing drainage procedures after esophageal replacement with a gastric conduit, patients should be questioned carefully about their symptoms. Patients with poor gastric drainage will describe early satiety, bloating, regurgitation, or emesis of undigested food. Patients with anastomotic strictures typically will describe dysphagia.
  - For patients undergoing or who have undergone a fundoplication, a history of postprandial abdominal pain, bloating, or early satiety should be sought, as this can be a symptom of poor gastric emptying, which can be confirmed with a gastric emptying study.

IMAGING AND OTHER DIAGNOSTIC STUDIES

- In patients undergoing emergency operations for upper gastrointestinal hemorrhage, all patients should undergo esophagogastroduodenoscopy (EGD) prior to operation with an attempt at endoscopic hemostasis. The operating surgeon should make every effort to be present during the endoscopy, as accurate anatomic information regarding the location of the ulcer will facilitate the operation.
- In patients suspected of having poor emptying of their gastric conduit after esophageal replacement, gastric emptying studies are of limited use due to the altered anatomy and the lack of reference values for emptying. The author has used EGD and botulinum toxin injection as a diagnostic test for patients with poor emptying of the conduit.[1] Those who have an improvement in symptoms have been offered surgical drainage procedures.
- In patients with prior fundoplication or paraesophageal hernia repair suspected of having delayed gastric emptying, nuclear medicine gastric emptying studies are helpful in identifying patients who could benefit from a drainage procedure. Hamrick et al.,[2] in a large series of revisional paraesophageal hernia patients, used a T1/2 emptying time of 90 minutes as an indication for the addition of a gastric drainage procedure with good results. Alternatively, EGD and botulinum toxin injection of the pylorus can also be used as a diagnostic study.

SURGICAL MANAGEMENT

Preoperative Planning

- Patients undergoing drainage procedures will have poor gastric emptying and will be at risk for aspiration during induction of anesthesia. For elective procedures, patients should be placed on a clear liquid diet 24 hours prior to surgery and made NPO the night before the procedure. Patients undergoing emergency surgery for peptic ulcer bleeding will have a stomach full of blood and are at significant risk of aspiration. Whenever feasible, rapid sequence induction should be used. Antibiotic prophylaxis with 1 to 2 g of cefazolin is the standard approach; clindamycin plus a fluoroquinolone or aminoglycoside is the appropriate choice for those patients with allergies to cefazolin. When performing an emergency operation for bleeding, the surgeon should ensure that blood is crossmatched and available. For laparoscopic procedures, having the ability to perform intraoperative EGD can facilitate the identification of the pylorus and bleeding source in difficult cases.

Positioning

- For open drainage procedures, the patient is positioned in the supine position with both arms extended. Space is left on the patient's left side to attach a Buchwalter or Omni retractor to the bed rail. During the surgical procedure, the patient will often be placed in reverse Trendelenburg to facilitate exposure of the upper abdominal organs. In a laparoscopic approach, the same position is used, but a footboard and safety strap should also be added to prevent the patient from sliding when steep reverse Trendelenburg position is used.

OPEN PYLOROPLASTY

Skin Incision and Retractor Positioning

- An upper midline incision is used for all open drainage procedures. This should begin at the level of the umbilicus and extend to just below the xiphoid process. Body wall retractor blades are placed on either side of the upper half of the incision to facilitate exposure. If necessary, a malleable or Harrington retractor blade can be placed on the left lobe of the liver to expose the pylorus (FIG 1).

Kocher Maneuver

- A Kocher maneuver is performed to facilitate exposure of the duodenum and pylorus and to eliminate tension on the suture line. A forceps is used to grasp the peritoneum lateral to the duodenum, which is then incised with scissors or the electrosurgical device. The surgeon then can insert an index finger behind the duodenum and head of the pancreas and sweep the finger to the right, elevating the lateral duodenal ligament and avascular retroperitoneal tissues, which can then be divided with the electrosurgical device (FIG 2). The plane of dissection should remain close to the duodenal wall to avoid injury to the gonadal vein on the anterior surface of the inferior vena cava. The duodenum and head of the pancreas should be mobilized from the junction of the duodenal bulb and second portion of the duodenum to just before the lateral aspect of the superior mesenteric vein. If the procedure is being performed for a bleeding duodenal ulcer, the Kocher maneuver step can be deferred until after control of the bleeding vessel has been achieved.

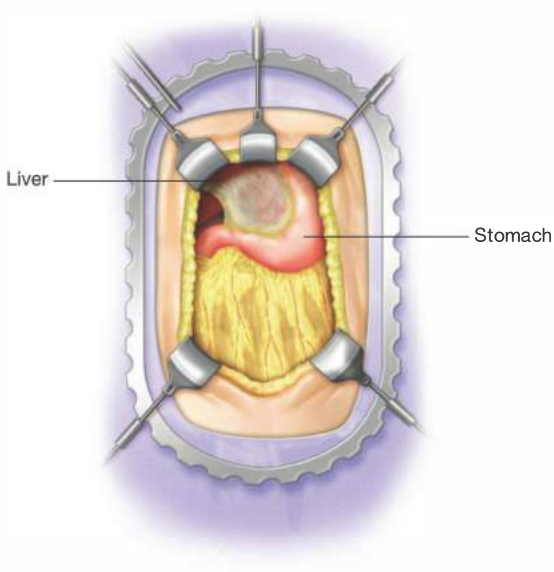


FIG 1 ● A Bookwalter style self-retaining retractor provides excellent exposure of the stomach and duodenum for drainage procedures. Placement of four abdominal wall blades, two on either side of the upper and lower aspect of the wound, will provide the optimum exposure. A Harrington or malleable retractor on the left lobe of the liver can facilitate exposure.

Pyloric Incision

- The pylorus is identified either visually or by palpation of the muscular ring with a finger inserted from the gastric side. Beginning roughly 2 cm proximal to the pylorus on the gastric antrum, incise the gastric wall, enter the lumen, and extend the incision distally parallel to the long axis of the bowel across the pylorus onto the duodenum to distance of roughly 5 cm using the electrosurgical device (FIG 3). This incision will provide reasonable exposure of the duodenal bulb. If the operation is being performed for ulcer bleeding, the incision can be extended further along the duodenum to expose the bleeding site. The pyloroplasty incision can be facilitated by placing a seromuscular stay stitch on the superior and inferior edge of the pylorus.

Bleeding Control

- If the operation is being performed for a bleeding duodenal ulcer, the ulcer is identified on the posterior aspect of the duodenal bulb. Temporary hemostasis is achieved by digital pressure, and then definitive hemostasis is achieved by placing three 2-0 silk suture ligatures. The first suture is placed at the cranial margin of the ulcer, encircling the proximal gastroduodenal artery (GDA). The second suture is placed at the caudal edge of the duodenal ulcer encircling the distal GDA. The final suture is a U suture placed underneath the ulcer crater to control the posterior entry of the transverse pancreatic artery into the back wall of the GDA (FIG 4).

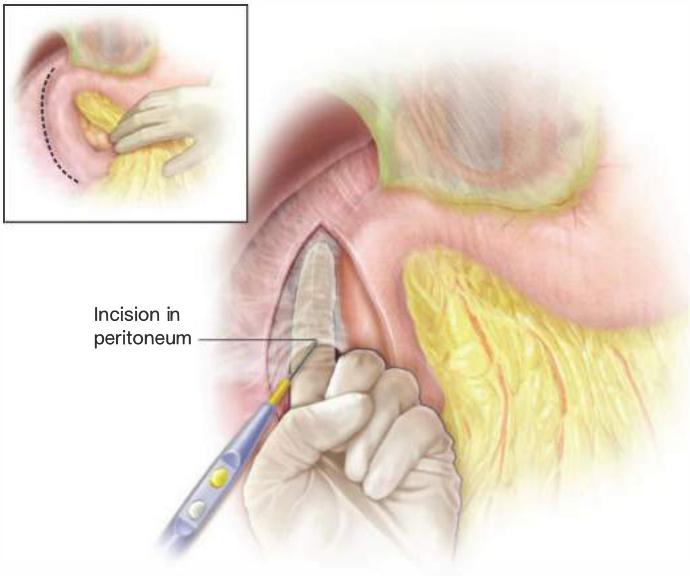


FIG 2 ● Application of leftward traction on the stomach and duodenum will allow the surgeon to score the peritoneum lateral to the duodenum with the electrosurgical device as shown in the *inset*. The surgeon's index finger can then bluntly elevate the avascular tissues between the duodenum, pancreas, and vena cava, making division of these tissues with the electrosurgical device easy.

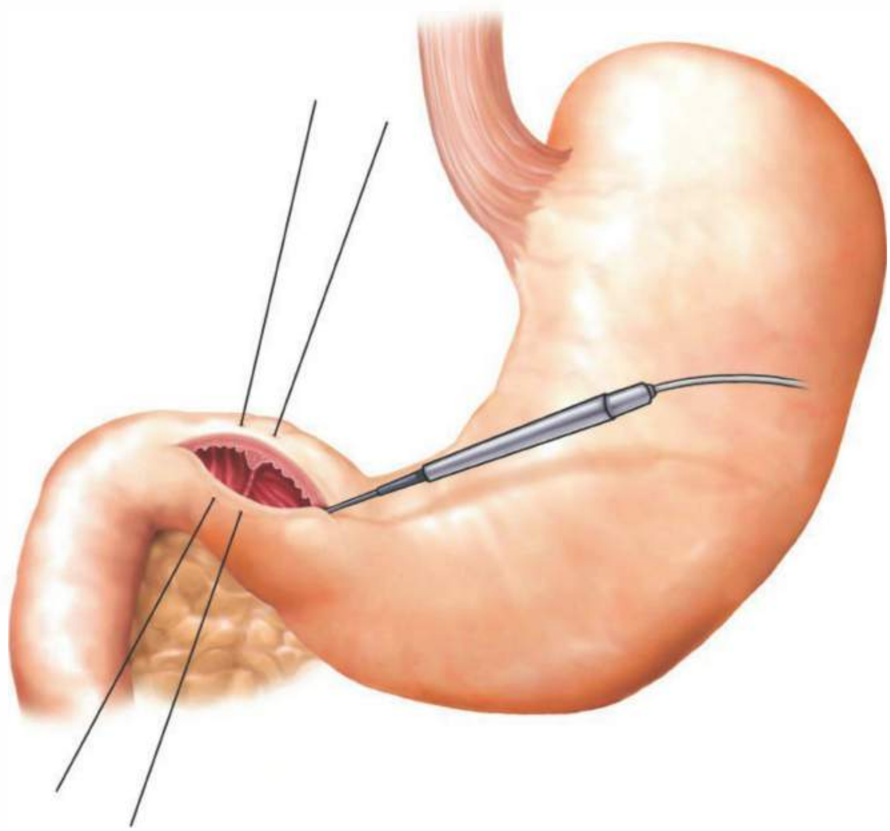


FIG 3 ● Placing silk stay sutures superior and inferior to the proposed pyloroplasty incision will make the entry into the duodenum easier. (From Nussbaum MS. *Master Techniques in Surgery: Gastric Surgery.* Philadelphia, PA: Lippincott Williams & Wilkins; 2013.)

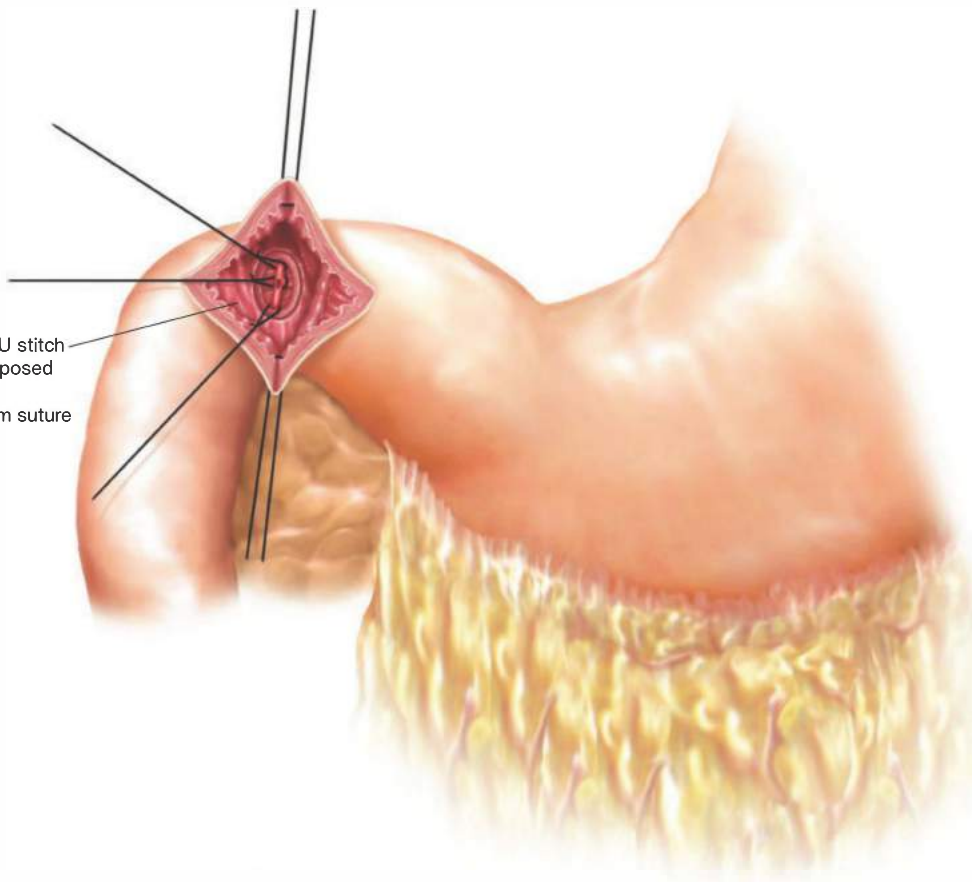


FIG 4 ● When operating to ulcer bleeding, placing the pyloroplasty incision directly over the ulcer crater will optimize exposure. Control of bleeding from the GDA is achieved with three sutures. A simple or figure-of-eight suture is placed at the cranial and caudal edge of the ulcer to ligate the trunk of the GDA. A third horizontal U stitch is placed under the ulcer crater to control the transverse pancreatic branches. GDA, gastroduodenal artery. (From Nussbaum MS. *Master Techniques in Surgery: Gastric Surgery*. Philadelphia, PA: Lippincott Williams & Wilkins; 2013.)

Closure of Pyloroplasty—Heineke-Mikulicz

- The most common closure of the pyloroplasty is the Heineke-Mikulicz approach, closing the longitudinal pyloroplasty with a single layer of sutures in a transverse fashion. This closure is appropriate when the duodenum is not distorted or scarred and the pyloroplasty incision is shorter than 6 to 7 cm. The closure is performed by applying superior and inferior traction on the stay sutures, converting the longitudinal gastroduodenal incision into a transverse incision. The incision is then closed with interrupted 3-0 silk sutures or 3-0 polyglycolic acid sutures with either a full-thickness simple stitch or a Gambee stitch. The closure is best performed by starting at the top corner of the incision and alternating from the top to the bottom proceeding toward the middle. The sutures may be tied as they are placed until the last three sutures, which should be left untied until all of the sutures are placed to ensure that the mucosal layer is included in all of the bites (**FIG 5**). A vascularized pedicle of omentum is then placed over the closure and the stay sutures tied over the omental pedicle to hold it in place in the fashion of a Graham patch.

Closure of Pyloroplasty—Finney

- If the duodenum is significantly inflamed or scarred from chronic peptic ulceration or if a longer duodenotomy is required to obtain hemostasis on a bleeding source beyond the duodenal bulb, a Finney closure of the pylorus is appropriate to prevent tension on the closure and gastric outlet obstruction. The Finney closure is in essence a side-to-side gastroduodenostomy with the pylorus at the cranial apex of the anastomosis. The duodenum will need to be completely mobilized to allow

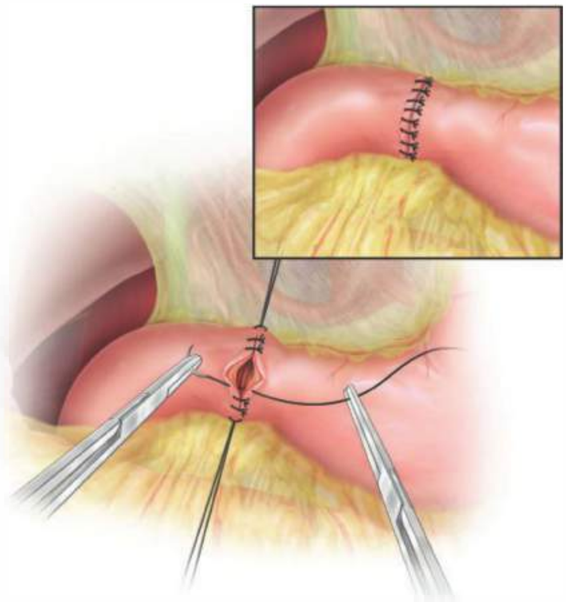


FIG 5 ● With traction applied to the stay sutures, the longitudinal pyloroplasty is closed transversely using interrupted sutures alternating from either end of the closure. The *inset* shows the completed closure.

this closure to be tension free. Remove the inferior stay suture and apply cranial tension on the superior stay suture to convert the longitudinal incision into an inverted U shape. The Finney closure is a standard two-layered anastomosis. A back row of interrupted 3-0 silk seromuscular (Lembert) sutures is placed between the inferior edge of the duodenum and the gastric wall (**FIG 6A**). These sutures should be placed 5 to 10 mm from the cut edge of the mucosa. It is often necessary to extend the incision on the gastric side of the pylorus to ensure that the lengths of the two arms of the incision are equal. When extending the pyloroplasty in this fashion, it is advisable to cheat toward the greater curvature of the stomach. Next, begin the inner layer of the closure using a 3-0 polyglycolic acid running suture beginning at the divided pylorus muscle, suturing the inferior edge of the duodenum to the inferior edge of the stomach (**FIG 6B**). Run this suture around the inferior edge of the closure onto the anterior edge of the gastroduodenal anastomosis. Next, begin a second running 3-0 polyglycolic acid at the superior edge of the cut pylorus, suturing the superior edge of the duodenum to the stomach and running toward the other suture (**FIG 7A**). Many surgeons prefer to use a Connell suture on the anterior wall to achieve better mucosal inversion. Tie the two sutures and then complete the pyloroplasty closure with an anterior layer of interrupted 3-0 silk seromuscular sutures (**FIG 7B**).

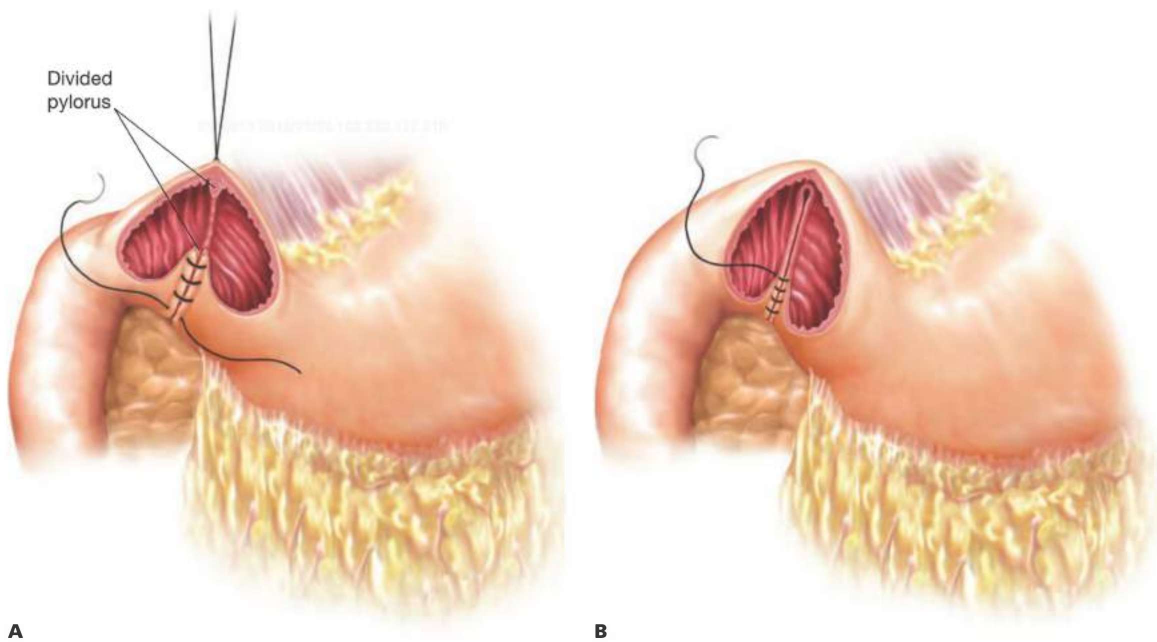


FIG 6 ● **A.** With superior traction on the superior stay suture, the back row of the Finney pyloroplasty is created by approximating the duodenum to the greater curvature of the stomach with seromuscular sutures. **B.** The back portion of the inner row is begun using a running suture approximating the duodenal mucosa to the gastric mucosa beginning at the inferior edge of the transected pylorus. This suture is then run up to the anterior surface of the pyloroplasty.

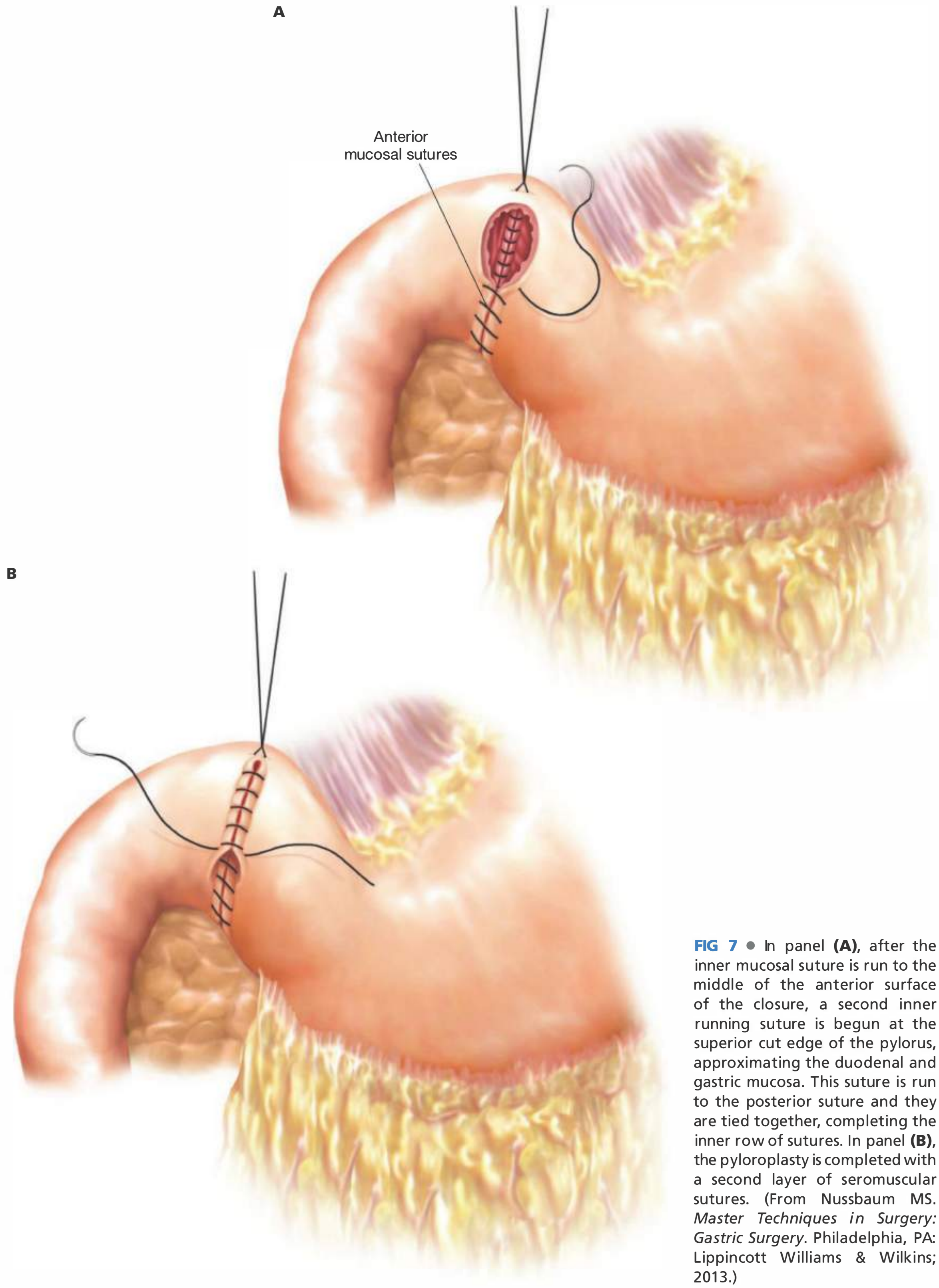


FIG 7 ● In panel **(A)**, after the inner mucosal suture is run to the middle of the anterior surface of the closure, a second inner running suture is begun at the superior cut edge of the pylorus, approximating the duodenal and gastric mucosa. This suture is run to the posterior suture and they are tied together, completing the inner row of sutures. In panel **(B)**, the pyloroplasty is completed with a second layer of seromuscular sutures. (From Nussbaum MS. *Master Techniques in Surgery: Gastric Surgery*. Philadelphia, PA: Lippincott Williams & Wilkins; 2013.)

OPEN PYLOROMYOTOMY

Incision and Identification of the Pylorus

- An upper midline incision and fixed retractor is used as described previously for pyloroplasty (**FIG 1**). The pylorus is identified either visually or by palpation of the muscular ring with a finger inserted from the gastric side.

Serosal Incision and Division of Muscular Fibers

- A 3-cm long longitudinal serosal incision is made across the pylorus, beginning 1 to 2 cm proximal to the pylorus on the gastric side and extending 1 cm distal to the pylorus. This serosal incision can be performed either with a knife or an electrosurgical device (**FIG 8A**). If the electrosurgical device is used, care should be exercised to avoid deep penetration into the muscularis and thermal injury to the mucosa. Beginning on the gastric side of the incision, use a fine tipped hemostat to dissect the muscular fibers off of the submucosa and divide the circular muscular fibers with a knife (**FIG 8B**). Muscular bleeders can usually be controlled with pressure, and there is a very limited role for cautery at this point of the operation. Great care should be taken to avoid mucosal injury especially on the duodenal side, as the submucosa is thinner and more fragile. When properly performed, the mucosa and submucosa will bulge out of the incision (**FIG 8C**).

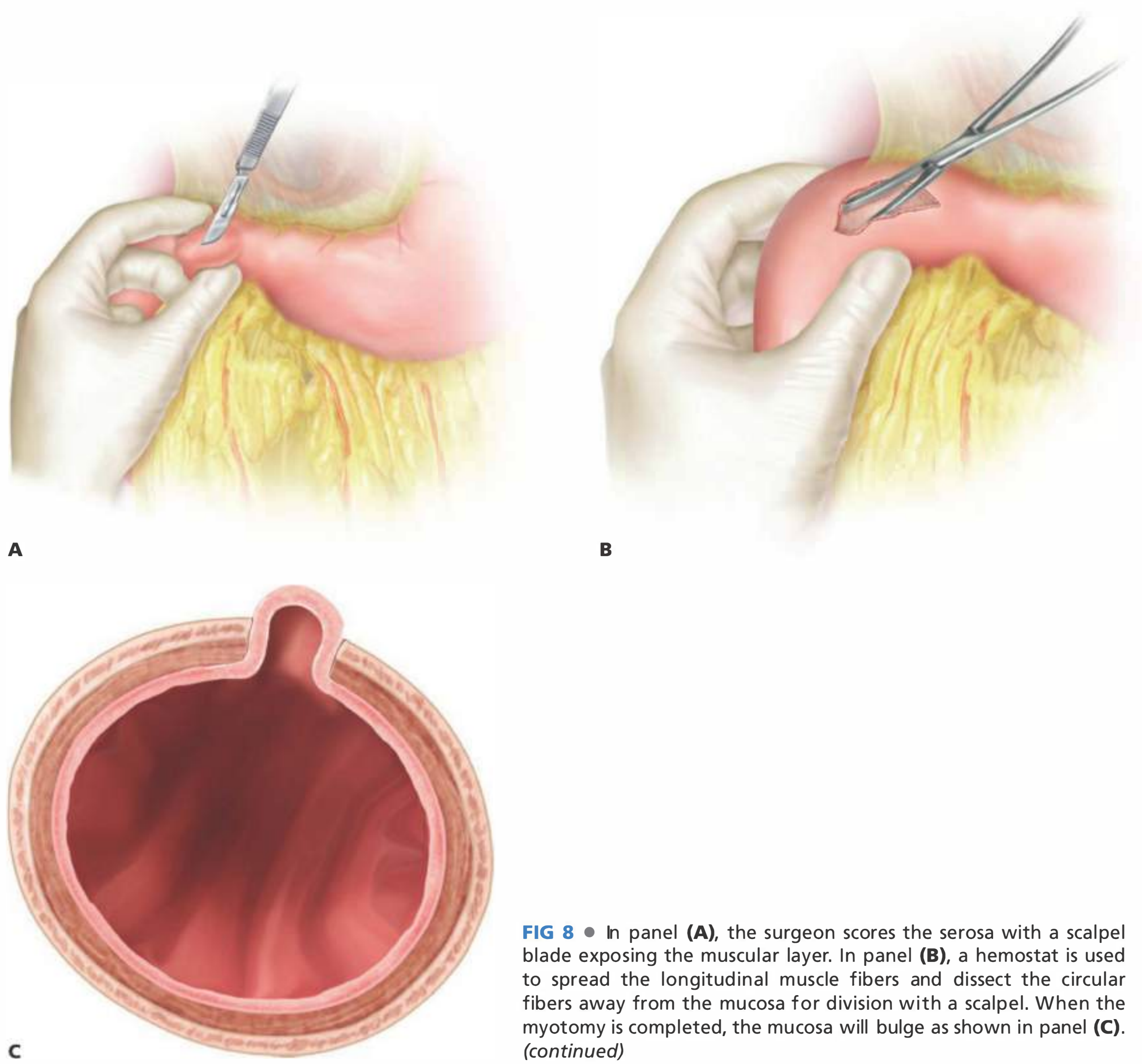
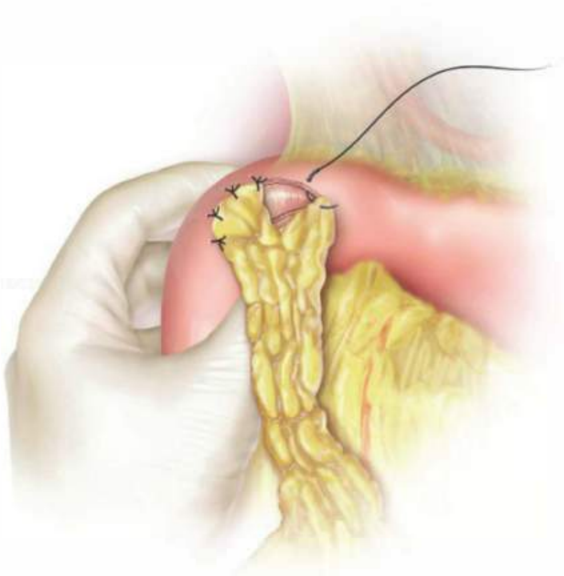


FIG 8 ● In panel **(A)**, the surgeon scores the serosa with a scalpel blade exposing the muscular layer. In panel **(B)**, a hemostat is used to spread the longitudinal muscle fibers and dissect the circular fibers away from the mucosa for division with a scalpel. When the myotomy is completed, the mucosa will bulge as shown in panel **(C)**. *(continued)*



D

FIG 8 ● *(continued)* An omental patch is then sewn to the serosal edges of the myotomy to cover the mucosa in as shown in panel **(D).**

Omental Patch

- A vascularized pedicle of omentum is placed over the pyloromyotomy and sutured with three 3-0 silk sutures. The first is placed through the superior edge of the divided pyloric ring and the superior edge of the omental pedicle to prevent the two cut edges of the pylorus from coming into contact. The next two are placed between each lateral edge of the serosal incision and the lateral edges of the omental patch to ensure that the patch covers the entire pyloromyotomy (**FIG 8D**).

OPEN GASTROJEJUNOSTOMY

Skin Incision and Retractor Positioning

- An upper midline incision is used for all open drainage procedures. This should begin at the level of the umbilicus and extend to just below the xiphoid process. Body wall retractor blades are placed on either side of the upper half of the incision to facilitate exposure (**FIG 1**). If necessary, a malleable or Harrington retractor blade can be placed on the left lobe of the liver to expose the stomach and pyloric region.

Preparation of the Stomach and Identification of Proximal Jejunum

- There is insufficient evidence to recommend a posterior gastrojejunostomy over an anterior gastrojejunostomy, and an antecolic, anterior gastric wall gastrojejunostomy is the easiest to create. Identify the pylorus, and then identify a point, 5 cm proximal to the pylorus, as the gastric site of the anastomosis. Next, identify the ligament of Treitz, and select a section of the jejunum 15 to 30 cm distal to the ligament of Treitz, which will easily reach the distal stomach without tension.

Construction of the Anastomosis

- A standard double-layered side-to-side anastomosis is constructed by aligning the small bowel with the stomach in an isoperistaltic fashion, with the distal portion of the small bowel located closest to the pylorus. The back row of the anastomosis is first created by suturing the jejunum to the greater curvature of the stomach using seromuscular 3-0 silk interrupted sutures. The tails of the sutures at either corner are left long to allow them to be used as stay sutures (**FIG 9A**). Using the electrosurgical device, a full-thickness jejunotomy is made in the small bowel, and a gastrotomy is made in the stomach roughly 5 mm from the outer layer of the anastomosis (**FIG 9B**). Beginning in the middle of the posterior portion of the anastomosis, the inner layer of the anastomosis is constructed by running two 3-0 polyglycolic acid sutures from the middle of the back row in opposite directions (**FIG 10A**). Many surgeons prefer to use Connell sutures on the anterior row to achieve better eversion, but this step is not necessary (**FIG 10B**). The anastomosis is completed with an outer anterior layer of seromuscular 3-0 silk interrupted sutures.

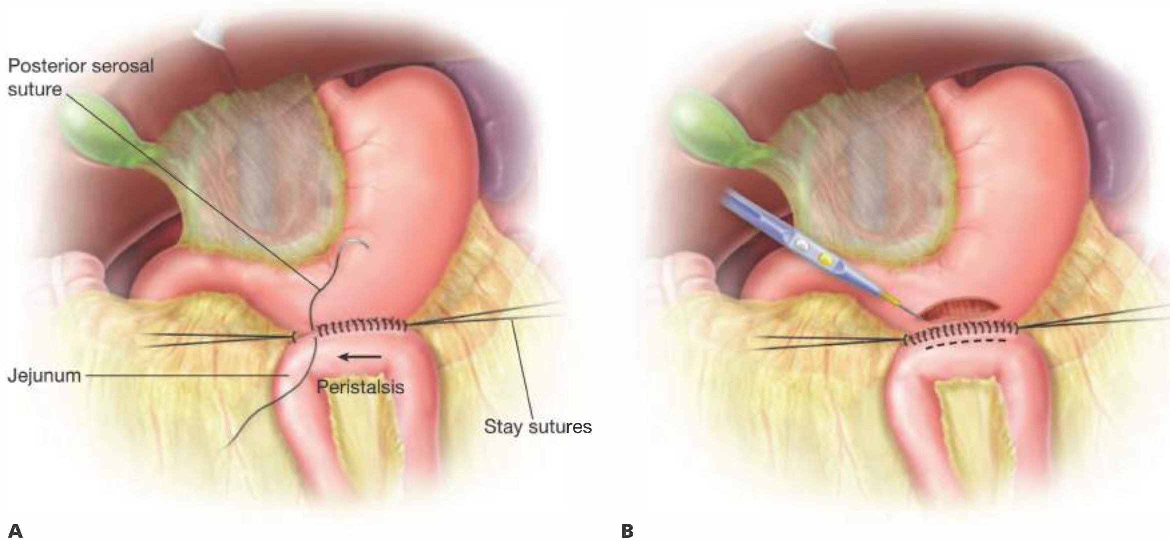


FIG 9 ● An antecolic, isoperistaltic gastrojejunostomy is begun by placing a back row of seromuscular sutures between the greater curvature of the stomach and the antimesenteric edge of the jejunum over a distance of 8 cm and shown in panel **(A)**. The stomach and the jejunum are then opened with the electrosurgical device in panel **(B)**.

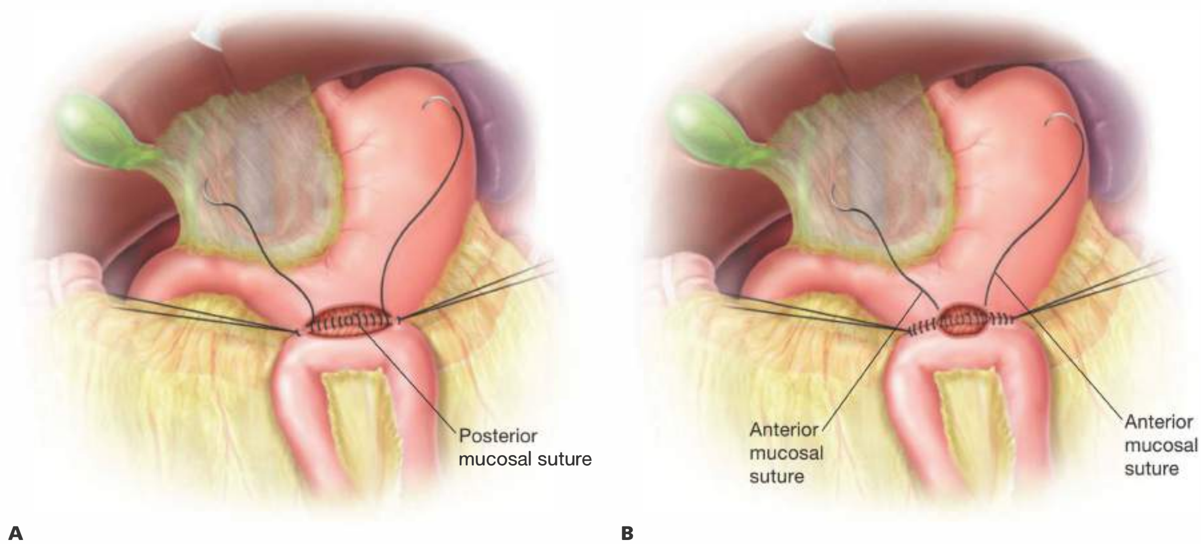


FIG 10 ● A double-armed suture is placed in the center of the back row of the anastomosis and run to the corners of each side as shown in panel **(A)**. This same suture is then run to the middle of the anterior row as shown in panel **(B)**. The anterior row can either be Connell sutures or simple sutures based on surgeon preference.

LAPAROSCOPIC PYLOROPLASTY

Port Placement and Liver Retraction

- We use a standard four-trocar approach for gastric procedures, with a 5-mm port in the left upper quadrant, a second 5-mm trocar just to the left of the umbilicus, a 12-mm trocar at the level of the umbilicus in the midclavicular line, and a 5-mm trocar in the right upper quadrant. A Nathanson liver retractor is placed to elevate the left lobe of the liver (**FIG 11**).

Identification of the Pylorus and Pyloric Incision

- The pylorus is identified either visually or by performing an EGD with CO_2 insufflation. Placing a 3-0 silk seromuscular stay suture at the superior and inferior edge of the duodenum at the level of the pylorus will facilitate the rest of the operation. Beginning roughly 2 cm proximal to the pylorus on the gastric antrum, incise the gastric wall, enter the lumen, and extend the incision distally parallel to the long axis of the bowel across the pylorus onto the duodenum to a total distance of roughly 5 cm using the electrosurgical device or an ultrasonic dissector (**FIG 12**).

Closure of the Pyloroplasty

- The assistant grasps the superior stay suture and applies cranial and leftward traction to convert the longitudinal incision into a transversely oriented closure. The surgeon then begins at the superior aspect of the duodenum and begins the closure. The easiest method is a running closure with 3-0 or 2-0 silk or polyglycolic suture. The surgeon should run this suture toward the inferior aspect of the duodenum stopping about two-thirds of the way down. A laparoscopic clip is placed on the suture to maintain tension while the surgeon focuses on the lower aspect of the closure. A second suture is then run

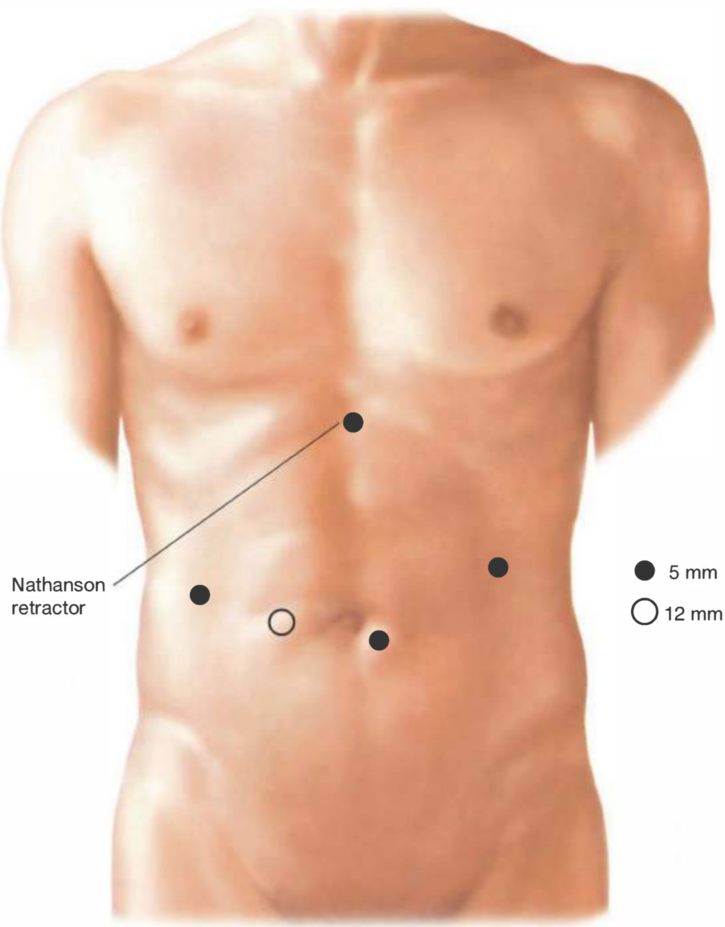


FIG 11 ● Shown is the standard port placement used for all laparoscopic drainage procedures. The surgeon stands on the patient's right. The first port placed is the left upper quadrant 5-mm port, which will be the assistant's instrument. The left periumbilical port is for the camera, and right 12-mm port is for the surgeon's dominant hand instrument. The lateral right port is for the surgeon's nondominant hand. A Nathanson liver retractor is placed in the subxiphoid position to retract the left lobe of the liver. (From Nussbaum MS. *Master Techniques in Surgery: Gastric Surgery*. Philadelphia, PA: Lippincott Williams & Wilkins; 2013.)

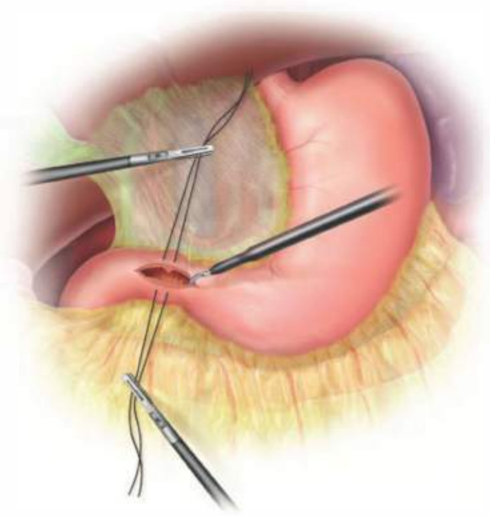


FIG 12 ● Two stay sutures are placed above and below the proposed pyloroplasty incision. The surgeon retracts the superior suture with their nondominant hand, and the assistant retracts the inferior suture from the far left port. A hooked cautery is then used to incise the pylorus beginning from the gastric side.

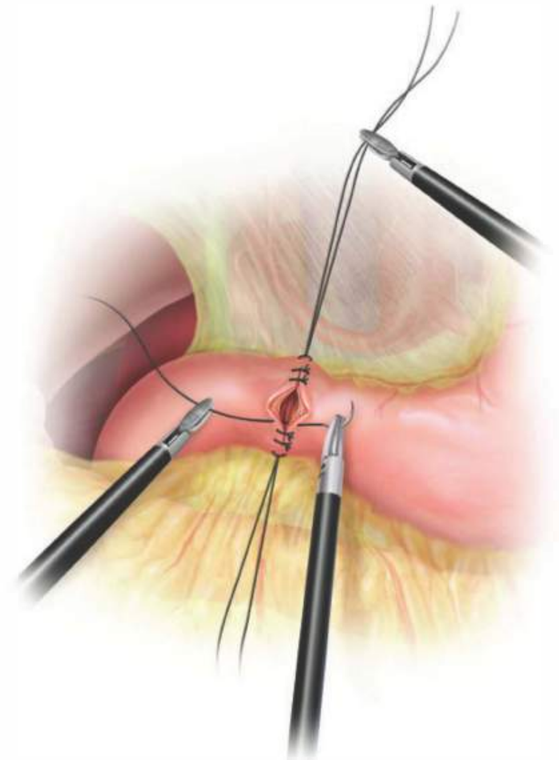


FIG 13 ● Although the assistant provides cranial traction on the superior stay suture to convert the longitudinal pyloroplasty incision into a transversely oriented incision, the surgeon closes the pyloroplasty with either interrupted or running sutures.

from the inferior edge of the pyloroplasty to the middle and tied to the upper suture after first removing the clip from the suture. The assistant can facilitate the suturing angles by retracting the inferior stay suture caudal and rightward. An alternative approach is to perform an interrupted closure. This allows for more precise suture placement but requires more intracorporeal knot tying (**FIG 13**). With an interrupted closure, alternating sutures from the either end and tying after placing each suture allows for precise suture placement. The last suture will be placed blindly, but if the assistant applies cranial traction on the tail of the suture just superior to the last one, it reduces the likelihood of back-walling the duodenum. Methylene blue can be placed into the distal stomach via the EGD scope to ensure the pyloroplasty closure is water tight.

Omental Patch

- The author then covers the completed pyloroplasty suture line with a vascularized pedicle of omentum, which is secured in place by tying the superior and inferior stay sutures over the pedicle in the fashion of a Graham patch. This is easier to perform and less likely to narrow the pyloric outlet than a second layer of seromuscular sutures.

LAPAROSCOPIC GASTROJEJUNOSTOMY

Port Placement

- We use a standard four-trocar approach for most gastric procedures, with a 5-mm port in the left upper quadrant, a second 5-mm trocar just to the left of the umbilicus, a 12-mm trocar at the level of the umbilicus in the midclavicular line, and a 12-mm trocar in the right upper quadrant. A Nathanson liver retractor is sometimes placed to elevate the left lobe of the liver and facilitate exposure of the anterior and inferior gastric wall (**FIG 11**).

Preparation of the Stomach and Identification of Proximal Jejunum

- First, identify the pylorus by either palpation with a grasper or by performing an intraoperative EGD. Identify a point 5 cm proximal to the pylorus, and then select a section of the jejunum 15 to 30 cm distal to the ligament of Treitz, which will easily reach the distal stomach without tension in an antecolic fashion.

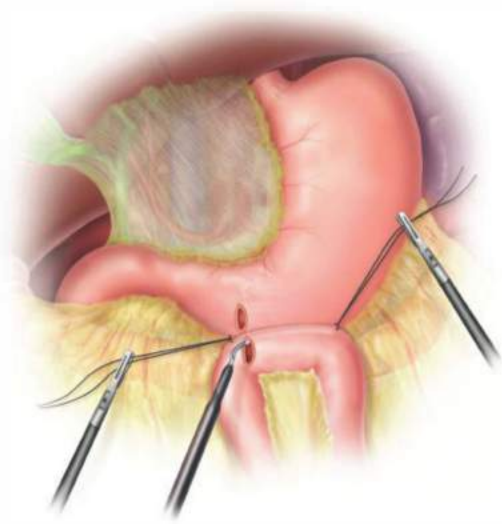
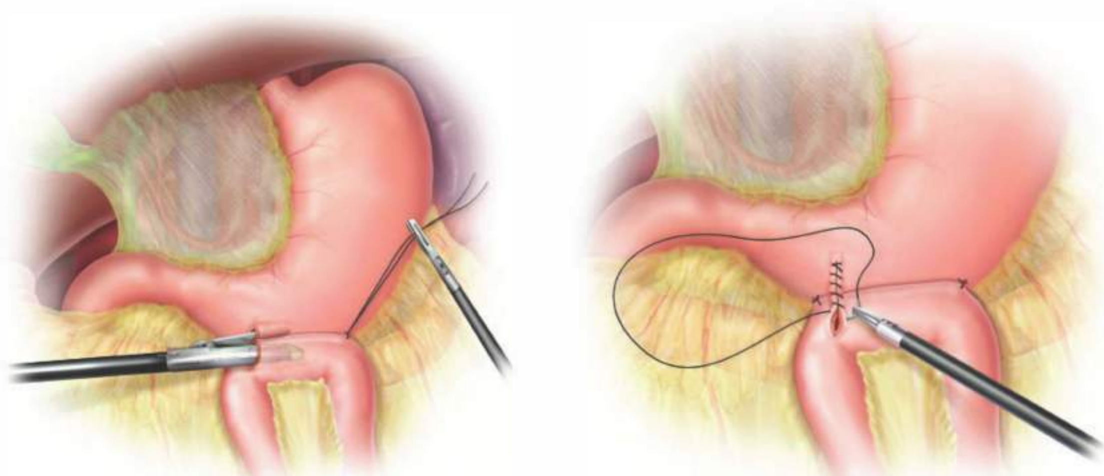


FIG 14 ● Two sutures are used to approximate the selected segment of jejunum to the greater curvature of the stomach in an antecolic, isoperistaltic fashion. With the assistant providing cranial traction from the left on the proximal suture and the surgeon providing caudal and rightward traction, the hooked cautery is used to make a full thickness open in the stomach and jejunum for insertion of a linear endocutting stapler.

Construction of the Anastomosis

- A stapled side-to-side gastrojejunostomy is then constructed in an isoperistaltic fashion by aligning the distal portion of the small bowel with the pyloric side of the stomach. Placement of two interrupted 2-0 silk seromuscular sutures between the greater curvature of the stomach and the small bowel 6 cm apart serves to align the bowel for the stapled anastomosis. Using the electrosurgical device, an enterotomy is made in the stomach and small bowel (**FIG 14**). A 60-mm Endo GIA stapler is inserted via the most lateral right side port and fired to construct the anastomosis (**FIG 15A**). A blue or green load of the stapler device should be used depending on the thickness of the stomach. The common enterotomy is then closed using two 3-0 polyglycolic acid sutures in either a running fashion or an interrupted fashion as described for pyloroplasty (**FIG 15B**). A second layer of seromuscular 3-0 silk Lembert sutures is placed to complete the closure of the common enterotomy.



A B

FIG 15 ● In panel **(A)**, a blue or green load 60-mm endostapler is fired to construct the anastomosis. In panel **(B)**, the common enterotomy defect is then closed in two layers with sutures. The assistant can facilitate the suturing with cranial traction on the distal stay suture.

PEARLS AND PITFALLS

Indications	■ When performing a drainage procedure for delayed gastric emptying with a fundoplication, documentation of poor emptying with a gastric emptying study is strongly recommended prior to surgery. ■ When operating for GI bleeding, being present at the initial endoscopy to see the precise bleeding location will help avoid having to make an excessively large pyloroplasty incision.
Pyloroplasty incision	■ Incisions longer than 7 or 8 cm are difficult to close in a Heineke-Mikulicz fashion without narrowing the pyloric lumen and may require a Finney closure.
Kocher manuever	■ Is not always necessary with a short pyloroplasty and a Heineke-Mikulicz closure but is always required with a Finney closure
Pyloromyotomy	■ Is very hard to perform without mucosal perforation in the setting of any duodenal inflammation. If a significant mucosa perforation occurs during pyloromyotomy, the safest approach is to convert to pyloroplasty.
Gastrojejunostomy	■ Predisposes to marginal ulceration if a vagotomy is not performed. Patients undergoing gastrojejunostomy drainage without vagotomy will require lifetime proton pump inhibitor therapy. ■ In the setting of a prior gastric outlet obstruction, a prolonged period of delayed gastric emptying may be encountered despite an adequate anastomotic lumen.

POSTOPERATIVE CARE

- Most patients will require nasogastric decompression for 24 to 48 hours after a drainage procedure.

OUTCOMES

- When performed in conjunction with fundoplication in patients with delayed gastric emptying, 80% of patients report an improvement in bloating symptoms.[3]
- The incidence of diarrhea reported when pyloroplasty is performed in conjunction with fundoplication in the setting of delayed gastric emptying is reported to be as high as 25%.[4]
- The incidence of clinically significant dumping syndrome after drainage procedures is less than 10%.[5]

COMPLICATIONS

- Leak from suture or staple line
- Delayed gastric emptying
- Surgical site infection
- Dumping syndrome
- Diarrhea
- Duodenogastric reflux is quite rare after pyloroplasty.
- Bile reflux gastritis following gastrojejunostomy

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Chapter 10 Antrectomy

J. Spencer Liles   John D. Christein

DEFINITION

- By strict definition, antrectomy refers to removal of the gastrin-secreting portion of the stomach and when combined with a vagotomy results in an 85% reduction in gastric acid secretion.[1,2] In the 1960s and 1970s, antrectomy with or without vagotomy was routinely performed for treatment of benign gastric and duodenal ulcers but, due to pharmacologic developments in reducing acid secretion and elucidation of the role of *Helicobacter pylori* in ulcer development, is now rarely performed for ulcer disease.[3,4]
- Today, the term antrectomy is loosely applied to any distal gastric resection and is indicated in recurrent or persistent gastric ulcers to rule out malignancy, complicated peptic ulcer disease (i.e., obstruction, hemorrhage, perforation), and for resection of certain neoplasms of the antrum and pyloric channel (Table 1).[3]
- When an antrectomy is performed for complicated peptic ulcer disease, a vagotomy may be included to reduce the chance of anastomotic ulcer formation in patients who are not candidates for *H. pylori* treatment and lifelong proton pump inhibitor therapy due to unreliability, noncompliance, or medication side effects.[5,6]
- Antrectomy is named by the type of gastrointestinal (GI) anastomosis performed.
  - Billroth I procedure—antrectomy and gastroduodenostomy
  - Billroth II procedure—antrectomy and gastrojejunostomy
    - A modification of the Billroth II procedure that involves a gastrojejunostomy via a Roux limb and is known as a Roux-en-Y gastrojejunostomy

DIFFERENTIAL DIAGNOSIS

- Complicated peptic ulcer disease and distal gastric neoplasms, both benign and malignant, account for the vast majority of the antral resections performed today. These diagnoses will be discussed separately.
- Peptic ulcer disease
  - Peptic ulcer disease refers to irritation of GI mucosa from gastric acid due to either increased acid presence or weakness in the mucosal protection and typically presents with epigastric pain.[2,4] Peptic ulcers can occur anywhere in the GI tract, but duodenal and gastric ulcers are most common. Duodenal ulcers typically arise within 2 cm of the pylorus, are highly associated with *H. pylori* infection (>90%), and frequently resolve with appropriate *H. pylori* therapy. Gastric ulcers are less likely to be associated with *H. pylori* infection and are classified into five types based on their location and association with acid secretion (Table 2).[7]
  - The differential diagnosis of epigastric pain similar to that found in complicated peptic ulcer disease is chronic cholecystitis, acute pancreatitis, chronic pancreatitis, functional indigestion or dyspepsia, gastritis, and reflux esophagitis. Complicated peptic ulcer disease can also present with upper GI hemorrhage, and a differential should include esophagitis (reflux and infectious); gastroesophageal varices, arteriovenous malformations; Mallory-Weiss tear; stress gastritis; and neoplasm of the esophagus, stomach, duodenum, pancreas, and biliary tree.
  - Lastly, pyloric obstruction due to chronic inflammation and scarring will cause nausea, emesis, and early satiety. The differential for these symptoms includes gastric motility disorders (i.e., gastroparesis), gastroenteritis, small bowel obstruction, electrolyte abnormalities, and extrinsic compression from pancreatic pseudocysts or neoplasms.
- Distal gastric neoplasms—Gastric neoplasms include benign polyps, adenocarcinoma, neuroendocrine tumors, lymphoma, B-cell mucosa-associated lymphoid tissue (MALT) lymphomas, GI stromal tumors, leiomyomas, and leiomyosarcomas. Any gastric neoplastic process can cause upper GI bleeding, epigastric pain, and luminal obstruction, and a differential similar to peptic ulcer disease should be considered.

Table 1: Indications for Antrectomy

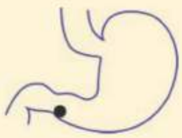
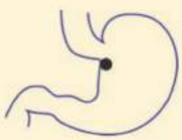
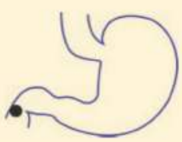
Peptic ulcer disease
- Intractability—persistent or recurrent gastric ulcers in order to rule out malignancy
- Perforation—distal gastric or duodenal ulcer
- Bleeding—type I, II, or III gastric ulcer
- Obstruction—any gastric outlet or duodenal obstruction due to chronic ulcer scarring

Neoplasm
- Benign—single giant gastric polyp or multiple gastric polyps not amenable to endoscopic resection, leiomyoma, lipoma
- Malignant—leiomyosarcoma, gastrointestinal stromal tumor, early-stage adenocarcinoma, neuroendocrine tumor
- Gastroparesis—role is debated in chronic gastroparesis only after extensive workup

PATIENT HISTORY AND PHYSICAL FINDINGS

- All patients should undergo a thorough history and physical exam with questions focusing on the nature of the symptoms, specifically determining the relationship between symptoms and eating, deciphering whether symptoms are acute or chronic, and determining the severity of the symptoms. A vast majority of patients will have abdominal pain. Pain related to peptic ulcer disease that results from the corrosive effect of gastric acid on vulnerable GI mucosa and typically occurs in the epigastrium is described as gnawing or burning and follows a daily cycle. This pain typically arises shortly after eating breakfast and persists until lunch at which time the oral intake alleviates the pain. Relief is transient and pain recurs in the early afternoon and again persists until dinner. Meals, specifically ones consisting of milk and dairy products, and antacids provide temporary relief from ulcer pain. Acute, severe epigastric pain can signify ulcer perforation, whereas back pain suggests ulcer penetration into the pancreas.[8]

Table 2: Peptic Ulcer Disease

Location			Common Complications	Acid Secretion	Other
Esophageal		Gastroesophageal junction and distal esophagus	Hemorrhage	High	
Gastric					
I		Gastric body on lesser curvature near the angularis incisura	Perforation	Normal or low	• Older patients • Associated with *Helicobacter pylori*
II		Two ulcers; gastric body and duodenal ulcer	Hemorrhage, obstruction, or perforation	High	• Younger patients • Association with active or quiescent duodenal ulcers
III		Prepyloric	Hemorrhage, perforation	High	• Younger patients • Similar to type II gastric ulcers and duodenal ulcers
IV		High on lesser curvature	Hemorrhage	Low	• Likely a variant of type I gastric ulcers • Difficult to treat surgically
V		Anywhere	Perforation	Normal	• Related to NSAID use
Duodenal		95% occur within 2 cm of pylorus	Hemorrhage, obstruction, or perforation	Normal or high	

NSAID, nonsteroidal antiinflammatory drug.

- Nausea and vomiting can be seen with ulcer disease even in the absence of pyloric obstruction. Nausea that is chronic in nature and associated with early satiety and weight loss suggests inflammation and scarring of the pyloric channel due to chronic ulceration.
- It is not uncommon for complicated peptic ulcers to present with upper GI bleeding, perforation, or obstruction in a patient with no history of peptic ulcer disease.
  - Bleeding—hematemesis, melena, recent diagnosis of anemia
  - Perforation—acute onset upper abdominal pain and peritonitis
  - Obstruction—nausea, emesis, food regurgitation, early satiety, weight loss
- Acute or chronic upper GI bleeding can signify complicated ulcer disease and may present as melena, weakness, fatigue, general malaise, or a recent diagnosis of anemia.
- Risk factors for developing ulcer disease include a history of *H. pylori* infection; smoking; Zollinger-Ellison syndrome; and use of nonsteroidal antiinflammatory drugs (NSAIDs), steroids, and other immunosuppressive medications.[1,8] Therefore, an accurate medication list should be obtained and reviewed with the patient. History of previous ulcer disease should be elicited, and the success and timing of previous treatment modalities should be documented. Presence of *H. pylori* infection, completion of antibiotic therapy, and documentation of eradication is crucial (Table 3). Ulcers that persist despite appropriate

Table 3: *Helicobacter pylori* Testing

	Sensitivity	Specificity	Other
Noninvasive			
Urease breath test	>95%	>90%	Determines active infection but must stop PPI 2 wk prior; takes 30–60 min and is used to confirm eradication
Fecal antigen detection	>90%	>95%	Determines active infection but is positive for up to 12 wk after eradication
Serology	85%	79%	Cannot be used to confirm eradication because antibodies persist
Invasive (endoscopic)			
Biopsy urease test	>90%	>95%	Decreased sensitivity with ongoing PPI, H2 antagonist, antibiotic, and bismuth compound use or with recent GI bleeding
Histology	>90%	>95%	Multiple available stains and widely used; increased sensitivity with increased biopsies
Culture	80%	100%	Difficult and expensive; reserved for persistent infections and antibiotic sensitivity testing

PPI, proton pump inhibitor; GI, gastrointestinal.

treatment of *H. pylori*, cessation of NSAID use, or are found in *H. pylori*–negative patients should raise suspicion for underlying malignancy.

- A gastric lesion can also present with epigastric pain and obstruction. This pain is typically vaguer in nature and lacks a gnawing or burning component. Furthermore, these patients may describe a sensation of persistent fullness and early satiety despite hunger.
- A subjective assessment of nutrition and functional status is necessary to evaluate the patient's ability to tolerate a major surgical procedure.

IMAGING AND OTHER DIAGNOSTIC STUDIES

- Diagnostic evaluation of suspected peptic ulceration and upper GI lesions can include endoscopy, contrast radiography, and computed tomography (CT) (**FIG 1**).
- Endoscopy is felt to be superior because it allows for tissue sampling. Sampling of gastric mucosa can be used to confirm the presence of *H. pylori*. On endoscopy, ulcers are sharply demarcated; often have exposed underlying submucosa; and frequently occur in the first portion of the duodenum, the prepyloric area, and the pyloric channel. All gastric ulcers should be biopsied at least six times at the ulcer edge and brush biopsied to evaluate for underlying malignancy. Even if negative for malignancy, repeat endoscopy after medical treatment is indicated to evaluate for therapeutic response, and in instances of persistent or intractable disease, ulcer resection is indicated.[8]
- Other relevant imaging modalities include contrast radiography and CT. Double-contrast radiography of the upper GI tract detects roughly 90% of gastric and duodenal ulcers but does not allow for tissue sampling. In the acute setting, CT is helpful in identifying gastric or duodenal ulcer perforation. Additionally, CT can identify wall thickening in chronic ulcer inflammation or neoplastic situations but again lacks the ability to provide tissue sampling.
- Zollinger-Ellison syndrome is a rare condition of increased serum gastrin levels secondary to a gastrinoma with resulting severe ulcer disease. In nonsmoking patients who are negative for *H. pylori*, serum fasting gastrin levels should be obtained to evaluate for Zollinger-Ellison syndrome. Normal basal gastrin levels average to 50 to 100 pg/mL, and levels over 200 pg/mL can almost always be considered high. Diagnosis of Zollinger-Ellison syndrome can alter your treatment approach.[9]

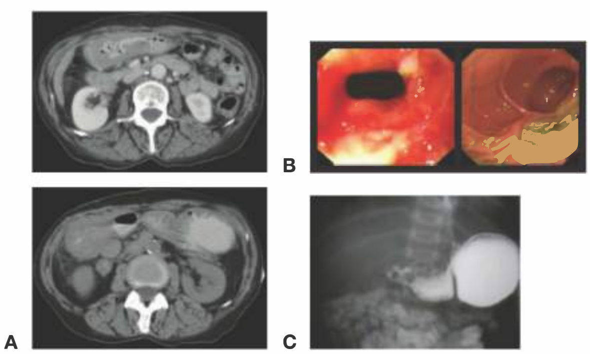


FIG 1 • Radiology. **A.** CT scan of pyloric obstruction from chronic pyloric inflammation. **B.** Endoscopic image of near-complete pyloric obstruction from chronic pyloric inflammation **(left)**; endoscopic image of a large gastric ulcer with a central necrotic region **(right)**. **C.** Contrast radiography demonstrating pyloric obstruction from chronic pyloric inflammation.

SURGICAL MANAGEMENT

- The indications for antrectomy are listed in Table 1. As explained earlier, an antrectomy is rarely performed for its original purpose of removing the antrum and reducing acid secretion.
- Antrectomy is not the primary treatment option for bleeding or perforated peptic ulcers. A vast majority of bleeding ulcers is controlled endoscopically and, in the 5% to 10% that require operative intervention, a formal antrectomy is rarely needed. Roughly 90% of perforated ulcers can be safely controlled with primary closure and omental patching. Thus, antrectomy for bleeding or perforated ulcers is reserved for cases when less invasive treatment options are ineffective.

Preoperative Planning

- All patients should undergo preoperative endoscopy to identify the extent of disease and preoperative nutritional assessment. All patients should receive preoperative antibiotics in a timely fashion to reduce the risks of perioperative infectious complications from gram-positive cocci and enteric gram-negative bacilli pathogens.

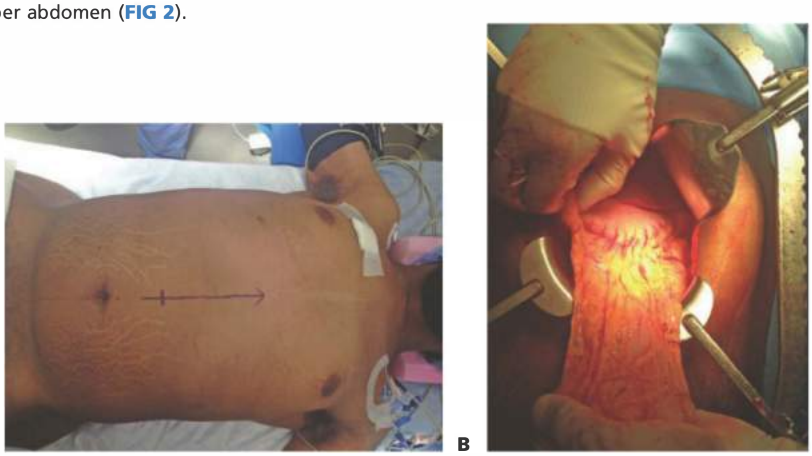
- Several factors must be considered when deciding between performing a Billroth I and Billroth II procedure. The advantage to a Billroth I procedure is that the anatomic arrangement of the GI tract is preserved, which maintains the innate regulatory pathways of bicarbonate and pancreatic enzymes and significantly decreases the rate of postprandial dumping. Unfortunately, the lack of a pylorus results in bile reflux gastritis in a majority of patients. A Billroth I procedure cannot always be performed due to inflammation and scarring from prepyloric, pyloric, or duodenal ulcers. In these instances, the Billroth II procedure allows for a tension-free anastomosis of noninflamed tissue but introduces the problems of potential afferent loop syndrome and bile reflux gastritis, whereas a Roux-en-Y gastrojejunostomy diminishes the occurrence of bile reflux at the cost of a second anastomosis. Lastly, in cases of invasive neoplasms or concerning gastric masses, a Billroth II procedure with or without reconstruction with a Roux-en-Y gastrojejunostomy is preferred as it allows for dissection of much wider margins and is less likely to obstruct in the unfortunate setting of recurrent disease.[10,11]

Positioning

- The patient should be positioned supine with arms out. A urinary catheter and a nasogastric tube should be placed to decompress the stomach. Positioning should allow for attachment of a self-retaining retractor system to the operating room table.

EXPOSURE

- A midline supraumbilical incision is made and carried to the level of the xiphoid. The falciform ligament is divided and a self-retaining retractor system is placed to widely expose the upper abdomen (**FIG 2**).



A B

FIG 2 ● **A.** A midline upper abdominal incision is used. **B.** Division of the falciform ligament and placement of self-retaining retractor allows adequate exposure of the upper abdomen.

GASTRIC MOBILIZATION

- Mobilization of the distal stomach is best achieved by starting on the greater curvature. The gastrocolic ligament is identified and incised to enter the lesser sac (**FIG 3**). Downward traction on the transverse colon and upward traction on the stomach will help expose this plane (**FIG 4**). Identification of the right and left gastroepiploic vessels along the greater curvature is essential. In benign disease, the plane of dissection can be very close to the stomach inside the gastroepiploic vessels. A large part of this plane is avascular and can be divided with electrocautery, whereas encountered vessels should be divided between clamps and ligated with 3-0 silk ligatures. Once the lesser sac is identified, electrosurgical devices can be used to further mobilize the greater curvature (**FIG 5**). Proximally, dissection is carried to the midpoint of the greater curvature preserving the left gastroepiploic artery. Distally, the plane is developed beyond the pylorus to the duodenum and, once identified, the right gastroepiploic artery should be clamped, ligated with 2-0 silk ligatures, and divided. Here, one should be aware of the underlying pancreatic tissue and dissection should be meticulous.
- Dissection along the greater curvature allows entrance to the lesser sac, and the stomach can be lifted superiorly exposing its posterior surface and the congenital

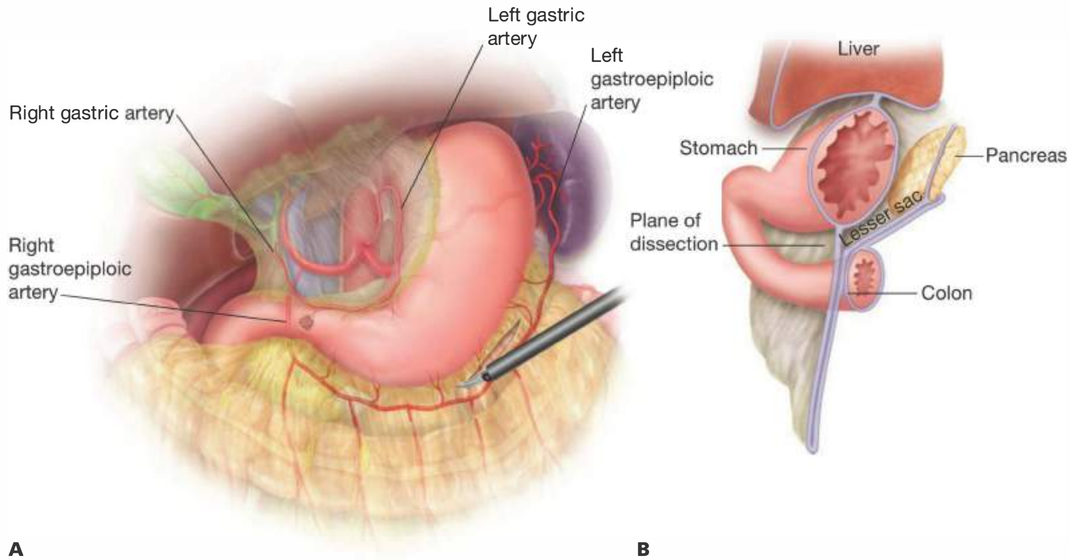


FIG 3 ● Dissection of the greater curvature. **A.** Division of the greater omentum along the greater curvature will allow access to the lesser sac. The gastroepiploic vessels should be identified and care should be taken to not damage the transverse colon and its mesentery. **B.** Cross-sectional view of the upper abdomen demonstrating the plane of dissection that allows entrance to the lesser sac and mobilization of the greater curvature.

attachments to the underlying pancreatic capsule (**FIG 6**). These attachments should be sharply divided. As this plane is developed in a superior direction, great care should be taken to not injure the left gastric artery at its origin from the celiac axis. Inflammation and scarring can be encountered in the setting of posterior gastric wall ulcers.

- Attention is then turned to division of the gastrohepatic ligament along the lesser curvature. Retracting the stomach inferiorly and to the patient's left facilitates exposure of the lesser curvature. This dissection can start in the transparent pars flaccida and is carried proximally to the incisura and distally to the right gastric artery, which should be clamped, ligated with 2-0 silk ligatures, and divided (**FIG 7**). Again, electrocautery or electrosurgical devices can be used along the lesser curvature. One must be aware of an aberrant or replaced left hepatic artery originating from the left gastric artery and traversing the gastrohepatic ligament. If encountered, attempts should be made to preserve this vessel. After clamping but before division of the right gastric artery, blood flow to the liver should be confirmed by palpation of the hepatoduodenal ligament.

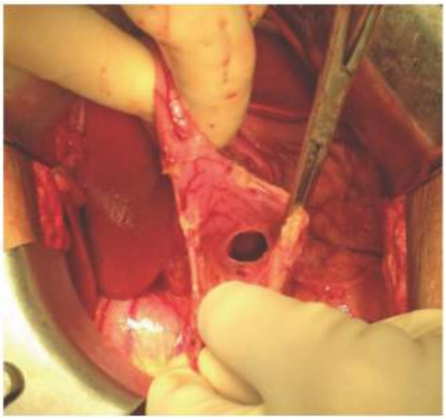


FIG 4 ● Traction on the stomach and the colon will aid dissection through the gastrocolic ligament allowing entrance to the lesser sac. As seen here, the lesser sac will be a true space that lies deep to the greater omentum.

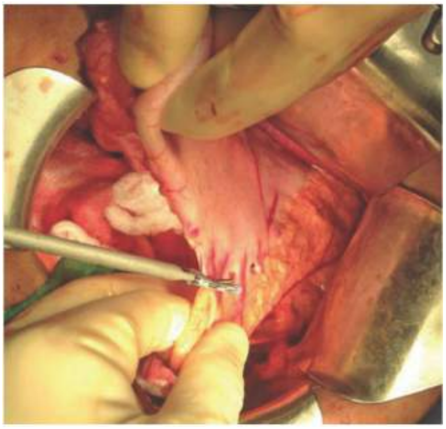


FIG 5 ● Once the lesser sac is identified, the greater curvature can be dissected both proximally and distally taking care to identify the gastroepiploic vessels.

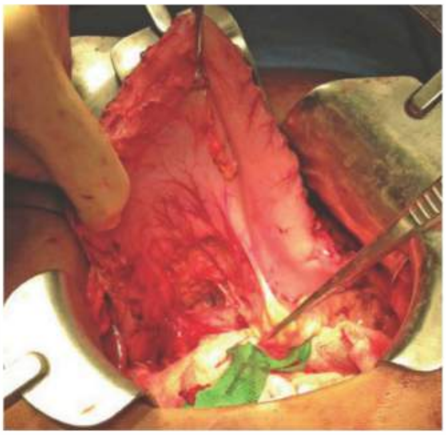


FIG 6 ● Dissection of the greater curvature allows for superior retraction of the stomach exposing its posterior surface and the underlying pancreas. Here, the lesser curvature and the left gastric artery are seen from the posterior aspect of the stomach.

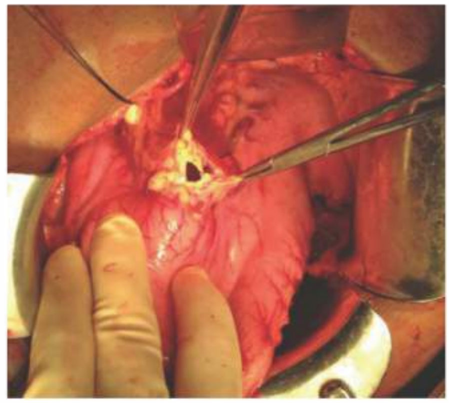


FIG 7 ● Dissection of the lesser curvature.

DIVISION OF THE STOMACH

- A stapling device is used to divide the stomach along a plane from just proximal to the incisura angularis on the lesser curvature to a point on the greater curvature two-thirds of the way from the gastroesophageal junction to the pylorus. Some recommend placing Babcock forceps distal to the staple line to prevent sliding or rotation of the gastric mucosa as the stapler is closed. This will help ensure a clean, even cut across the anterior and posterior layers of gastric mucosa (**FIG 8**).
- Division of the duodenum varies based on the type of reconstruction planned. The duodenum is divided between Potts clamps for a Billroth I procedure in order to facilitate the gastroduodenal anastomosis. If possible, a stapling device should be used to divide the duodenum in a Billroth II procedure.

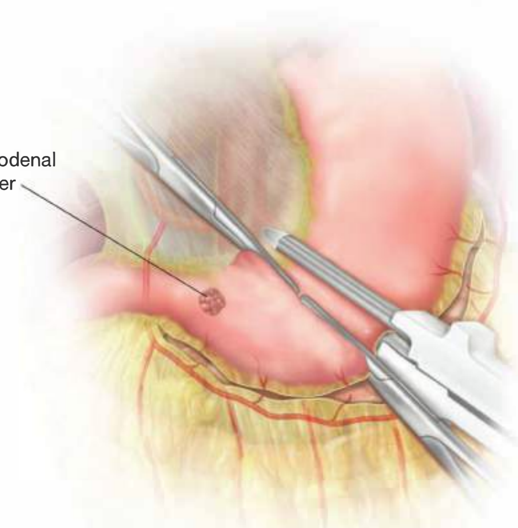


FIG 8 ● Division of the stomach.

RECONSTRUCTION: GASTRODUODENOSTOMY (BILLROTH I)

- If a Billroth I anastomosis is planned, a Kocher maneuver is needed to mobilize the duodenum.
- The duodenum is transected distal to the diseased area but proximal to the ampulla between Potts clamps, and the specimen is handed off the sterile field (**FIG 9**). It is essential that all gastric antrum be resected to prevent persistent ulcer disease from retained gastric antrum. If there is question, a frozen section can be sent to confirm duodenal tissue at the resection line.
- At this point, one can gauge the mobility of the stomach, and if limited, the attachments of the fundus to the base of the diaphragm can be divided along with the gastrosplenic ligament taking care to preserve the left gastroepiploic vessels. This further mobilization should allow for a tension-free gastroduodenal anastomosis. If there

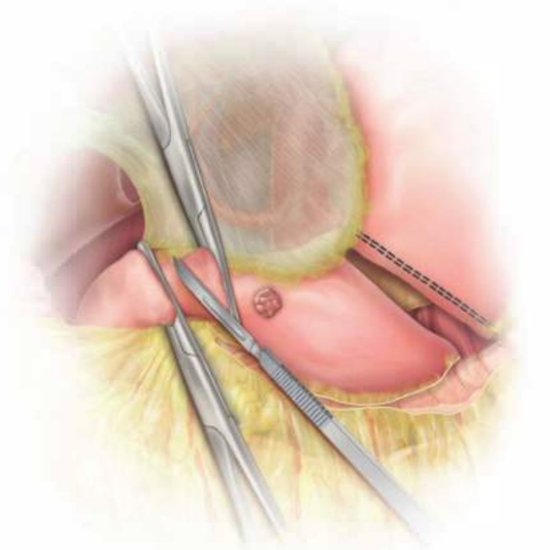
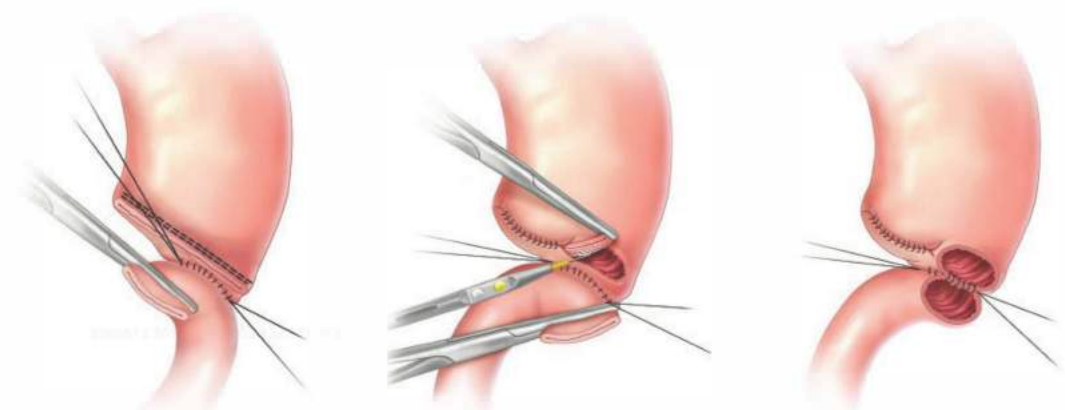


FIG 9 ● Division of proximal duodenum.

is concern about the ability to perform a tension-free anastomosis due to difficulty mobilizing the duodenum or the stomach, then a Billroth II procedure should be performed.

- For a Billroth I procedure, the duodenal stump is cleared of adjacent adipose tissue for roughly 1.5-cm distance in preparation for an end-to-end anastomosis. This anastomosis is constructed in standard two-layer fashion. Silk 3-0 seromuscular "stay" sutures are placed at the ends of the anastomosis to approximate the duodenum to the inferior aspect of the gastric staple line and the posterior layer is completed with interrupted 3-0 silk seromuscular sutures. Next, the inferior portion of the gastric staple line is removed using electrocautery for a length that correlates with the width of the duodenal stump. Two running 3-0 polydioxanone (PDS) sutures are used for the inner layer and an anterior layer of interrupted 3-0 silk seromuscular sutures completes the anastomosis. The remaining gastric staple line can be oversewed with interrupted 3-0 silk sutures (**FIG 10**).

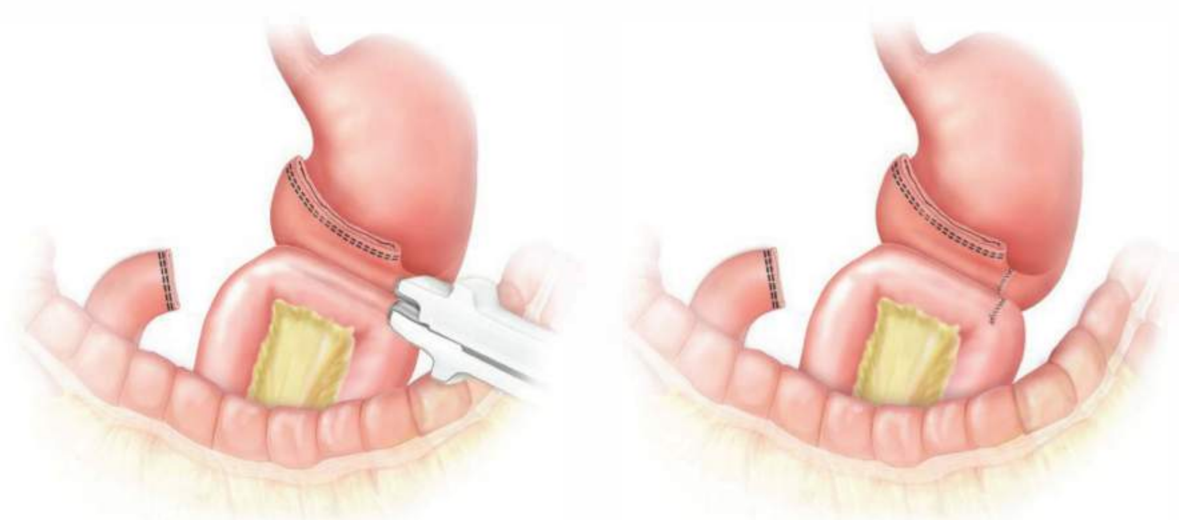


A B C

FIG 10 ● **A–C.** Billroth I.

RECONSTRUCTION: GASTROJEJUNOSTOMY (BILLROTH II)

- In performing a gastrojejunostomy, the gastric staple line is oversewed with interrupted 3-0 silk sutures.
- Next, the duodenum is divided distal to any disease with a stapling device. If it is not possible to fit a stapler into this plane, the duodenum can be divided with electrocautery and closed with a running 3-0 PDS. To buttress this closure, 3-0 silk full-thickness sutures can be placed and left untied. Omentum can be mobilized and loosely secured in place over the closure with the silk suture ends.
- We preferentially perform an isoperistaltic, retrocolic gastrojejunostomy, although an antecolic anastomosis is widely accepted. In the setting of malignancy, an antecolic approach may be favored as concern exists that progression of disease and future diffuse mesenteric lymphadenopathy may obstruct a retrocolic anastomosis. The anastomosis should be performed as close to the ligament of Treitz as possible (usually 10 to 15 cm), allowing for a tension-free anastomosis to minimize the risk of developing afferent limb syndrome.
- Although we prefer a stapled anastomosis, both stapled and hand-sewn techniques are widely accepted with similar rate of postoperative complications. A 45-mm stapled



A B

FIG 11 ● **A,B.** Billroth II.

gastrojejunal anastomosis is formed by creating a posterior wall gastrotomy and an antimesenteric enterotomy. Care is taken to ensure that the anastomosis is away from the prior gastric staple line on the posterior wall of the stomach. The common enterotomy is then closed with a 3-0 PDS full-thickness layer and an overlying layer of interrupted 3-0 silk sutures (**FIG 11**). Interrupted 3-0 silk sutures are then used to close the colonic mesentery defect to prevent bowel herniation (**FIG 12**).

FIG 12 ● Retrocolic gastrojejunostomy.

PEARLS AND PITFALLS

Indication	▪ Today, there is no role for antrectomy in treatment of noncomplicated peptic ulcer disease. ▪ A vast majority of peptic ulcers complicated by hemorrhage or perforation can be controlled with less invasive procedures.
Operative planning	▪ Preoperative endoscopy is essential to evaluate for the scope of disease and to allow biopsy of persistent gastric ulcers to rule out malignancy. ▪ In the setting of malignancy, preoperative staging is warranted and a more extensive, oncologic resection may be indicated.
Laparotomy	▪ Prior to extensive dissection, the extent of disease should be gauged to determine the operative plan and feasibility of a Billroth I anastomosis.
Gastric mobilization	▪ With mobilization of the greater curvature, the middle colic vein is at risk of injury. Caudal traction on the transverse colon during dissection can help prevent an inadvertent injury.
Duodenal transection	▪ Great care should be taken to not fracture or injure the head of the pancreas, which can be closely adherent due to chronic inflammation. ▪ If the common bile duct is difficult to identify, a cholecystectomy can be performed and a catheter can be placed in the cystic duct. Palpation of the catheter can aid in safely identifying the portal structures during dissection of the duodenum.

Reconstruction	■ Billroth I and II procedures are performed with acceptable postoperative morbidity. ■ A Billroth II anastomosis should be performed if there is concern about mobility of the duodenum or the stomach. ■ A short afferent limb (10 to 15 cm from the ligament of Treitz) can help minimize the likelihood of significant postoperative complications.

POSTOPERATIVE CARE

- Unless concerning comorbidities exist, patients can be monitored on the hospital floor/ward. A nasogastric tube is positioned intraoperatively in the proximal stomach and typically can be removed on postoperative day (POD) 1. There is no role for postoperative antibiotic prophylaxis. Unless contraindicated, all patients receive chemical prophylaxis for deep vein thrombosis and are encouraged to ambulate on POD 1 and begin pulmonary toilet with incentive spirometry. There is no convincing evidence for routinely placing abdominal drains after Billroth I and Billroth II procedures. If there is concern for the GI anastomosis or adequate closure of the duodenal stump, a closed suction abdominal drain can be placed. Oral intake is reintroduced on POD 3 and advanced as tolerated.

OUTCOMES

- Serious morbidity from postgastrectomy syndromes develops in 3% to 5% of patients.
- Thirty-day mortality for uncomplicated gastric ulcer disease is 1% to 2% and increases in emergency settings.[11]

COMPLICATIONS

- After an antrectomy, short-term complications include delayed gastric emptying, anastomotic leak, bleeding, and pancreatitis. Long-term complications include the postgastrectomy syndromes (described below) and anastomotic stricture. Additionally, chronic anemia, neuropathy, and osteopenia can result from iron, copper, and calcium malabsorption due to bypassing of the proximal small bowel in a Billroth II procedure.[12]
- Postgastrectomy syndromes
  - Afferent loop syndrome
    - Postprandial right upper abdominal colicky pain that accumulates in bilious emesis that alleviates the pain
    - Results from chronic dilation, obstruction, or stasis of the duodenum (afferent limb) after a Billroth II procedure
    - Rarely occurs but can be corrected by revision of the Billroth II, conversion to a Roux-en-Y reconstruction, or performing an afferent to efferent bypass (Braun enteroenterostomy)
  - Reflux gastritis—Patients report epigastric burning pain resulting from reflux of bile into the stomach. As expected, bile reflux is more common after Billroth I and Billroth II procedures than Roux-en-Y reconstruction and if severe can be treated by conversion to a Roux-en-Y reconstruction.
  - Dumping—Early dumping presents as crampy abdominal pain and diarrhea shortly after eating due to the large hyperosmolar load of simple sugars which quickly enter the small bowel in the absence of a pylorus. Late dumping occurs roughly 2 hours postprandial with the symptoms of hypoglycemia likely due to insulin response to the large sugar bolus. Dumping occurs in 5% of postgastrectomy and is controlled with diet modifications, and rarely, octreotide is given with success in severe and refractory cases.
  - Retained gastric antrum—Incomplete antrectomy with retained G cells within the duodenal stump can result in recurrent ulceration from continued intense gastrin secretion. Exposure of the jejunum to high levels of acid results in an anastomotic or marginal ulcer. A sodium 99m technetium scan identifies antral tissue and reexcision is needed for complete symptom relief.

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Chapter 11

Subtotal Gastrectomy for Cancer

Vikas Dudeja   Patrick G. Jackson   Waddah B. Al-Refaie

DEFINITION

- Subtotal gastrectomy is removal of 70% to 80% of distal stomach. This is performed when the necessary 5- to 6-cm proximal margin can be obtained while maintaining a gastric remnant of reasonable size.

PATIENT HISTORY AND PHYSICAL FINDINGS

Presentation

- In United States, gastric cancer is often diagnosed at an advanced stage and nearly 65% of patients harbor node-positive disease.[1,2] The most common symptoms are weight loss, anorexia, and early satiety. Some of these symptoms overlap with those of benign peptic ulcer disease. Patients with distal gastric cancer may present with symptoms of gastric outlet obstruction, including postprandial vomiting and weight loss. Patients may also present with progressive abdominal distension secondary to malignant ascites.
  - Special attention should be paid to weight loss. Although this may reflect metastatic disease or gastric outlet obstruction, in patients with resectable disease, it signifies a need for preoperative nutritional optimization. Specifically, patients with more than 10% weight loss are at increased risk of perioperative complications.
  - Attention to pretherapy performance status is critical, as this correlates well with ability to tolerate various oncologic therapies including major surgical resection and systemic therapy.
- Patients presenting with gastric outlet obstruction may have dehydration and electrolyte imbalances. Placement of a nasogastric (NG) tube, volume replacement (initially with normal saline), and correction of electrolyte imbalance is paramount.

Physical Findings

- Most patients with early stage disease will have a normal physical examination. However, signs of malnutrition, cachexia, and jaundice should be sought. Patients with advanced stage disease may present with supraclavicular lymphadenopathy, pleural effusion, abdominal mass, hepatomegaly, malignant ascites, or drop metastases in the cul-de-sac known as "Blumer's shelf." Presence of any of these physical findings suggest unresectability.

IMAGING AND OTHER DIAGNOSTIC STUDIES

Laboratory Tests

- A baseline hemoglobin will assess whether iron deficiency anemia is present. Patient's renal function and hydration status should be assessed by measuring serum blood urea nitrogen (BUN) and creatinine in preparation for cross-sectional imaging. Evaluation and correction of abnormalities in electrolytes are important in patients with gastric outlet obstruction. Serum albumin and prealbumin are essential tools for assessing nutritional status.

Diagnostic Studies and Staging Evaluation

- The evaluation of any upper gastrointestinal (GI) symptomatology begins with an upper GI endoscopy, especially if gastric cancer is suspected. Endoscopy provides histopathologic diagnosis as well as guidance toward the location and extent of the gastric tumor (**FIG 1A,B**). For example, the endoscopist needs to comment on the location of the tumor as well as the relationship to the first portion of the duodenum. Additionally, it is important to exclude the presence of linitis plastica by insufflating the stomach and evaluating its distensibility, as patients with linitis plastica carry a higher risk of metastatic disease and a median survival of approximately only 14 to 16 months.
- Endoscopic ultrasound performed at the time of or subsequent to diagnostic endoscopy provides the most accurate estimation of the tumor depth (T stage) and needle biopsy of surrounding lymph nodes can be performed.[3]
- Pretherapy cross-sectional imaging (contrast computed tomography [CT] scan or magnetic resonance imaging [MRI] of abdomen and pelvis) is important to exclude distant metastatic disease to the liver or omentum (**FIG 2A**). In patients with proximal gastric cancer, the addition of chest cross-sectional imaging is helpful to exclude the presence of metastases to the lung. The presence of bulky adenopathy adds prognostic value but should not preclude resection unless it is outside the area of resection, such as the periportal area or mesenteric vessels. Fewer than 15% of patients present with locally advanced disease extending to the pancreas. In these patients, we perform staging laparoscopy to exclude M1 disease and then recommend neoadjuvant chemotherapy.

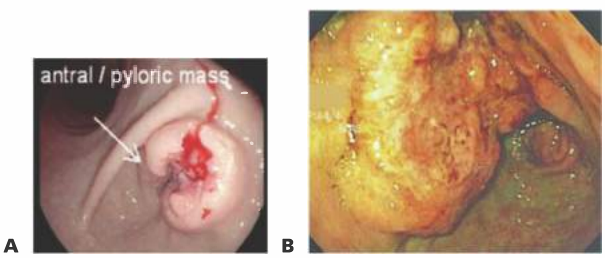

FIG 1 • Esophagogastroduodenoscopy helps with histologic diagnosis as well as provides information about extent of tumor. **A.** Biopsy-proven poorly differentiated adenocarcinoma with signet cell features in the antral/prepyloric region of stomach. **B.** Fungating adenocarcinoma of the distal third of the stomach in a 75-year-old male who presented with iron deficiency anemia.

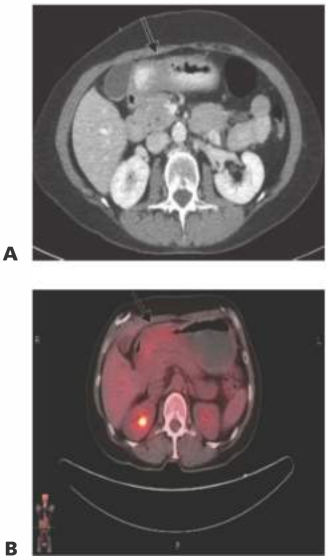

FIG 2 ● Cross-sectional imaging in the form of CT and CT/PET helps to evaluate for distant metastatic disease as well as extent of locoregional disease. **A.** CT scan in a patient with gastric cancer demonstrates thickening of the gastric antrum with nodularity in the gastrocolic ligament suggestive of direct spread to the transverse colon. **B.** PET/CT corroborated with CT scan to suggest involvement of gastrocolic ligament. No metastatic disease was observed.

- Positron emission tomography (PET)/CT scan has evolved as a noninvasive radiographic staging modality to exclude the presence of metastatic disease (**FIG 2B**).
- **Staging laparoscopy:** Due to the natural history of gastric cancer, up to a third of patients who have localized disease on staging evaluation have unsuspected hepatic and/or peritoneal disease.[4] Thus, all patients should undergo staging laparoscopy to detect "subradiologic" disease. Staging laparoscopy is typically performed in a reverse TNM fashion. The operating surgeon should inspect the intraabdominal cavity for presence of peritoneal, omental, or hepatic metastases. The addition of peritoneal washing for cytology is an area of debate.[5,6] It may have a place in patients at risk of undeclared metastatic disease or suboptimal performance status, as patients with positive peritoneal cytology have unfavorable overall prognosis.[6] In the absence of concerning radiographic features, staging laparoscopy is typically performed at the time of the intended resection.

SURGICAL MANAGEMENT

- Margin-negative resection along with an adequate lymphadenectomy are the most critical components of the surgical resection.

Preoperative Planning

- **Addressing preoperative malnutrition:** Gastric outlet obstruction caused by tumor as well as anorexia associated with malignancy contribute to malnutrition. As such, these patients may benefit from a placement of a preoperative nasojejunal tube and enteral nutrition. In patients presenting with malignant distal gastric obstruction, an endoscopic transpyloric stent may address the gastric outlet obstruction and thus help in optimizing the nutrition. Staging laparoscopy and placement of a feeding jejunostomy tube is another option.
- **Evaluation of the patient's functional status:** A careful review and optimization of underlying comorbidities (e.g., cardiac, pulmonary, diabetes) and performance status should be performed. A subset of high-risk individuals may benefit from preoperative admission to optimize the nutrition, electrolytes imbalance, and improve performance status (e.g., physical therapy) in preparation for the oncologic resection.
- **Preoperative antibiotics:** Patients should have preoperative first- or second-generation cephalosporins prior to incision to reduce the risk of wound infection.
- **Deep venous thrombosis (DVT) prophylaxis:** All patients should have a sequential compression device applied during the procedure. Use of subcutaneous heparin/low-molecular-weight heparin is initiated on postoperative day 1 and continued throughout the hospitalization unless contraindicated.

Positioning

- The patient is placed in supine position with both arms out at 90 degrees. Nipples to upper thigh should be prepped and draped in the operative field.

STAGING LAPAROSCOPY

- Pneumoperitoneum is created by either open technique or Veress needle. A 30-degree scope is inserted at the umbilicus. One to two additional 5-mm ports on left or right side of the abdomen are needed for additional visualization, grasping, and biopsy of suspicious tissue. A complete survey of the peritoneal cavity is performed, including undersurface of the diaphragm, liver surface, spleen, lining of peritoneal cavity, pelvis, small bowel surface, and omentum, for metastatic disease. If suspicious disease is observed, it is sent for frozen section. In the setting of biopsy-proven peritoneal disease, gastrectomy should not be considered and nonsurgical treatments should be initiated. However, selective palliative surgical procedures may be indicated, for example, in bleeding or obstructing cancers that cannot be palliated by endoscopic procedures. These decisions need to be individualized based on the performance status of the patient, extent of metastatic burden, and the projected survival.
- If the staging laparoscopy is negative for peritoneal spread of the disease, operative resection is performed.

EXPLORATORY LAPAROTOMY

- Abdomen is entered through a midline incision extending from the xiphoid process to just below the umbilicus. A bilateral subcostal incision, approximately 2 cm below the costal margin, also provides good exposure. During entry into the abdomen, the falciform ligament should be preserved as it can be used to buttress the duodenal closure.
- A careful exploration of the peritoneal cavity is performed to exclude presence of subradiographic peritoneal or metastatic disease. The liver is carefully examined for any suspicious nodules.

MOBILIZATION OF THE GREATER CURVATURE OF THE STOMACH

- In this step, the transverse colon is separated from the greater omentum in an avascular plane (**FIG 3**). The stomach and the greater omentum are reflected superiorly, and the transverse colon is reflected inferiorly. The plane of fusion between the greater omentum and the transverse mesocolon is identified as a faint white line. This plane is incised with electrocautery to enter the lesser sac. This plane is advanced proximally and distally along the transverse colon.
- The dissection proceeds to the proximal greater curvature of the stomach using either clamps and ties or an energy device, such as Harmonic™ or LigaSure™, to divide the short gastric vessels. When performing a subtotal gastrectomy, this dissection should stop at the beginning of the short gastric vessels as short gastric arteries provide the blood supply to the proximal gastric remnant.

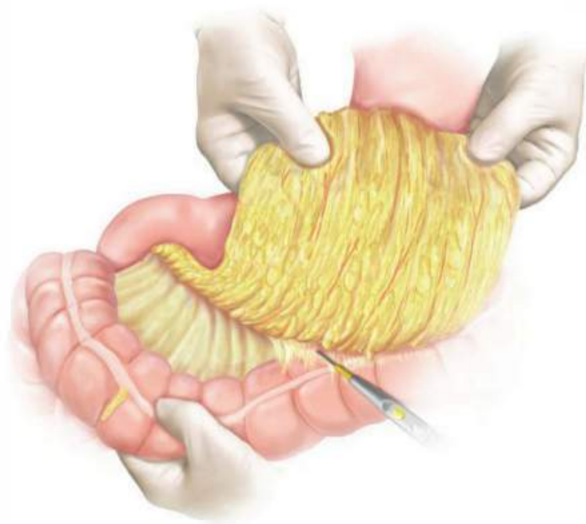

FIG 3 ● Separation of the omentum from the transverse colon. Omentum is separated from the transverse colon along the avascular embryonic planes of fusion thus allowing access to the lesser sac.

DUODENAL MOBILIZATION AND TRANSECTION

- The hepatic flexure of the colon is mobilized by dividing the avascular attachment of the right colon to the retroperitoneum. The separation of the greater omentum from the transverse mesocolon is continued to the hepatic flexure. This exposes the gastrocolic trunk, which is formed by the confluence of right gastroepiploic vein with a colonic vein and drains into the superior mesenteric vein (**FIG 4**). The right gastroepiploic vein is divided at its junction with the gastrocolic trunk. Alternatively, the gastrocolic trunk can be divided with a single fire of

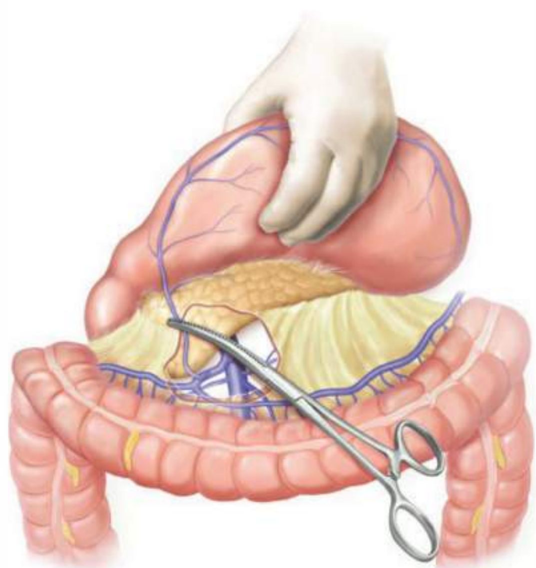

FIG 4 ● Ligation of the right gastroepiploic vein. Right gastroepiploic vein is ligated at its junction with the colonic veins. Alternatively, the gastrocolic trunk can be divided with a single fire of a vascular stapler load.

FIG 5 ● Dissection of the infrapyloric nodal packet at the level of right gastroepiploic vessels.

vascular stapler. At this stage, the right gastroepiploic artery is divided at its origin at the infraduodenal level. The infrapyloric nodes, located adjacent to the origin of gastroduodenal artery, are mobilized with the specimen (**FIG 5**).

- The lesser curvature is mobilized by dividing the lesser omentum as close to the liver as possible (**FIG 6**). If a replaced or accessory left hepatic artery is identified, it should be temporarily ligated, and the perfusion of the left lobe of the liver should be assessed prior to transecting the vessel. The dissection is carried distally to the portal triad. The right gastric artery arising from the common hepatic artery is divided including the lymphatic tissue with the specimen. The duodenum is circumferentially dissected about 2 to 3 cm distal to the pylorus, encircled with a Penrose drain and divided with either a stapler or in between straight bowel clamps (**FIG 7**). Care is taken not to injure the bile duct, hepatic artery, or portal vein when encircling the duodenum. The stapled duodenal line is oversewn with 3-0 silk Lembert sutures and can be buttressed with the falciform ligament (Moossa's patch). However, in the setting of extensive inflammation around the periduodenal area, consideration should be given to dividing the duodenal stump in between two straight bowel clamps and suture closure of the duodenal stump.

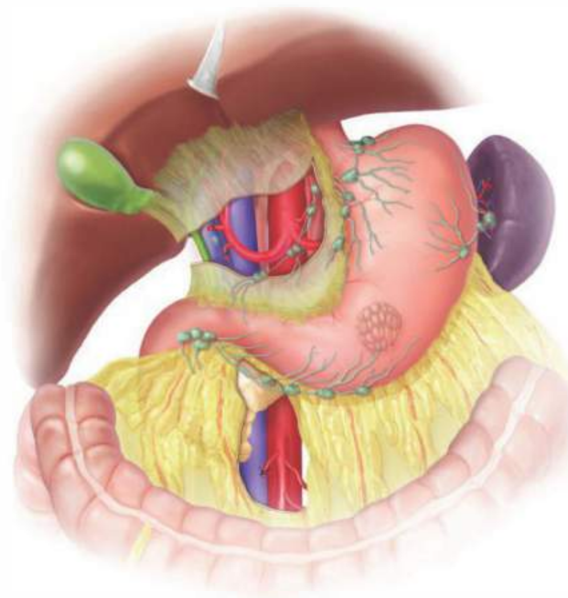

FIG 6 ● Mobilization of the lesser curvature of the stomach. Lesser omentum is divided as close to the liver as possible. Presence of replaced or accessory left hepatic artery is carefully sought for.

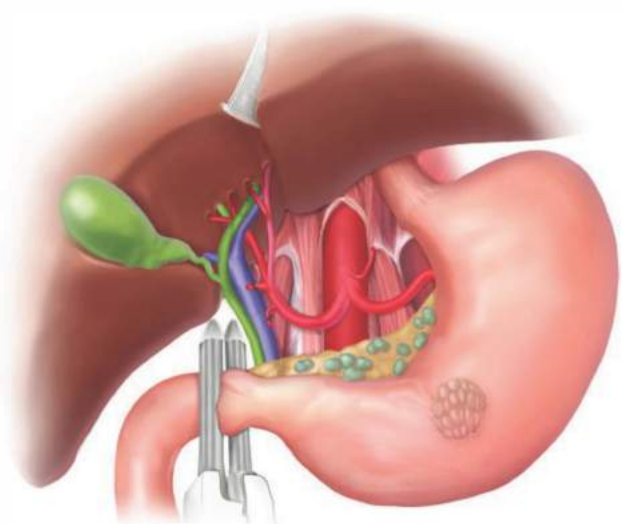

FIG 7 ● Division of duodenum. Duodenum is encircled with a Penrose and divided with a blue GIA stapler load. Care is taken to avoid injury to portal vein, bile duct, and hepatic artery.

- The gastrectomy specimen, now disconnected distally, is lifted upward. The left gastric artery is identified, suture ligated, and divided at its origin (**FIG 8**). The lymph–areolar tissue with the left gastric artery is mobilized with the specimen.

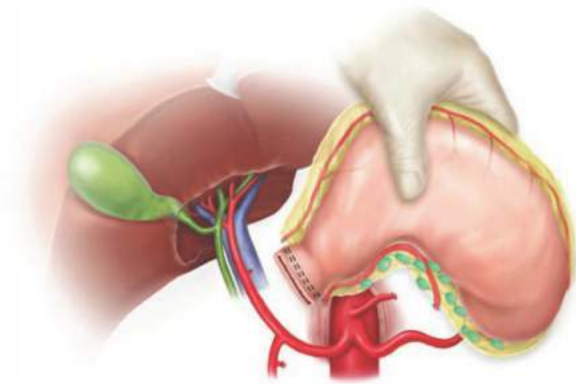

FIG 8 ● Division of left gastric artery. Stomach is lifted upward, left gastric artery is identified, and suture ligated. The lymph node packet along the left gastric artery is mobilized along with the specimen.

GASTRIC TRANSECTION

- Next, the stomach is divided about 4 to 6 cm proximal to the gastric cancer (**FIG 9**). Our preference is to use several green loads of a GI stapler.
- We send the resected specimen in separate containers in the following manner: (1) stomach with a marking stitch on proximal end, (2) greater omentum, (3) infrapyloric nodal packet, and (4) lesser curvature nodal packet with a long stitch on the left gastric artery. The operating surgeon should communicate with the pathologist to orient him/her to the specimen and indicate the proximal and distal margins for frozen section assessment.

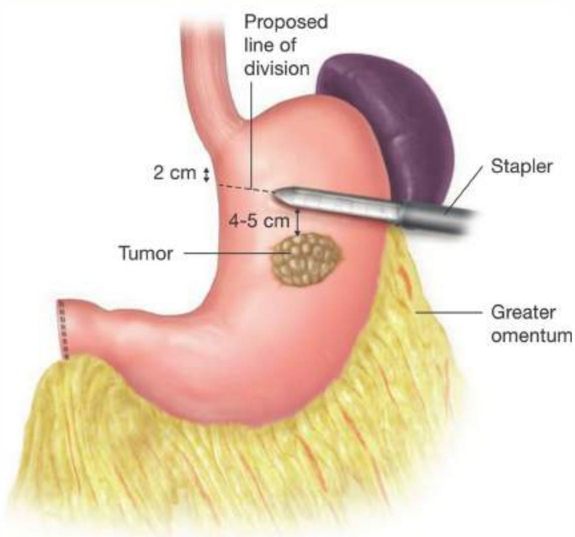

FIG 9 ● Division of the stomach. Stomach is divided 5 to 6 cm proximal to the most proximal extent of the tumor along a line extending from 2 cm distal the gastroesophageal (GE) junction to the greater curvature.

EXTENT OF LYMPHADENECTOMY

- The extent of lymphadenectomy in patients with operable gastric cancer is an area of controversy.[7,8] To ensure adequate lymphadenectomy, the gastric arteries need to be divided at their origin. We typically perform a pancreas- and spleen-preserving lymphadenectomy. That is, taking the right gastric artery, right gastroepiploic artery, and left gastric arteries at their origin along with celiac axis nodal dissection. We acknowledge that the addition of a celiac axis dissection is an area of controversy.

RECONSTRUCTION

- Restoration of GI continuity can be achieved by performing a Billroth II loop gastrojejunostomy or Roux-en-Y gastrojejunostomy. Our preference is Roux-en-Y gastrojejunostomy.
- **Roux-en-Y reconstruction:** While awaiting frozen section on the gastric margins, we proceed with the reconstruction. A loop of jejunum distal to the ligament of Treitz that reaches the stomach pouch without tension is identified. The jejunum is divided at this point

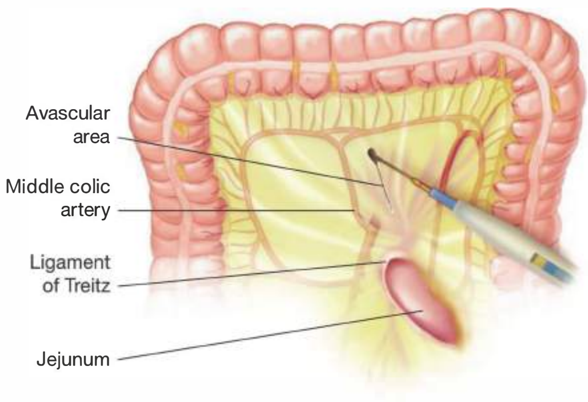

FIG 10 ● Creation of defect in transverse mesocolon. A defect is created in the transverse mesocolon to the left of middle colic veins. The Roux limb is taken to the gastric remnant in a retrocolic fashion.

with a blue gastrointestinal anastomosis (GIA) stapler. The staple line on the end of the Roux limb is oversewn with 3-0 silk stitches in Lembert fashion. The Roux limb needs to be at least 40 cm (i.e., from its beginning at the level of stomach to the jejunojejunostomy). A defect is created in the transverse mesocolon to the left of the middle colic vessels (**FIG 10**). We then confirm that the Roux limb can easily reach the stomach without tension when placed in the retrocolic position. Our preference is to first perform a stapled side-to-side anastomosis between the biliopancreatic limb and the jejunum. Our rationale behind this order of reconstruction is to allow for an easier reconstruction of this anastomosis away from the transverse mesocolon defect. Stay sutures are placed between the biliopancreatic limb and the jejunum. Enterotomies are made in the biliopancreatic limb and the jejunum. One limb of the blue GIA stapler is introduced into the biliopancreatic limb and the other in the jejunum. The blue load is fired and the common enterotomy is closed either in a hand-sewn fashion or with a single fire of GIA or thoracoabdominal (TA) stapler.

- Then, the Roux limb is navigated through the defect in the transverse mesocolon. A two-layered side-to-side anastomosis is created between the anterior surface of the gastric pouch and the Roux limb. A posterior layer of interrupted 3-0 silk seromuscular (Lembert) sutures are placed (**FIG 11A**). Two opposing enterotomies are made on the stomach and the antimesenteric border of the Roux limb. The length of the opening in jejunum should be shorter than that made in the stomach as the opening in the small bowel tends to expand. Next, an inner posterior layer of full-thickness interrupted 3-0 silk (or absorbable) sutures are placed, followed by an anterior layer of interrupted 3-0 silk (or absorbable) full-thickness stitches (**FIG 11B**). Prior to completion of anterior layer, the anesthesiologist advances the NG tube into the afferent limb of the jejunum. Following completion of the inner layer of the two-layered anastomosis, an anterior layer of interrupted 3-0 silk seromuscular (Lembert) sutures are placed (**FIG 12**). Alternatively, the surgeon can perform this anastomosis as a stapled anastomosis. The Roux limb is sutured to the transverse mesocolon to prevent herniation of small bowel through this defect.

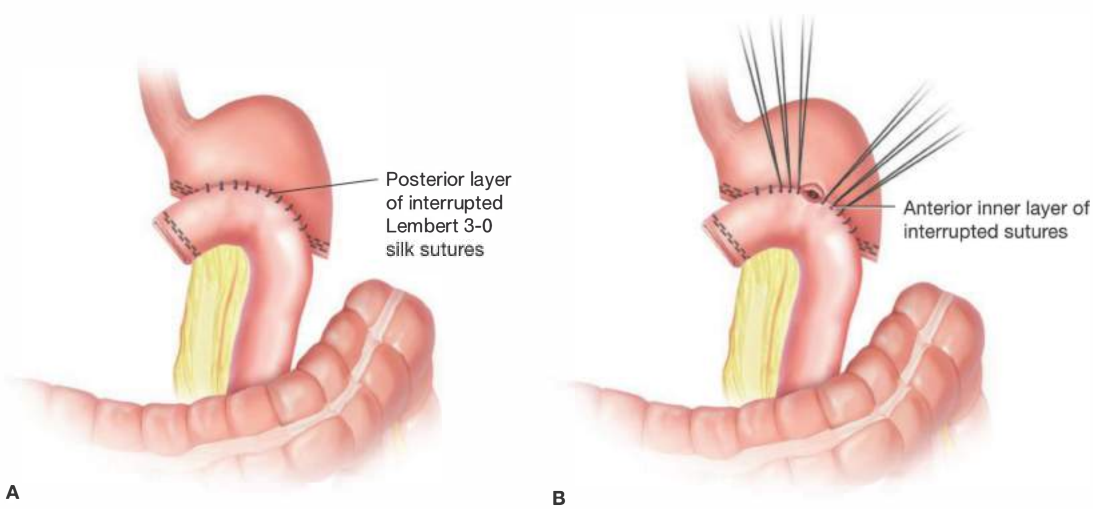

FIG 11 ● Construction of two-layered hand-sewn gastrojejunal anastomosis. **A.** A series of posterior layer of interrupted 3-0 silk sutures are placed. **B.** Anterior inner layer also consists of interrupted 4-0 absorbable full-thickness stitches. Prior to completion of anterior layer, an NG tube is advanced into the afferent limb of the jejunum. Following completion of the inner layer of the two-layered anastomosis, an anterior layer of interrupted 3-0 silk is placed.

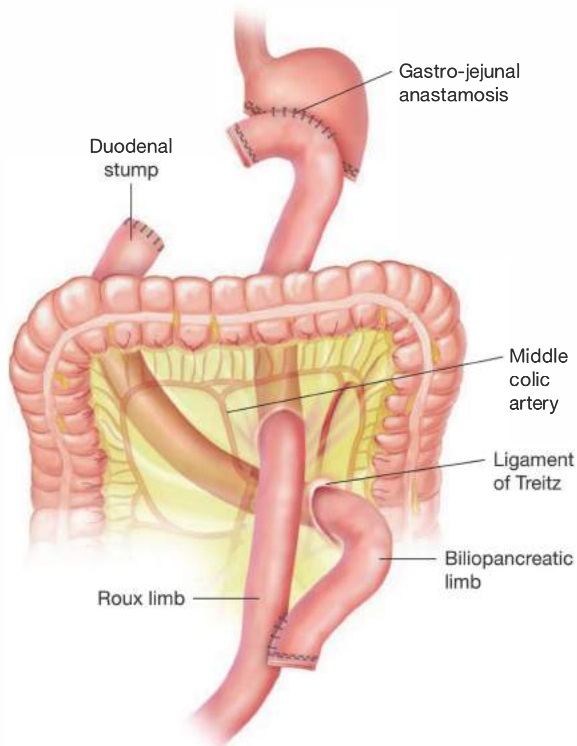

FIG 12 ● Final anatomy after completion of gastrojejunal anastomosis.

CLOSURE

- At this point, abdomen is irrigated and the fascia closed with a running no. 1 absorbable monofilament suture.

The skin is closed with staples or running subcuticular absorbable suture.

PEARLS AND PITFALLS

Diagnostic studies	■ The endoscopy should be performed or personally discussed with the endoscopist for better operative planning and intraoperative localization of the tumor.
Staging laparoscopy	■ Staging laparoscopy is critical to avoid nontherapeutic laparotomy. Up to a third of the patients with localized disease on imaging will have subradiologic peritoneal spread.
Preoperative nutrition	■ Preoperative nutrition should be addressed by nasojejunal tube placement and enteral nutrition. Addressing gastric outlet obstruction by endoscopic means (e.g., stenting) or placement of a jejunostomy tube (J tube) at the time of staging laparoscopy also helps with nutritional optimization.
Mobilization of greater curvature of the stomach	■ Greater curvature of the stomach should be mobilized, taking care to avoid unnecessary traction on splenic adhesions thus avoiding splenic injury and splenectomy. The blood supply to the proximal gastric pouch is from short gastric vessels, which should be preserved above the point of transection. If injury to spleen requires a splenectomy then total gastrectomy should be performed, as the removal of spleen jeopardizes the vascular supply of the proximal gastric remnant.
Circumferential dissection of duodenum	■ Careful dissection around the duodenum in the infrapyloric area is a key step to ensure adequate lymphadenectomy and avoid injury to common bile duct and portal vein.
Left gastric pedicle dissection	■ Identification and ligation of left gastric vein should be done with care to avoid bleeding or venous tear propagating to the portal vein.

Reconstruction of the gastrointestinal continuity	■ Before constructing the gastrojejunal anastomosis, the orientation of the Roux limb should be carefully checked to prevent twisting or undue tension on the anastomosis.
Delayed gastric emptying	■ Up to 15% to 20% of the patients demonstrate delayed gastric emptying after gastric surgery. Early recognition of symptomatology, by not mistaking vomiting or early satiety as postoperative ileus, is important. Treatment is supportive with gastric decompression and trial of prokinetic agents (e.g., metoclopramide or intravenous [IV] erythromycin).

POSTOPERATIVE CARE

- **General management:** Similar to other intraabdominal operation, patients with subtotal gastrectomy should undergo a regimen of aggressive pulmonary hygiene, early ambulation, and physical therapy. Careful attention should be paid to the volume status, electrolytes, and input/output balance.
- **DVT prophylaxis:** We start patients on DVT prophylaxis within 24 hours after completion of the procedure unless contraindicated.
- **NG tube:** We keep the NG tube until 2 to 3 days postoperatively. If the tube gets dislodged accidently, we do not replace it. If replacement of an NG tube is necessary, it should be performed under fluoroscopy to avoid accidental disruption of the anastomosis by a blindly placed NG tube.
- **Diet:** A clear liquid diet is initiated on postoperative day 3 or 4 and advanced as tolerated. We consult a dietitian to educate patients on issues related to postgastrectomy diet.

OUTCOMES

- **Prognosis:** 5-year survival is 70% for stage IA, 57% for stage IB, 45% for stage IIA, 32% for stage IIB, 20% for stage IIIA, 14% for stage IIIB, 9% for stage IIIC, and 4% for stage IV.[9]
- In a landmark study,[10] adjuvant chemoradiation therapy for the treatment of stage IB to IV M0 (AJCC 1988) resectable gastric cancer improved the 3-year overall and relapse-free survival from 41% to 50% and 31% to 48%, respectively.
- Similarly, perioperative chemotherapy without radiation[11] for gastric cancer led to an improvement of overall 5-year survival from 23% to 36%.

COMPLICATIONS

- **Pulmonary complications**
  - Pulmonary complications are frequent after upper abdominal surgery including atelectasis, aspiration, pneumonia, DVT, and pulmonary embolism. Good pulmonary toilet, early mobilization, elevation of the head of the bed, close attention to fluid balance, and early initiation of DVT prophylaxis are paramount to minimize the occurrences.
- **Postoperative bleeding**
  - **Presentation:** Postoperative bleeding can occur intraluminal or intraabdominal. Intraluminal bleeding presents with fresh blood in NG tube, melena, falling hemoglobin, and if severe, as hemodynamic instability. Bleeding from the anastomosis line is the major cause of the intraluminal bleeding and usually occurs around postoperative days 5 to 7.[12] Intraabdominal bleeding presents with hypotension, tachycardia, dropping hemoglobin, and abdominal distension. Intraabdominal bleeding usually presents in the first 12 to 24 hours following surgery. Unrecognized splenic injuries in the form of capsular tears and lacerations and/or inadequate control of short gastric vessels are the major causes of postoperative intraabdominal bleeding.[12]
  - **Management:** Intraluminal bleeding can generally be managed by supportive measures in the form of correction of coagulopathy and volume resuscitation. Bleeding that causes hemodynamic compromise or does not respond to supportive measures requires careful endoscopic therapeutic measures. Reoperation for bleeding not controlled with endoscopy is rare. Intraabdominal bleeding requires volume resuscitation and correction of coagulopathy. Patients with hemodynamic compromise or who do not immediately respond to supportive measures (suggesting ongoing bleeding) should return to the operating room for definitive control of the bleeding source.
- **Anastomotic leak**
  - **Presentation:** The overall incidence of anastomotic leak after subtotal gastrectomy is much less as compared to esophagojejunal anastomosis leak after total gastrectomy and is about less than 2%. Anastomotic leak presents with intraabdominal sepsis with fever and leukocytosis.
  - **Management:** When anastomotic leak or intraabdominal sepsis is suspected, a CT scan of the abdomen and pelvis with oral and IV contrast is performed. CT scan may suggest the presence of anastomotic leak and would demonstrate the presence of any drainable abdominal collection. The anastomotic leak can further be confirmed and characterized with a Gastrografin swallow study. Most leaks can be managed by making the patient NPO, parenteral nutrition, and drainage of any intraabdominal collection. Weekly Gastrografin swallow studies can document when the leak is healed. Rarely is surgical intervention required. Small leaks can be closed primarily and buttressed with an omental patch. Larger leaks may require a revision of anastomosis with wide drainage and jejunostomy tube for enteral feeding.
- **Duodenal stump blowout**
  - **Presentation:** Duodenal stump blowout can present as either peritonitis and hemodynamic instability or in a more localized fashion as signs and symptoms of intraabdominal abscess. Overzealous dissection of duodenum leading to its devascularization, chronic scarring of duodenum complicating its closure, and obstruction of the biliopancreatic limb are potential etiologies.
  - **Management:** A CT scan will demonstrate an abscess in the right upper quadrant and will not contain oral contrast. A percutaneous drain with a contrast study through the drain will confirm connection with duodenum. Management is largely through supportive measures

including NPO, parenteral or enteral nutrition, and replacement of fluid losses. A percutaneous transhepatic duodenal diversion can assist with closure of the leak by diverting the bile and pancreatic juices away from the fistula. Operative management might be required if the fistula does not close. If the duodenal blowout presents as acute abdomen, then exploratory laparotomy, placement of a tube duodenostomy, and wide drainage of right upper quadrant is performed.

- **Delayed complications:**
  - **Delayed gastric emptying**
    - **Presentation:** Disruption of normal mechanisms of gastric emptying and motility with gastric surgery leads to delayed gastric emptying. Delayed gastric emptying presents as nausea, vomiting, bloating, hiccoughs, and continued high NG tube output in presence of antegrade bowel function. The diagnosis is clinical and can be confirmed by slow emptying of stomach on contrast study or nuclear medicine gastric emptying study.
    - **Management:** Treatment is largely supportive and includes gastric decompression with NG and trial of promotility agents such as metoclopramide (10 mg three times daily) and/or erythromycin (up to 250 mg four times a day).
  - **Alkaline reflux gastritis**
    - **Presentation:** Contact of gastric mucosa with biliary contents causes alkaline reflux gastritis and presents as epigastric pain unrelieved by antacids, nausea, and bilious vomiting. Diagnosis is clinical and one of exclusion. Anastomotic ulceration, afferent and efferent loop syndrome, and disease of the gallbladder and pancreas must be ruled out. Endoscopy demonstrates hyperemic gastric mucosa with biliary staining, which supports the diagnosis. Bile reflux can be further documented using a HIDA scan.
    - **Management:** Alkaline reflux gastritis does not respond well to medical therapy. However, a trial of medical therapy with cholestyramine, sucralfate, or antacid is still warranted. Surgical treatment involves diverting duodenal contents away from the stomach by converting loop gastrojejunostomy to a Roux-en-Y gastrojejunostomy with a 45- to 60-cm Roux limb. A vagotomy should be performed at the time of reoperation to reduce the risk of marginal ulcer.
  - **Afferent and efferent loop syndrome**
    - **Presentation:** Afferent or efferent loop syndrome occurs due to obstruction of the afferent or the efferent loop when a loop gastrojejunostomy has been used to restore GI continuity. This can present as an acute problem if the obstruction is complete or as a chronic problem due to partial obstruction. The potential causes are numerous and include internal herniation, volvulus, or kinking at the anastomosis. Acute afferent limb obstruction is the most common cause of duodenal stump blowout and is a surgical emergency. Patient presents with severe epigastric and right upper quadrant pain associated with nausea and vomiting. Physical examination may reveal an intraabdominal mass, and CT scan of the abdomen reveals the diagnosis. When the afferent limb is partially blocked, then it presents as chronic afferent loop syndrome where patients complain of postprandial abdominal pain with nausea and projectile vomiting, which typically does not contain food and relieves the pain. Diagnosis is clinical and is complemented with endoscopy and upper GI fluoroscopy studies. Obstruction of the efferent loop is less common and presents as abdominal pain, nausea, and bilious vomiting with food particles in it. The diagnosis can be confirmed by Gastrografin study, which shows a holdup in the passage of contrast into the efferent limb. Potential causes include retroanastomotic hernia, adhesions, and stricture.
    - **Management:** Acute afferent loop syndrome is an emergency and requires immediate operative exploration. If the duodenum and afferent limb are viable, then addressing the etiology may include shortening the redundant afferent limb, reducing internal herniation, closing the mesenteric defects, or revision of gastrojejunal anastomosis. However, necrosis of the duodenum in this condition is a difficult problem and may require a pancreaticoduodenectomy. In case of chronic afferent loop syndrome, conversion of a loop gastrojejunostomy to Roux-en-Y anastomosis addresses the problem. Surgery is usually required for efferent loop obstruction and involves correction of the underlying cause.
  - **Nutritional consequences:** Gastrectomy is associated with specific mineral and vitamin deficiencies[12] as described below.
    - **Iron deficiency:** Iron deficiency is the most common cause of anemia after gastrectomy. Iron malabsorption, decreased intake, and increased losses from friable mucosa are reasons for iron deficiency. Daily supplementation of 150 to 300 mg per day in divided doses should be provided.
    - **Vitamin B_{12} deficiency:** Reduction in production of intrinsic factor and decrease in stomach acidity thus decreasing absorption of vitamin B_{12} leads to vitamin B_{12} deficiency. Daily supplementation of 100 μg of oral vitamin B_{12} or a monthly 1 mg intramuscular vitamin B_{12} injection is recommended following subtotal gastrectomy.
    - **Other mineral and vitamin supplementation:** Decreased oral intake and decreased absorption due to decreased gastric acid secretion can contribute to folate deficiency thus supplementation of folate is also recommended. Supplementation of vitamin D and calcium is also recommended after gastric surgery.

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Chapter 12

Minimally Invasive Total Gastrectomy

Elliot Newman Marcovalerio Melis

DEFINITION

- Please refer to the *Minimally Invasive Distal Gastrectomy* chapter for details on definitions and indications.
- Currently, total gastrectomy is indicated for adenocarcinoma of the stomach where the proximal location precludes a lesser resection with a proximal 5- to 6-cm grossly negative margin.
- Randomized trials have shown that total gastrectomy offers no oncologic value over a distal gastrectomy as long as a negative margin can be obtained.[1,2]
- Occasionally, gastrointestinal stromal tumors located near the gastroesophageal junction may also require a total gastrectomy to achieve negative resection margins.

IMAGING AND OTHER DIAGNOSTIC STUDIES

- Following the diagnosis of gastric adenocarcinoma, accurate clinical staging is necessary.
- Endoscopic ultrasound will evaluate depth of tumor invasion and possible lymph node metastases
- Computed tomography (CT) scan of the chest abdomen and pelvis will evaluate for metastatic disease.
- Positron emission tomography (PET)/CT is recommended if no metastatic disease is detected by the CT.
- Diagnostic laparoscopy can be considered for advanced tumors (e.g., T3N1) to rule out subradiographic peritoneal dissemination.

SURGICAL MANAGEMENT

Preoperative Planning

- Same as *Minimally Invasive Distal Gastrectomy*. Please refer to the appropriate chapter.

Positioning

- Same as *Minimally Invasive Distal Gastrectomy* (**FIG 1**)
- Please refer to the appropriate chapter for further details.

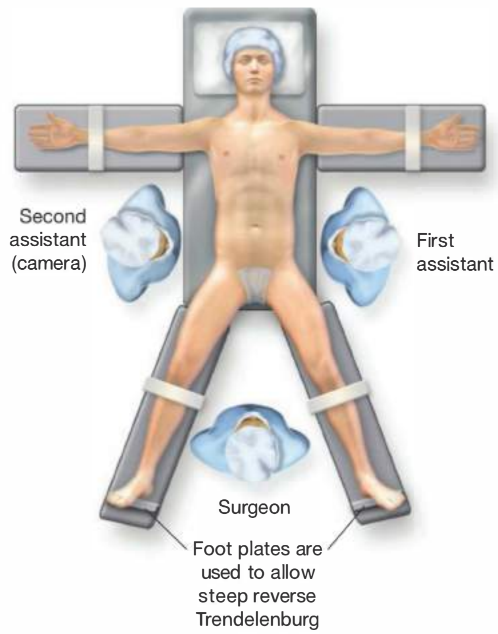

FIG 1 • Positioning of the patient on the operative table.

TECHNIQUES

ACCESS AND PORT PLACEMENT

- Same as *Minimally Invasive Distal Gastrectomy*, except for the camera port, which is placed routinely two to three fingerbreadths above the umbilicus and to the left of the midline, and a 15-mm trocar used for the most lateral trocar site on the left (**FIG 2**).
- Please refer to the appropriate chapter for further details.

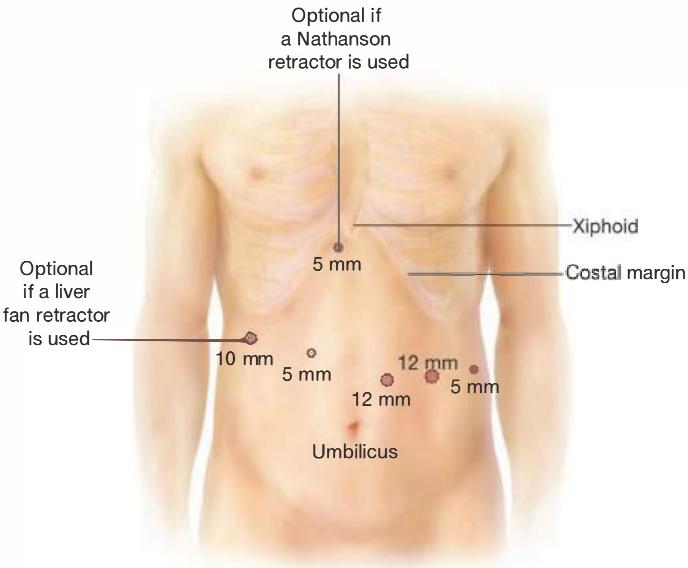

FIG 2 ● Port placement for laparoscopic distal gastrectomy. Depending on surgeon's preference for liver retraction, either a 5-mm trocar is placed at the epigastrium for a Nathanson retractor or a 10-mm trocar is placed in the lateral right upper quadrant for a fan retractor.

DISSECTION OF THE GREATER CURVE

- Retract the transverse colon and the greater omentum caudally.
- Access the lesser sac by entering the gastrocolic ligament in an avascular area with ultrasonic shears.
- Extend the dissection of the gastrocolic ligament distally toward the pylorus and cephalad toward the spleen with the ultrasonic shears.
- Continue the dissection of the gastrocolic ligament along the upper third of the greater curvature with the division of the left gastroepiploic vessels and then the gastrosplenic ligament including the short gastric vessels. This portion of the dissection is greatly facilitated by bringing the stomach down and rolling it up to expose the back wall of the stomach.
- By performing the dissection of the greater curvature lateral to the gastroepiploic arcade, the lymph nodes along the gastroepiploic vessels (stations 4d and 4sb) are included in the specimen.
- In order to expose the lesser cavity in its entirety, divide the avascular posterior gastropancreatic adhesions that are almost always present between the posterior wall of the stomach and the anterior surface of the pancreas. Division of those adhesions will also facilitate anterior retraction of the stomach (**FIG 3**).

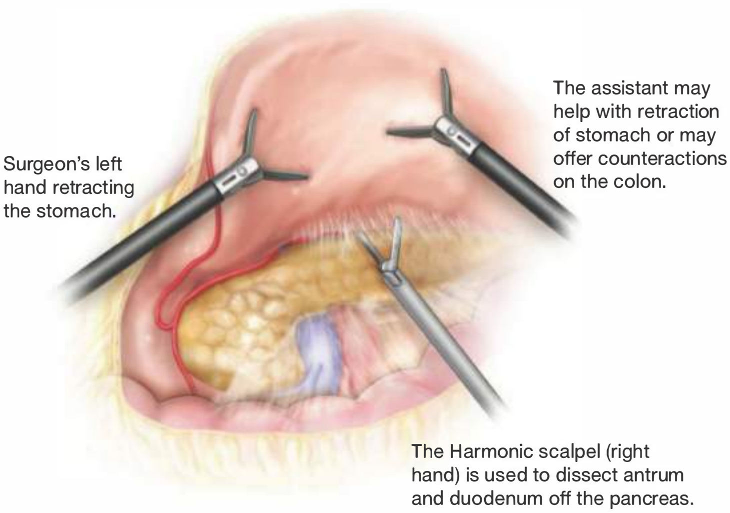

FIG 3 ● The stomach is retracted anteriorly to the patient's right, and adhesions between pancreas and posterior aspect of the stomach are divided.

- Next, continue the dissection more cranially along the greater gastric curvature, until all of the short gastric vessels are divided and the fundus is completely mobilized. At this time, the left crus and the hiatus with the distal esophagus should be visualized (**FIG 4**). Having the operating surgeon retract the anterior fundus toward the anterior abdominal wall and to the patient's right with the assistant retracting the posterior fundus in the same direction can improve the exposure.
- Using the ultrasonic dissector, divide the lateral portion of the phrenoesophageal ligament and expose the fibers of the left crus.

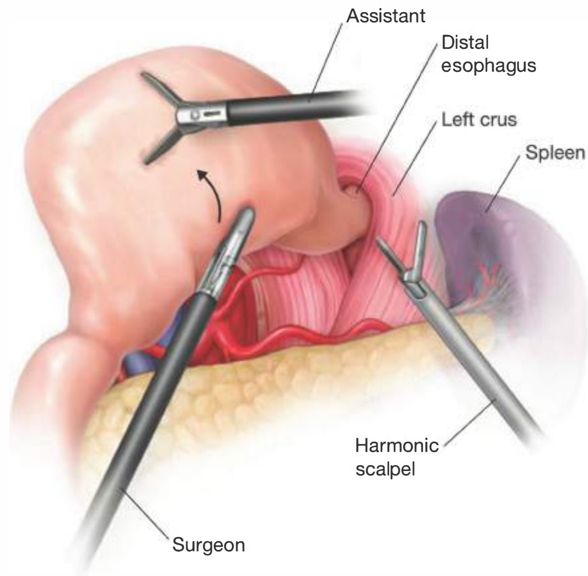

FIG 4 ● The greater curvature is completely dissected off the spleen and the stomach is elevated and rotated to the right, exposing the diaphragmatic hiatus.

ANTRAL DISSECTION

- Firm anterior retraction of the stomach aids in the duodenal dissection. While retracting the antrum toward the abdominal wall, separate bluntly or with Endoshear the posterior wall of the duodenum off the anterior surface of the pancreatic head. The gastroduodenal artery marks the limit of this pancreaticoduodenal dissection (**FIG 5**).
- Identify the origin of the right gastroepiploic artery. This is usually a direct continuation of the gastroduodenal

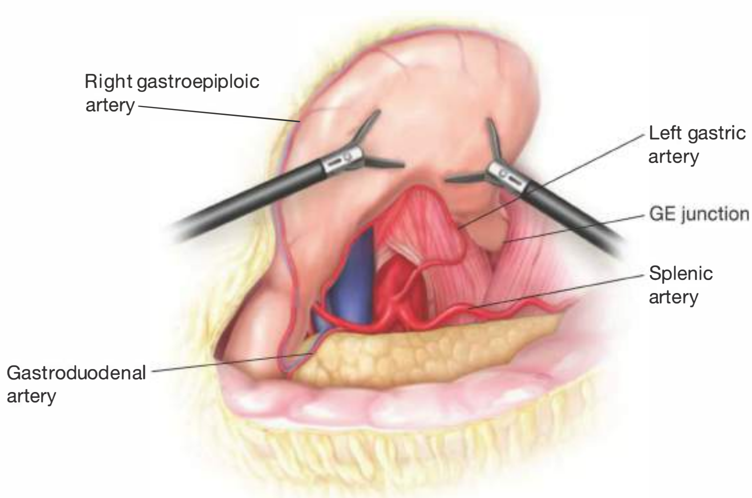

FIG 5 ● The antrum and the first portion of the duodenum are dissected off the pancreas. The gastroduodenal artery marks the limit of the duodenal dissection. The right gastroepiploic artery is identified at its takeoff from the gastroduodenal artery.

artery caudally emanating from the inferior edge of the pancreas. Use the lower border of the pancreas as a guide for where to divide the right gastroepiploic artery.

- Sweep the lymphatic tissue around the right gastroepiploic vessels (infrapyloric nodes, station 6) toward the specimen. Now, divide the right gastroepiploic vessels between clips or using a vascular load stapler. If clips have been used in proximity of the vessels, take great care to ensure they are not included in the stapler line.
- The right gastric artery can be dissected from behind the stomach and duodenum with good visualization. Dissect the filmy adhesions superior and posterior the first portion of the duodenum until the right gastric artery is visualized. Sweep the lymphatic tissue around the right gastric artery toward the specimen. This maneuver clears the suprapyloric lymph nodes (station 5).
- You can also retract the duodenum caudally and visualize the right gastric artery anteriorly at its takeoff from the common hepatic artery. Dissect it free, doubly clip, and divide it.

DIVISION OF THE DUODENUM

- Remove nasogastric tubes and/or temperature probes from the patient's mouth to prevent their inclusion in the jaws of the stapler.
- Make sure adequate length of duodenum is mobilized to easily allow placement of a linear stapler across the first portion of the duodenum, just distal to the pylorus.
- Place an Endo GIA with 3.5-mm cartridge close to the level of the duodenal dissection to avoid the pyloric ring and minimize duodenal ischemia. We often use a staple line reinforcement of biologic material, although usefulness of this device for prevention of postoperative leakage has not been proven. Before firing, make sure that any esophageal tube has been removed and that the portal structures are excluded from your stapler line.
- Make every attempt to divide the duodenum in one firing. Carefully inspect the integrity of duodenal staple line.

DISSECTION OF THE HEPATODUODENAL LIGAMENT

- Incise the peritoneum overlying the common hepatic artery and the bile duct with the hook electrocautery. Divide the gastrohepatic ligament, remaining along the left lobe of the liver and paying attention to identify and preserve an accessory or replaced left hepatic artery.
- Identify the base of the right crus.
- The lymph nodes along the common hepatic (station 8) and proper hepatic (station 12) arteries are removed en bloc just anterior to the portal vein. Our preference is to use the hook for dissection and the ultrasonic scalpel for division of larger vessels. Frequently, a vessel loop around the hepatic artery aids in retraction.

DISSECTION OF THE INTRAABDOMINAL ESOPHAGUS

- Have the assistant retract the stomach down and to the patient's left. This will improve exposure to the right crus, which had been previously identified.
- Free the gastroesophageal junction from the hiatus by dissecting up the right crus with ultrasonic shears.
- Take down the phrenoesophageal ligament and proceed through the connective tissue posterior to the esophagus to extend the dissection toward the left crus.
- Divide the right and left vagus nerves when identified.
- The gastroesophageal junction is now dissected circumferentially. Guide a 2-cm wide Penrose drain around the esophagus. Secure the two ends of the Penrose together with an Endo GIA stapler (Covidien, Norwalk, CT) or an Endo loop, leaving little space between the drain and the esophageal wall.
- The assistant may now use the Penrose drain to retract the esophagus caudally and increase exposure of the hiatal region. Complete the dissection of the lower esophagus using blunt and ultrasonic dissection.

DIVISION OF THE LEFT GASTRIC ARTERY

- Use either the Nathanson liver retractor or a handheld retractor to elevate the stomach and identify the left gastric artery and the celiac trunk.
- The left gastric vessels at this time should be readily identifiable caudad to the Penrose drain, between the two "windows" created by the hiatal dissection, and by the opening of the gastrohepatic ligament.
- Once the celiac anatomy is evident, dissect the left gastric artery and skeletonize its takeoff from the celiac trunk, therefore mobilizing nodal tissue of station 7 (left gastric artery) and 9 (celiac artery) anteriorly toward the specimen. Once the left gastric pedicle is skeletonized, divide it at its origin, using a 2.5-mm Endo GIA cartridge flush, with the anterior pancreatic body. Our practice is to take the coronary vein and the left gastric together in a single fire of the stapler.
- Once the left gastric artery is divided, skeletonize the splenic artery thus mobilizing station 11 nodes. Again, vessel loops may aid in retraction of the larger arteries in concert with gentle downward retraction of the

pancreatic body. Care must be taken to identify and preserve the splenic vein.

- We do not routinely include the peritoneum covering the anterior surface of the pancreas in our dissection.
- We do not routinely perform a splenectomy or a distal pancreatectomy, because in the western literature, potential benefits of a complete dissection of the lymph nodes in station 11 is outweighed by a significant increase in postoperative morbidity (specifically pancreatic leaks) without measurable effect in long-term survival.

PROXIMAL DIVISION

- Division of the left gastric artery will increase exposure to the hiatus.
- With the assistant pulling on the Penrose to retract the stomach caudally, complete (if necessary) the mobilization of the intraabdominal esophagus using ultrasonic shears.
- Place two stay sutures on each side of the esophagus, proximally to the planned division. Those sutures will facilitate retrieval of the esophagus should it retract in the mediastinum after removal of the specimen.
- Transect the distal esophagus using a 3.5-mm Endo GIA of appropriate length.
- The specimen is placed in a 15-mm endo bag and extracted by enlarging as needed the most lateral trocar site on the left. If you have to make a large incision to remove the specimen, you may need to use a ballooned trocar for this site to seal the peritoneal cavity and avoid loss of the pneumoperitoneum.
- Obtain hemostasis.
- The stump of the excised portion of esophagus may be submitted for frozen section examination to assure a microscopically negative margin.

RECONSTRUCTION WITH STAPLED ESOPHAGOJEJUNOSTOMY

- Our choice for the reconstruction is a Roux-en-Y esophagojejunostomy in an antecolic fashion, using an end-to-end anastomosis (EEA) OrVil™ stapler device with a 25-mm diameter. Alternatively, a 21-mm diameter EEA stapler can be used for a smaller caliber esophagus.
- The OrVil™ is a device prepared with an EEA anvil head fastened in a tilted state to a long polyester tube.
- End-to-side esophagojejunostomy
  - Exposure of the distal esophagus is facilitated by gentle tension on the stay sutures previously placed.
  - Insert the OrVil™ device through the patient's mouth and guide it into the esophagus until the tip reaches the stapled line at its blinded end.
  - Create a small esophagotomy in the midportion of the stapled line, and let the tip of the OrVil™ pass through it.
  - Use a grasper inserted through a left trocar to pull the tube outside the esophagus, until the anvil is seen effacing the stapled line at the end of the esophageal stump. You must pay extreme attention during this maneuver, as it is relatively easy to tear the esophagus. Maneuvers that assist in passing the OrVil™ include adequate paralysis, jaw thrust, and deflating the balloon in the endotracheal tube.
  - The anvil head and the tube are kept connected by two pieces of polyester yarns; while securing the anvil, cut one thread and detach the tube from the anvil.
  - Identify the ligament of Treitz at the base of the transverse mesocolon. Proper anatomy is confirmed by visualization of the inferior mesenteric vein.
  - Divide the jejunum 20 cm away from the ligament of Treitz with a 3.5-mm Endo GIA.
  - Starting from the mesenteric side, remove most of the stapled line from the distal limb of the divided jejunum. Make sure not to completely excise the stapled line from the jejunum, but leave it attached to the antimesenteric side; you can use it as a handle to facilitate maneuvering this loop of bowel over the stapler.
  - Remove the trocar from the left lateral incision and use this opening to insert the EEA stapler into the abdomen. Enlarge this incision as needed to accommodate the EEA. Usually, two fingerbreadths are sufficient. Your assistant should now use two graspers to grab the mesenteric side and the thin strip of jejunum with the staples still attached to the antimesenteric side. While your assistant provides adequate exposure of the jejunal lumen with the two graspers, guide the EEA inside the lumen of the jejunum.
  - Select an appropriate site on the antimesenteric side of the jejunum for the esophagojejunostomy. Make sure it can easily reach the esophageal stump without tension.
  - Once you are satisfied with the site for the anastomosis, advance the spike of the EEA through the antimesenteric wall of the jejunum.
  - Ask your assistance to maintain tension on the jejunum, so that it does not retract off the EEA. Paying extreme attention to keep the spike of the EEA through the jejunotomy, advance the EEA toward the esophageal stump (**FIG 6**).
  - Firmly hold the anvil with a right-angle grasper, and use the other hand to progressively guide the spike of the EEA into the anvil until the two parts of the stapler click together.
  - Now close the EEA while advancing it toward the esophagus in order to avoid excessive tension of the anvil against the esophageal stapled line.
  - The anvil and the main unit are now connected. Make sure that nothing is caught between the esophagus and the jejunum while you fire the EEA stapler. Fire the stapler to complete the anastomosis.

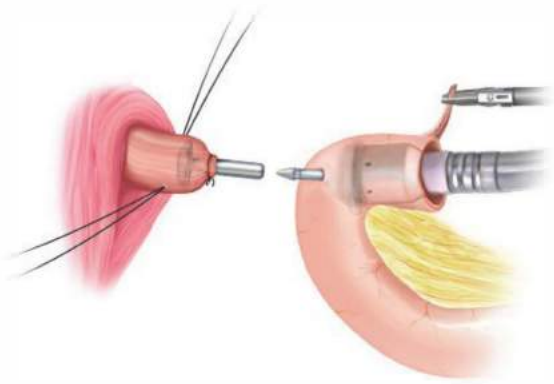

FIG 6 ● An end-to-side esophagojejunostomy is created with a mechanical stapler. The assistant holds the jejunum to avoid its displacement off the stapler. The surgeon advances the stapler over the colon toward the anvil while avoiding excessive tension of the anvil against the esophageal stapled line.

  - Use a 3.5-mm Endo GIA to close the open end of the jejunum. Our practice is to leave approximately 3 cm of jejunum as blind end.
- Side-to-side jejunojejunostomy
  - The jejunojejunostomy is typically created 40 to 50 cm distal to the esophagojejunostomy.
  - Use stay sutures to secure in a side-to-side fashion the stapled end of the biliopancreatic limb to the alimentary limb of the jejunum, just caudal to the transverse colon and avoiding any tension.
  - Use the ultrasonic shears to make a small enterotomy in the antimesenteric side of each limb.
  - Insert the jaws of a 3.5-mm Endo GIA in the enterotomies. Make sure that no mesentery or other loops of bowel are caught in the stapler prior to firing.
  - Once the stapler is fired, the staple line is inspected for bleeding.
  - Close the remaining anastomotic defect, which corresponds to the proximal end of the staple rows in two layers using running nonabsorbable suture.

CLOSING

- Complete a final inspection of all staple lines and vascular pedicles for hemostasis and well-formed staples. Bleeding points and areas of malformed staples should be oversewn with absorbable suture.
- Closed suction drainage is optional.
- Abdominal fascia is closed for all port sites larger than 5 mm.

POSTOPERATIVE CARE

- We usually keep a nasojejunal tube for 24 hours in order to avoid distension of the proximal jejunum, which may compromise the integrity of the anastomosis. Whether this decreases the leak rate has not been proven.
- Immediately after surgery, the patient is instructed to use incentive spirometry, cough, and take deep breaths. Patients are encouraged to stay out of bed and ambulate within 6 hours from surgery.
- Prophylactic antibiotics are not indicated in the postoperative period.
- Unless an epidural catheter is used for analgesia, the Foley catheter is removed in postoperative day 1.
- If the patient is able to protect his or her airway and the abdomen is not distended, clear liquids are allowed on postoperative day 1, then diet is advanced to a postgastrectomy diet as tolerated.

OUTCOMES

- Minimally invasive total gastrectomy is a safe and effective treatment of gastric cancer.
- Available evidence shows no major differences in morbidity, mortality, number of nodes harvested, or disease-free survival.
- The addition of a D2 dissection elevates this operation to much higher difficulty level.
- Oncologic principles and safety are paramount and should not be sacrificed for a less invasive approach.

COMPLICATIONS

- The postoperative complications observed after minimally invasive total gastrectomy generally are comparable with those of an open procedure.
- *Intraoperative*
  - Bleeding
  - Splenic injury
  - Iatrogenic enterotomy
- *Early postoperative*
  - Esophagojejunal leak
  - Duodenal leak
  - Bleeding
- *Late postoperative*
  - Dumping
  - Afferent limb syndrome
  - Malnutrition
  - Anastomotic stricture

REFERENCES

1. Bozzetti F, Marubini E, Bonfanti G, et al. Subtotal versus total gastrectomy for gastric cancer: five-year survival rates in a multicenter randomized Italian trial. *Ann Surg*. 1999;230:170–178.
2. Gouzi JL, Huguier M, Fagniez PL, et al. Total versus subtotal gastrectomy for adenocarcinoma of the gastric antrum: a French prospective controlled study. *Ann Surg*. 1989;209:162–166.

Chapter 13

Minimally Invasive Distal Gastrectomy

John K. Saunders Marcovalerio Melis

DEFINITION

- The indications for minimally invasive distal gastrectomy (MIDG) do not differ from the indications for open gastrectomy and include both benign and malignant diseases.
- Gastric malignancies (adenocarcinomas, neuroendocrine tumors, gastrointestinal stromal tumors [GIST], and other submucosal neoplasms) account for the single largest indication for gastric resection and will be the focus of this chapter.
- MIDG performed for malignancies should follow the same standard oncologic principles generally followed during open resections.
- For adenocarcinomas, gastric resection should be extended proximally for 5 to 6 cm from the gross tumor margins. For tumors of the distal stomach, this is generally achievable with a partial gastrectomy. Randomized trials have shown that total gastrectomy offers no oncologic value over a distal gastrectomy as long as a negative margin can be obtained.[1,2] Appropriate extent of lymphadenectomy for gastric adenocarcinoma in the western population is a topic of great debate and beyond the scope of the present chapter. In our practice, we usually perform a D2 lymph node dissection. A recent meta-analysis has shown that MIDG for gastric adenocarcinoma is safe and associated with reduced overall morbidity.[3] Comparative studies with long-term follow-up are still lacking, but available evidence suggests that oncologic outcomes are comparable after either MIDG or open distal gastrectomy. Perioperative chemotherapy is indicated for any gastric adenocarcinoma stage T2N0M0 or greater as recommended by National Comprehensive Cancer Network (NCCN) guidelines.
- For GIST, gastric resection follows different oncologic principles. A lymph node dissection is not required and surgery is considered curative as long as the resection margins are negative. Therefore, more limited resections (e.g., wedge resections) are appropriate for GIST. Partial gastrectomies may still be required for large tumors or when the gastroesophageal junction or the pylorus is involved.
- Although decreasing in frequency, complications of peptic ulcer disease (bleeding, gastric outlet obstruction, failure of medical treatment) are still significant indications for distal gastrectomy. The same technique described in this chapter may be used for benign pathologies, omitting the lymphadenectomy.

IMAGING AND OTHER DIAGNOSTIC STUDIES

- Following the diagnosis of gastric adenocarcinoma, accurate clinical staging is necessary.
- Endoscopic ultrasound will evaluate depth of tumor invasion and possible lymph node metastases.
- Computed tomography (CT) scan of the chest abdomen and pelvis will assess metastatic disease.
- Positron emission tomography (PET)/CT is recommended if no metastatic disease is detected by the CT.
- Diagnostic laparoscopy can be considered for advanced tumors (e.g., T3N1) to rule out subradiographic peritoneal dissemination but not routinely indicated.

SURGICAL MANAGEMENT

Preoperative Planning

- The choice of laparoscopic versus open techniques should be at the discretion of the surgeon.
- Regardless of the technique, the primary goals of the operation are the same: resection of the cancer with negative margins and restoration of intestinal continuity.
- The patient should be medically optimized for surgery. Special attention needs to be given to malnourished patients.
- Preoperative nutritional panels are mandatory, and occasionally, the placement of a preoperative feeding jejunostomy is warranted. Consider preoperative tube feedings in patients with significant weight loss or other evidence of malnutrition, especially if candidates for neoadjuvant treatment.
- Consider neoadjuvant treatment for lesions T2 or greater and/or for suspected lymph node involvement.
- Insist on smoking cessation to reduce postoperative pulmonary and wound complications.
- Consider a preoperative liquid protein diet to improve steatohepatitis in obese patients.
- Perioperative antibiotic should be given within 30 minutes prior to the initial skin incision.
- Deep vein thrombosis (DVT) prophylaxis with calf length pneumatic compression devices or subcutaneous heparin (or both) should be instituted prior to induction of anesthesia.
- General anesthesia may be supplemented with epidural analgesia.
- The bladder is decompressed with a Foley catheter.
- An orogastric or a nasogastric tube is inserted.

Positioning

- Use an operating room (OR) table that may accommodate very steep reverse Trendelenburg position.
- Preferred position is supine split leg with foot plate attachments to prevent patient migration. The foot plates should be snugly placed with the toes pointing slightly outward (**FIG 1**).
- Pad pressure points along arms and legs and secure the knees in the locked position. Pillow cases or folded sheets and 2-in silk tape can be used to keep the knees from buckling. Arms are secured either by Kerlix™ gauze wrapped around the armboard or by commercially made arm straps.
- Prior to prepping and draping, check the positioning by manipulating the bed in all of the positions that will be used during the operation.

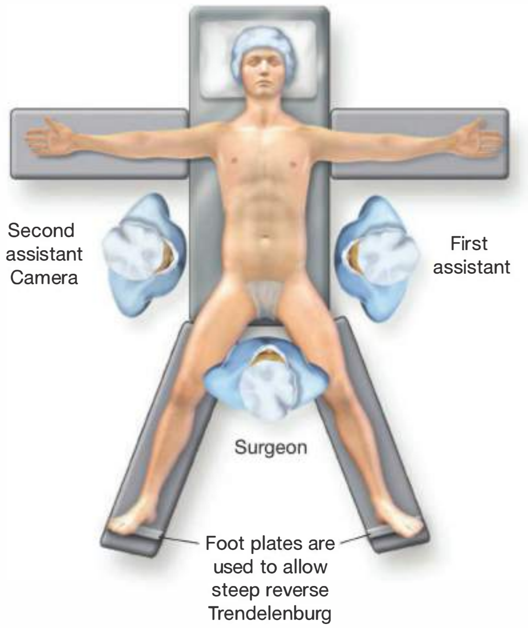

FIG 1 ● Positioning of the patient on the operative table.

ACCESS AND PORT PLACEMENT

- Port placement is dictated by the body habitus of the patient. The umbilical trocar is generally used for the camera. In obese patients, or with an unusually low umbilicus, the camera port may need to be more cephalad, often two or three fingerbreadths above the umbilicus and left to the midline.
- Place a 10-mm trocar at the umbilicus with usual Hassan technique.
- Establish a 15 mmHg pneumoperitoneum and perform a diagnostic laparoscopy to rule out peritoneal or hepatic metastases. If metastatic lesions are suspected, they should be biopsied and sent for frozen section prior to committing to gastrectomy. If ascites is present, washings should be performed.
- Identify the neoplasm by visualization or by palpation. If unsuccessful, intraoperative endoscopy is encouraged.
- Place the patient in steep reverse Trendelenburg position and insert the trocars under direct visualization and in a direction that minimize torque. Our typical port setup is shown in **FIG 2**.
- Retract the liver with a subxiphoid Nathanson retractor. However, stiff or floppy livers are best retracted with a 10-mm handheld fan retractor from the patient's right side.

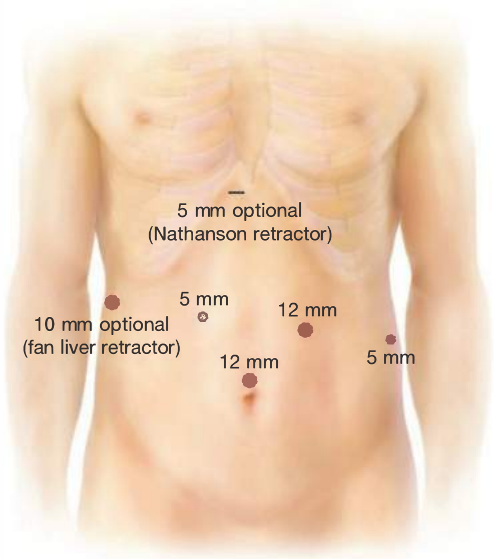

FIG 2 ● Port placement for laparoscopic distal gastrectomy. Depending on surgeon's preference for liver retraction, either a 5-mm trocar is placed at the epigastrium for a Nathanson retractor or a 10-mm trocar is placed in the lateral right upper quadrant for a fan retractor.

GASTROCOLIC DISSECTION

- Reflect the greater omentum cephalad. Retract the transverse colon caudally.
- Mobilize the omentum off of the transverse colon using ultrasonic scissors. In the course of this mobilization, the lesser sac is entered. It is helpful to widely open the lesser sac in order to aid the anterior retraction of the distal stomach.
- Care must be taken to preserve at least the most proximal short gastric vessels to assure adequate perfusion to the remnant stomach.
- Lysing the gastropancreatic adhesions is helpful in obtaining the proper retraction.

ANTRAL DISSECTION

- Once the greater curvature is fully mobilized, complete the gastric dissection by dividing sharply any gastropancreatic or retrogastric adhesions until the entire posterior wall of the stomach are visualized in its entirety (**FIG 3**).
- Firm anterior retraction of the stomach aids in the duodenal dissection. By retracting the antrum toward the abdominal wall, the duodenum may be freed from the anterior surface of the pancreatic head. The gastroduodenal artery marks the limit of this pancreaticoduodenal dissection.
- Identify the origin of the right gastroepiploic artery (which corresponds to lymph node station 6 [**FIG 4**]). This is usually a direct continuation of the gastroduodenal artery, caudally emanating from the inferior edge of the pancreas. Use the lower border of the pancreas as a guide for where to divide the right gastroepiploic artery.
- Sweep the lymphatic tissue around the right gastroepiploic vessels toward the specimen. Then divide the right gastroepiploic vessels between clips or using a vascular load stapler. If clips have been used in proximity of the vessels, take great care to ensure they are not included in the stapler line.
- The right gastric artery can be dissected from behind the stomach and duodenum with good visualization. Dissect the filmy adhesions superior and posterior to the first portion of the duodenum until the right gastric artery is visualized. You can also retract the duodenum caudally and visualize the right gastric anteriorly at its takeoff from the common hepatic artery. Dissect it free, doubly clip, and divide it.

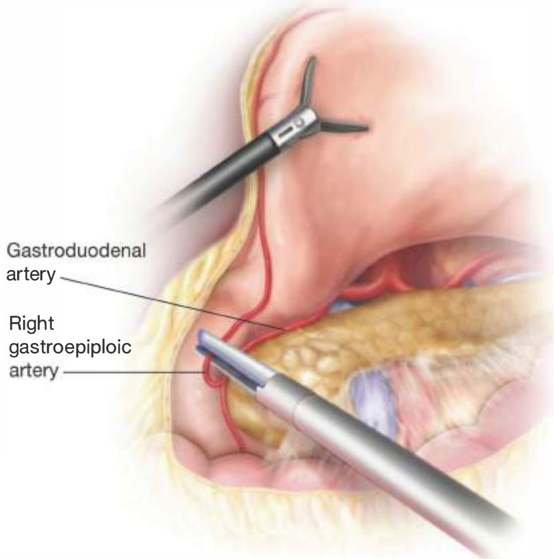

FIG 4 ● The right gastroepiploic artery is divided between clips or using a stapler or energy-sealing device.

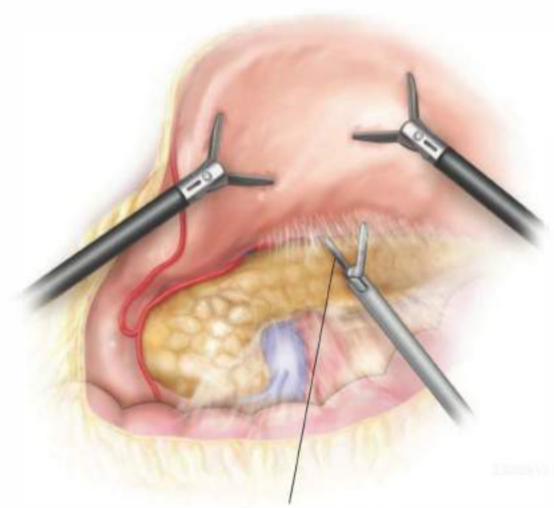

FIG 3 ● Posterior dissection of the antrum. The stomach is retracted anteriorly to the patient's right, and adhesions between pancreas and posterior aspect of the stomach are divided. The first portion of the duodenum has to be completely mobilized in order to allow safe use of the Endo GIA stapler for its transection.

DIVISION OF THE DUODENUM

- Remove nasogastric tubes and/or temperature probes from the patient's mouth to prevent their inclusion in the jaws of the stapler.
- Make sure adequate length of duodenum is mobilized to easily allow placement of a linear stapler across the first portion of the duodenum, just distal to the pylorus.
- Place an Endo GIA with 3.5-mm cartridge close to the level of the duodenal dissection to avoid the pyloric ring and minimize duodenal ischemia. We often use a staple line reinforcement of biologic material, although usefulness of this device for prevention of postoperative leakage has not been proven. Before firing, make sure again that any esophageal tube has been removed and that portal structures are excluded from your stapler line.
- Make every attempt to divide the duodenum in one firing. Carefully inspect the integrity of the duodenal staple line.

DISSECTION OF THE HEPATODUODENAL LIGAMENT

- Incise the peritoneum overlying the common hepatic artery and the bile duct with the hook electrocautery. Take care to identify aberrant left hepatic arteries. Divide the entire lesser omentum remaining along the left lobe of the liver.
- The base of the right crus is identified.
- Identify the hepatic artery and skeletonize it, mobilizing stations 12, 5, and 8. Our preference is to use the hook for dissection and the ultrasonic scalpel for division of larger vessels. Frequently, a vessel loop around the hepatic artery aids in retraction.

DIVISION OF THE LEFT GASTRIC ARTERY

- Use either the Nathanson liver retractor or a handheld retractor to elevate the stomach and identify the left gastric artery and the celiac trunk.
- Once the celiac anatomy is evident, dissect the left gastric artery and skeletonize its takeoff from the celiac trunk by mobilizing station 9 nodal tissue anteriorly. Once the left gastric pedicle is skeletonized, divide it at its origin using a 2.5-mm Endo GIA cartridge flush with the anterior pancreatic body (**FIG 5**). Our practice is to take the coronary vein and the left gastric together in a single fire.
- Once the left gastric artery is divided, skeletonize the splenic artery thus mobilizing station 11 nodes. Again, vessel loops may aid in retraction of the larger arteries in concert with gentle downward retraction of the pancreatic body. Care must be taken to identify and preserve the splenic vein.

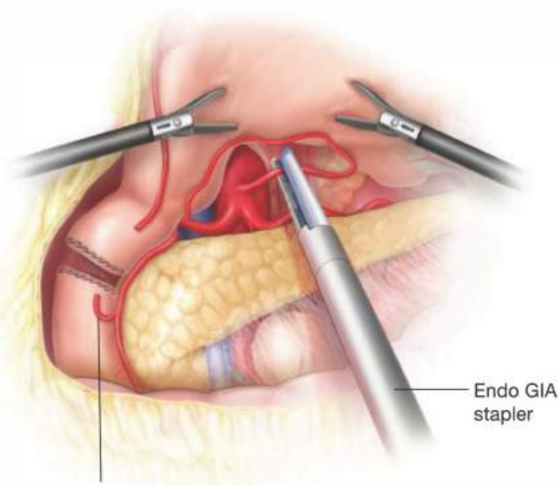

FIG 5 ● Elevating the stomach toward the abdominal wall and to the patient's right helps identification and isolation of the left gastric artery, which is then divided with a vascular stapler. Hepatic and splenic arteries should also be identified prior to firing the stapler.

PROXIMAL DIVISION OF THE STOMACH

- Divide the greater omentum and the gastroepiploic arcade (may use a vascular stapler) at the level chosen on the greater curvature for the proximal resection margin.
- Divide the stomach, taking care to achieve a minimum of 5- to 6-cm margin of normal stomach from the tumor. Our choice is Endo GIA 4.8-mm cartridge with bioabsorbable buttressing.
- The specimen is placed in a 15-mm endo bag and extracted via the 15-mm trocar in the right midclavicular line.
- Oversew any bleeding points with absorbable suture.

RECONSTRUCTION WITH STAPLED ANASTOMOSIS

- Our choice for the reconstruction is a stapled antecolic isoperistaltic gastrojejunostomy.
- Identify the ligament of Treitz at the base of the transverse mesocolon. Proper anatomy is confirmed by visualization of the inferior mesenteric vein.
- Use an umbilical tape cut to 40 cm to identify the jejunal loop to be used for the anastomosis. Make sure that this loop of jejunum can lie next to the gastric pouch without tension. If tension is encountered, the approach should be converted to a retrocolic position. If additional length is required, consider a Roux-en-Y reconstruction and/or mobilization of the intraabdominal esophagus and esophageal hiatus to decrease the anastomotic tension.
- Use stay sutures to secure the jejunum to the lesser curvature of the stomach. The planned line of the gastrojejunal anastomosis should be 2 to 3 cm from distal resection margin to ensure adequate blood supply.
- Use the ultrasonic shears to make a small enterotomy and a small gastrotomy that can accommodate the Endo GIA stapler.
- At this point, you should have an idea regarding the thickness of the stomach. A thicker stomach requires a 4.8-mm stapler; otherwise, use a 3.5-mm cartridge (**FIG 6**).
- Once the stapler is fired, the staple line is inspected for bleeding.
- Close the remaining anastomotic defect which corresponds to the proximal end of the staple anastomosis in two layers using running absorbable suture.

Reconstruction With Hand-Sewn Anastomosis

- Depending on the skill set of the surgeon, a hand-sewn gastrojejunostomy may be accomplished either intracorporeally or through a carefully positioned midline or subcostal small incision. For extracorporeal anastomoses, it is our practice to use a wound protector; this incision can also be used to extract the operative specimen.

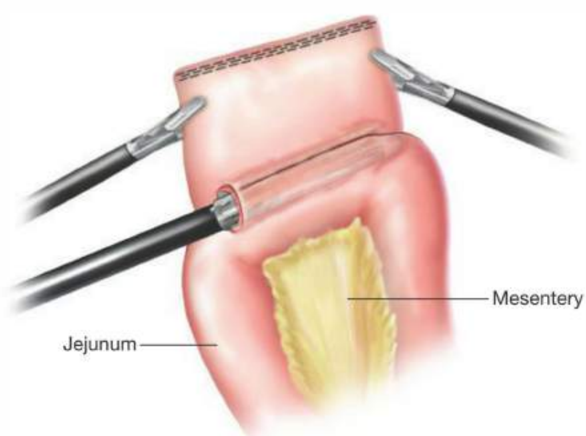

FIG 6 ● A mechanical linear stapler is used for the hepaticojejunostomy. The stapler should be introduced from the afferent limb side. This maneuver minimizes the risk of anastomotic stricture of the efferent limb when closing the anastomotic defect used for introduction of the stapler.

CLOSING

- Complete a final inspection of all staple lines and vascular pedicles for hemostasis and integrity. Bleeding points and areas of malformed staples should be oversewn with absorbable suture.
- Closed suction drainage is optional.
- Abdominal fascia is closed for all port sites larger than 5 mm.

POSTOPERATIVE CARE

- We usually keep a nasogastric tube for 24 hours in order to decrease gastric distension, which may compromise the integrity of the anastomosis. Whether this decreases the leak rate has not been proven.
- Immediately after surgery, the patient is instructed to use an incentive spirometer, cough, and take deep breaths. Also, patients are encouraged to ambulate within 6 hours from surgery.
- Prophylactic antibiotics are not indicated in the postoperative period.
- Unless an epidural catheter is used for analgesia, the Foley catheter is removed in postoperative day 1.
- If the patient is able to protect his or her airway and the abdomen is not distended, clear liquids are allowed on postoperative day 1, then diet is advanced as tolerated.

OUTCOMES

- Available evidence shows no major differences in morbidity, mortality, number of nodes harvested, or disease-free survival.
- MIDG is a safe and effective treatment of gastric cancer.
- The addition of a D2 dissection elevates this operation to much higher difficulty level.
- Oncologic principles and safety are paramount and should not be sacrificed for a less invasive approach.

COMPLICATIONS

- The postoperative complications observed after MIDG generally are comparable with those of an open procedure.
- *Intraoperative*
  - Bleeding
  - Splenic injury
  - Iatrogenic enterotomy
- *Early postoperative*
  - Gastrojejunal anastomotic leak
  - Duodenal leak
  - Bleeding
  - Delayed gastric emptying
- *Late postoperative*
  - Dumping
  - Afferent limb syndrome
  - Marginal ulcer
  - Bile reflux gastritis
  - Malnutrition

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Chapter 14

Proximal Gastrectomy

Sushanth Reddy Martin J. Heslin

DEFINITION

- Proximal gastrectomy is defined as a procedure to remove the upper third to one-half of the stomach and the distal portion of the esophagus. This is a procedure to remove cancers or premalignant lesions in the cardia of the stomach, the gastroesophageal (GE) junction, or the distal esophagus. Proximal gastrectomy is usually used in conjunction with systemic chemotherapy and external beam radiation for malignant lesions in this area.

PATIENT HISTORY AND PHYSICAL FINDINGS

- Patients typically present with difficulty swallowing, dysphagia, upper gastrointestinal (GI) bleeding, or reflux symptoms, especially in the setting of unexplained weight loss. Initial diagnostic evaluation typically includes an esophagogastroduodenoscopy (EGD) with biopsy showing malignancy.
- A thorough history and physical examination should be performed prior to surgery. Particular attention should be paid to cardiac and pulmonary comorbidities and nutritional status. Risk factors for cancer including acid reflux disease, history of Barrett's esophagus, and tobacco use should be identified.
- Patients who have disease in the proximal to midesophagus should not undergo proximal gastrectomy.[1] These patients should be considered for either an Ivor-Lewis (Part 1, Chapter 30) or transhiatal esophagectomy (Part 1, Chapter 29).
- All patients with cancer should undergo staging prior to consideration for surgery.
- Patients with high-grade dysplasia or T1 tumors without lymph node metastases should be considered for surgery first. Patients with advanced tumors (T2 or greater) or those with lymph node involvement should be considered for upfront (neoadjuvant) chemotherapy and radiation therapy.[2,3] Those patients who are nutritionally depleted should have a feeding jejunostomy tube placed prior to initiating therapy.[4]
- Following completion of chemotherapy and radiation therapy, patients should be restaged. The presence of distant metastases is a contraindication for surgery.
- The period of upfront therapy allows for optimization of cardiac and pulmonary comorbidities prior to surgery.

IMAGING AND OTHER DIAGNOSTIC STUDIES

- All patients should undergo staging evaluation prior to surgery. Endoscopic ultrasound (EUS) is used to identify tumor depth (T stage) and regional lymph node metastases (N stage). Computed tomography (CT) scan or positron emission tomography (PET) scan is used to identify distant metastases. The liver is the most common site of distant metastases for adenocarcinoma and squamous cell carcinoma (the two most common tumor histologies).
- Staging should be repeated after the completion of upfront chemotherapy prior to surgery.
- The celiac axis anatomy should be carefully studied prior to surgery to look for anomalies. Specific attention should be paid toward an accessory or replaced left hepatic artery within the gastrohepatic ligament.

SURGICAL MANAGEMENT

Preoperative Planning

- Many patients with gastric or esophageal malignancy have comorbid conditions related to age or tobacco use. These patients should undergo optimization of their comorbidities prior to surgery.
- Anesthesia should consider placement of an arterial monitoring catheter and/or a central venous catheter. During hiatal dissection, the heart may be compressed and invasive monitoring can be useful in guiding resuscitation in the operating room.
- A nasogastric (NG) tube will be placed during the operation. It may not be possible to pass an NG tube prior to removal of the tumor (if it is obstructing). The surgeon should have good communication with anesthesia in regard to NG tube position as it will be manipulated through the operation.

Positioning

- The patient is positioned with both arms at 90 degrees with the torso. This will facilitate with exposure by spreading the lower ribs laterally. Alternatively the right arm can be tucked to the patient's side to aid in attachment of the self-retaining retractor device to the operating room table. If a feeding jejunostomy tube has already been placed, the tube should be prepped into the sterile field.

TECHNIQUES

DIAGNOSTIC LAPAROSCOPY

- The abdomen is entered through the supraumbilical midline and a laparoscope placed (Part 2, Chapter 13). The entire abdomen should be evaluated with specific attention to the liver and the peritoneal surfaces for the presence of metastatic disease. Any suspicious lesions should be biopsied and sent for frozen section analysis in the pathology. The presence of metastatic disease is a contraindication for surgical resection.

MOBILIZATION OF THE STOMACH

- A formal laparotomy is performed and a self-retaining retractor is placed. Excision of the xiphoid process may be used to aid with retraction (this allows for wider retraction of the costal margin).
- The lesser sac is entered along the avascular plane that separates the gastrocolic omentum from the transverse mesocolon. The dissection should proceed away from the greater curve of the stomach to avoid injury to the right gastroepiploic artery. The right gastroepiploic artery will be the primary blood supply of the residual stomach (**FIG 1**). The right gastric artery can be spared to keep the gastric conduit well vascularized. Mobilization of the stomach is usually sufficient for resection and reconstruction for a proximal gastrectomy without the need for ligation of the right gastric artery and a Kocher maneuver to mobilize the duodenum (needed for transhiatal esophagectomy [Part 1, Chapter 29] or Ivor-Lewis esophagectomy [Part 1, Chapter 30]).
- The left lateral section of the liver is mobilized to expose the lesser curve of the stomach and the esophageal hiatus: The left triangular ligament is incised. This is avascular. The falciform ligament may also be incised to aid with visualization of the left triangular ligament (**FIG 2**). The ligament need not be mobilized to its confluence with the falciform to avoid injury to the left hepatic vein. The gastrohepatic ligament is divided. This structure is typically also avascular, but attention should be paid for any accessory or replaced left hepatic artery (**FIG 3**). This will allow exposure of the esophageal crura.
- The gastrosplenic ligament is divided between clamps and ties. The *vasa brevia* are individually dissected and divided between ties. Alternative strategies for division of this structure would include an advanced energy device or an articulating 45-mm stapler with vascular loads.
- The distal esophagus is circumferentially freed using a combination of sharp and blunt dissection. A Penrose drain is placed around the esophagus to aid with retraction (**FIG 4**). The Penrose drain can be used to retract the esophagus to expose the diaphragmatic hiatus and aid with lower mediastinal dissection. The hiatal attachments of the esophagus are taken down with an advanced energy device. The hiatus should be opened to facilitate dissection of the esophagus. During this dissection, it may be necessary to put pressure on the heart to free the mediastinal attachments of the esophagus. The proximal extent of the tumor and the length of the intraabdominal esophagus will dictate the amount of mediastinal dissection necessary.
- With the stomach reflected anteriorly, the left gastric vessels are ligated (**FIG 5**). Prior to ligation, the left gastric artery is test clamped to make sure that flow remains in both the common hepatic artery and the splenic artery. The left gastric artery is ligated at its root off the celiac trunk to facilitate appropriate lymphadenectomy.

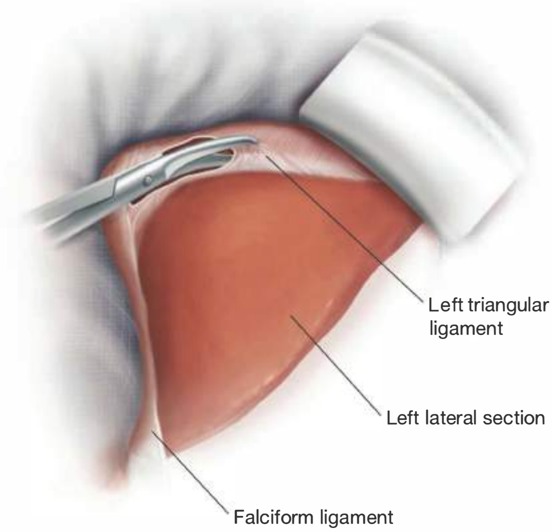

FIG 2 ● The left lobe of the liver is mobilized. The falciform ligament has already been divided and the left triangular ligament is being incised. Both of these structures are avascular. The falciform ligament should be divided near the liver. As dissection proceeds cephalad, the falciform will divide into the right and left triangular ligaments when dissection is closer to the liver. If dissection is closer to the abdominal wall, division of the falciform will lead into the hepatic venous confluence. Injury to one of these vessels can lead to catastrophic blood loss.

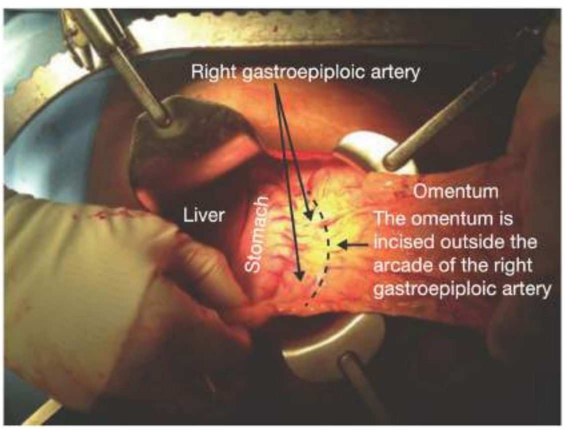

FIG 1 ● The greater curve of the stomach is mobilized. Care is taken to stay outside the right gastroepiploic artery as this is the vascular pedicle of the gastric conduit. This portion of the gastrocolic omentum is typically avascular, although small blood vessels may be encountered requiring ligation. The vasa brevia should be ligated as dissection proceeds cephalad.

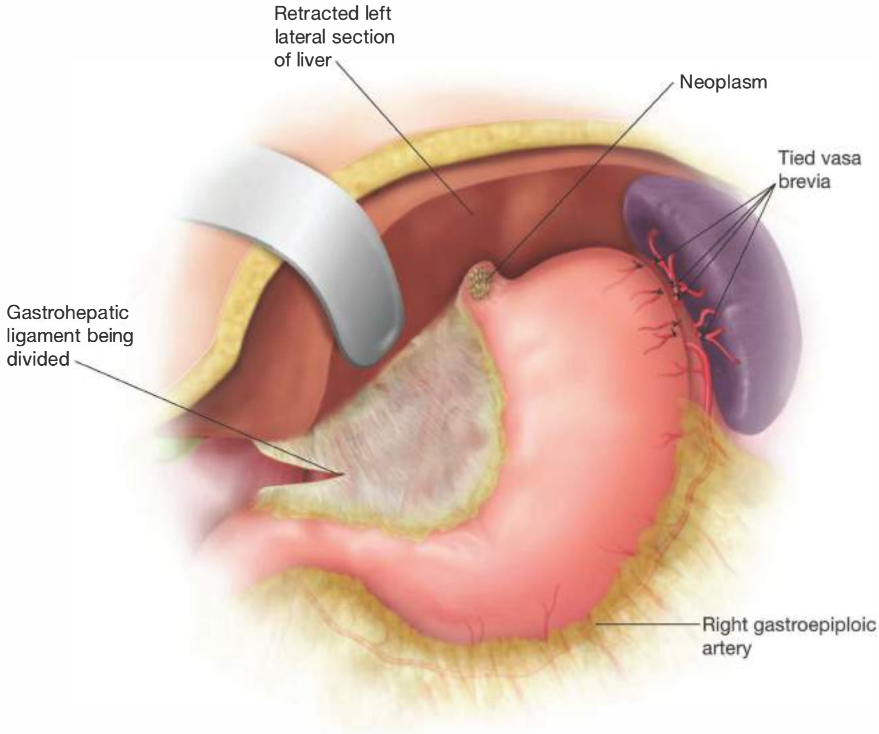

FIG 3 ● The lesser curve of the stomach is mobilized. By mobilizing the left lobe of the liver, the left lateral section can be retracted to expose the gastrohepatic ligament. This is also typically avascular. Attention should be given in case there is an accessory or replaced left hepatic artery. This can usually be seen on preoperative contrast CT scans. By opening the gastrohepatic ligament, the diaphragmatic crura can be visualized.

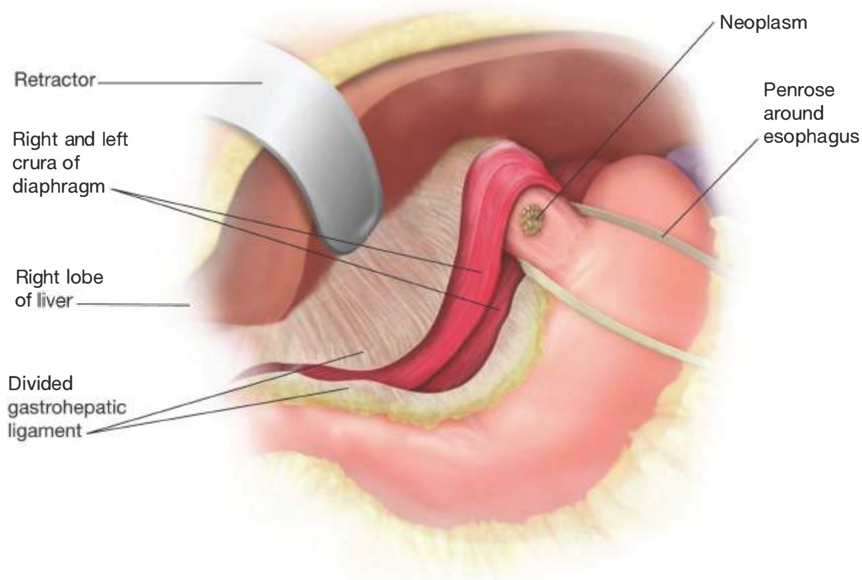

FIG 4 ● The distal esophagus and GE junction are dissected. Once the stomach's greater and lesser curve have been mobilized, this dissection can be performed bluntly. In patients who have undergone preoperative radiation therapy, scarring in this region can make dissection difficult. A Penrose drain is placed around the esophagus. This drain allows the esophagus to be manipulated in all directions to aid with transhiatal dissection. A sufficient length of esophagus should be mobilized into the abdomen so that the proximal esophageal margin is grossly clear from the tumor. A high-energy device can be used to aid with distal esophageal mobilization (minimizing blood loss seen with blunt or cautery dissection).

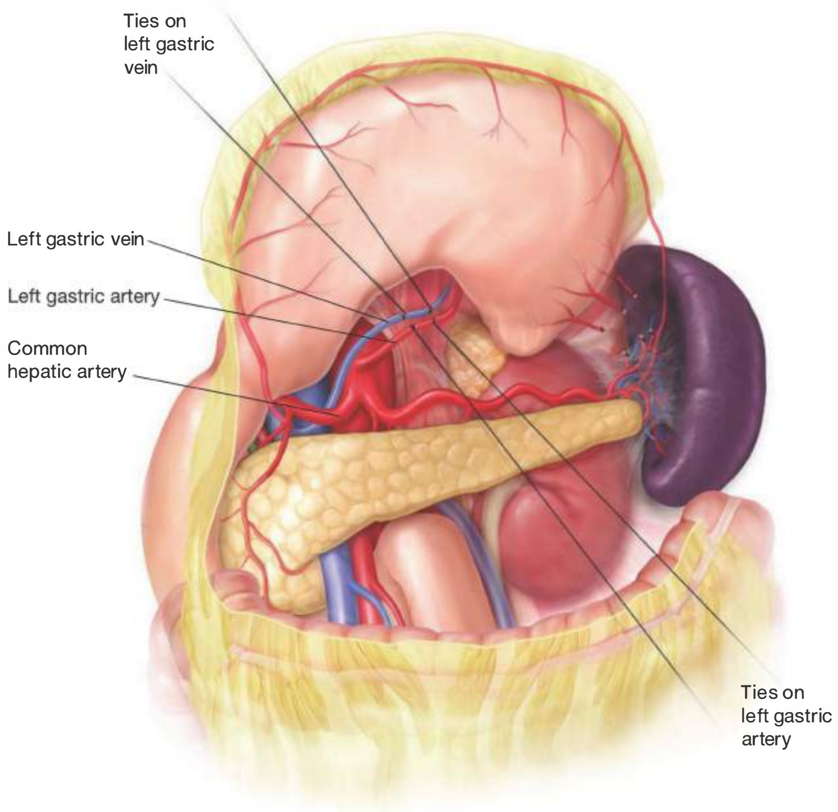

FIG 5 ● The left gastric pedicle is divided. The stomach should be reflected to expose the lesser sac. This will facilitate exposure of the left gastric artery near its origin at the celiac axis. This structure should be test clamped prior to ligation (pulses should be assessed in both the common hepatic and splenic arteries). Ligation of the left gastric artery near its origin will facilitate with lymphadenectomy (for patients with malignancy).

GASTROESOPHAGEAL RESECTION AND RECONSTRUCTION

- Using the NG tube as a guide, place two purse-string sutures in the esophagus proximal to the neoplasm (**FIG 6**). These will be an alternating horizontal mattress to ensure complete donuts after stapling. Do not allow the sutures to go through the NG tube.
- Anesthesia should retract the NG tube into the esophagus. Partially divide the esophagus with electrocautery below the purse-string sutures and above the neoplasm. The posterior wall of the esophagus and the purse-string sutures are used to keep the proximal esophagus in an intraabdominal position. The anvil of a circular linear stapling device is placed in the esophagus and the purse-string sutures are tied. The division of the esophagus is completed. The GE junction can now be delivered extracorporally. A proximal surgical margin is sent for frozen section analysis. Typically, a 25-mm circular stapler will be sufficient for reconstruction.
- Multiple firings of the gastrointestinal anastomosis (GIA) linear stapler are used to both resect the proximal stomach while tubularizing the remaining stomach for the reconstruction. The first staple load is deployed perpendicular to the greater curvature of the stomach. The stapler is fired sequentially toward the lesser curve, creating a gastric tube (**FIG 7**). The stomach should not be completely transected.
- A gastrotomy is created along the lesser curve to allow placement of the handle of a circular stapling device. This gastrotomy should be positioned so that it will be resected as part with additional firings of the GIA linear stapler to completely transect the proximal stomach. The stapler is attached to its anvil in the proximal esophagus and fired (**FIG 8**). The anastomotic donuts are examined to ensure that two intact rings are present. The esophagogastrectomy is completed with additional firings of the GIA stapler to excise the gastrotomy site, the proximal stomach, the tumor, and the distal esophagus. Tension from the proximal esophagus will usually retract the anastomosis into the thorax. A closed suction drain should be placed at the anastomosis. The NG tube should be advanced into the stomach.

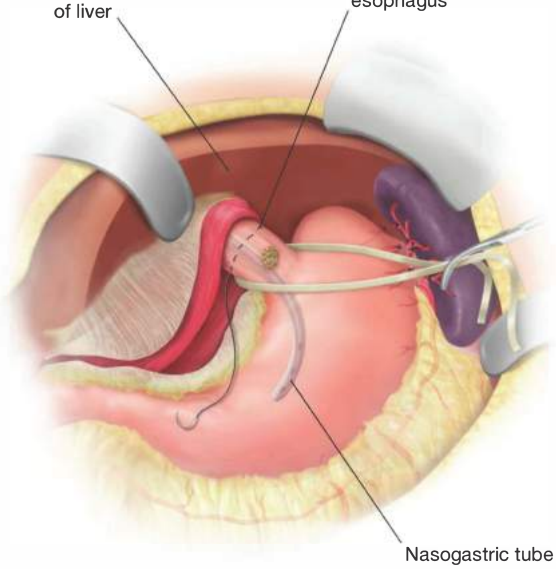

FIG 6 ● The resection margins are planned. The proximal resection margin can be grossly approximated based on the tumor's location. Two purse-string sutures are placed on the esophagus just above the planned proximal margin. The NG tube can be used as a guide to ensure the sutures are transmural (as the needle meets resistance from the NG tube, it should be rotated away from the tube). The suture should not pass through the NG tube. After the sutures are placed, the NG tube should be retracted into the esophagus above the sutures. The anterior wall of the esophagus is then transected, and the anvil of a 25-mm circular stapler is placed into the esophagus. The sutures are tied to keep the anvil in place. The posterior wall of the esophagus is then divided. The distal esophagus and stomach can now be delivered extracorporally. An esophageal margin should be sent for frozen section to ensure negative resection margins (this can be taken from the distal esophagus above the tumor).

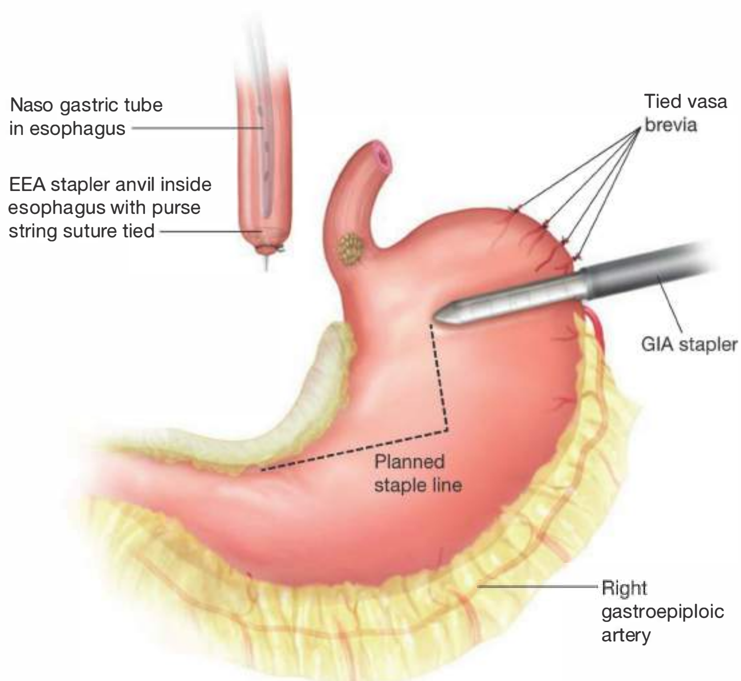

FIG 7 ● A GIA stapler is then used to begin gastric transection. The first staple load should be horizontally across the stomach just below the vasa brevia (to a portion of the stomach with vascular supply from the right gastroepiploic artery). Subsequent staple loads should be fired in a manner to create a gastric tube for the esophagogastrostomy anastomosis.

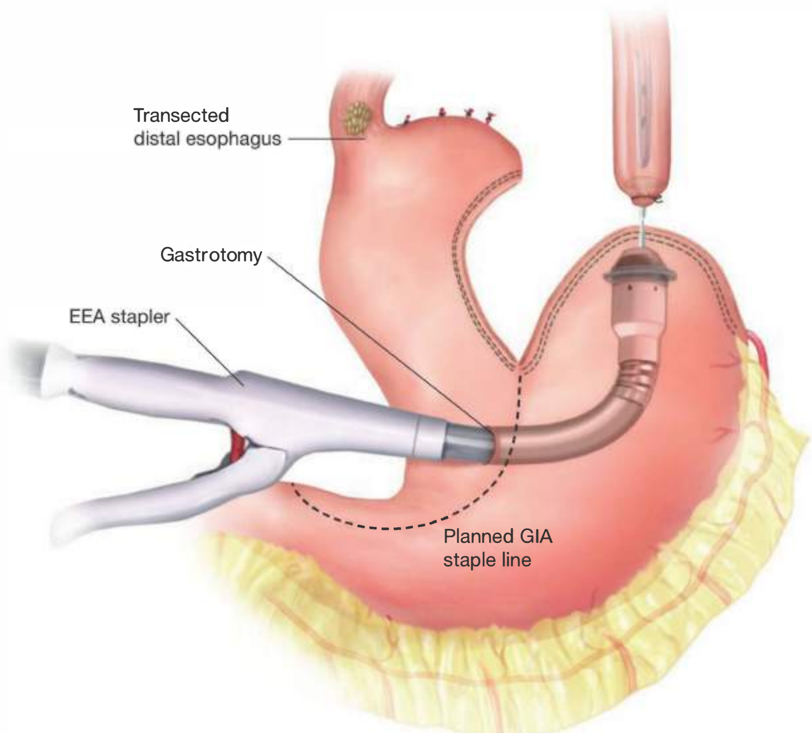

FIG 8 ● Prior to completing the gastric resection, a gastrotomy is made in the lesser curve in a portion of the stomach that will be transected with the GIA stapler. The handle of the circular stapler is inserted to create an end-to-side esophagogastrostomy. The handle is opened so that it can dock with the anvil in the proximal esophagus. This stapler is fired to create an end-to-side esophagogastric anastomosis. The stapler is removed and the anastomotic donuts are retrieved. Both donuts should be intact. After removing the circular stapler, additional firings of the GIA stapler are used to complete the gastric transection along the lesser curve. The NG tube is then advanced into the gastric conduit and secured at the nose. A closed suction drain is left in proximity of the anastomosis.

PYLOROMYECTOMY

- The pylorus is identified by palpation and the presence of the vein of Mayo. Stay sutures are placed at the 12 o'clock and 6 o'clock positions. The pylorus muscle is opened sharply and a piece of the muscle is removed with a 15 blade knife to the level of the mucosa without entering the GI tract.
- The pyloromyectomy is closed transversely with interrupted sutures (**FIG 9**).
- If the mucosa is opened inadvertently, a Heineke-Mikulicz–type pyloroplasty is performed instead (Part 2, Chapter 9). A drain should be left in Morrison's space (hepatorenal recess).[5]

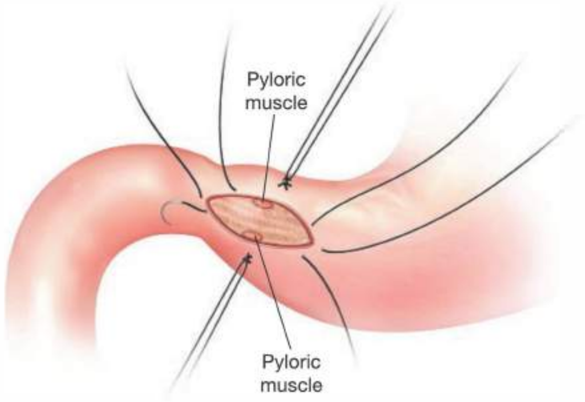

FIG 9 ● A pyloromyectomy is performed. First, stay sutures are placed at the 6 o'clock and 12 o'clock positions (to ligate the vein of Mayo). The serosa and submucosa of the pylorus are incised with a knife. The mucosa should not be entered. In most patients, the pyloric muscle can be visible after sharp transection. The pyloromyectomy should be closed transversely with interrupted sutures. If the mucosa is opened, a Heineke-Mikulicz pyloroplasty should be performed. A closed suction drain should be placed.

FEEDING JEJUNOSTOMY

- If a jejunal feeding tube has not already been placed, one should be created at this time (Part 2, Chapter 17).[4]

PEARLS AND PITFALLS

Workup	■ The nutritional status of the patients should be assessed prior to proximal gastrectomy with strong consideration of a feeding jejunostomy tube prior to attempting proximal gastrectomy. ■ Careful preoperative and intraoperative staging should take place to assure that there is no distant metastatic disease. ■ Patients with comorbid conditions should undergo optimization of their cardiopulmonary status prior to proximal gastrectomy.
Mobilization	■ Care should be taken to avoid injury to the right gastroepiploic artery when entering the lesser sac through the gastrocolic omentum. ■ While mobilizing the lesser curve of the stomach, attention should be paid for a replaced left hepatic artery. ■ The left gastric artery should be test clamped prior to ligation in case there is a celiac axis anomaly.
Postoperative care	■ The NG tube should not be manipulated or replaced blindly. ■ Most postoperative leaks can be managed with drainage alone. ■ Many patients will have symptoms of reflux requiring prolonged use of proton pump inhibitors.
Nutrition	■ The feeding jejunostomy tube should be left in place until the patient can demonstrate adequate oral intake to maintain nourishment—especially if the patient will undergo adjuvant therapy. ■ If the patient does not have a feeding jejunostomy placed prior to operation, there should be one placed in all cases of a proximal gastrectomy because leaks and delayed gastric emptying are two major complications.

POSTOPERATIVE CARE

- Most patients have medical comorbidities related to advanced age and tobacco use. Intensive care unit (ICU) care with special attention to aspiration precautions should be considered for the immediate postoperative period.
- The NG tube should remain in place until a contrast esophagogastrogram is performed. If the NG tube is inadvertently removed, it should not be blindly replaced.
- On postoperative days 4 to 5, the anastomosis should be studied with a contrast esophagogastrogram. A water-soluble contrast agent should be used initially followed by barium to evaluate for anastomotic leaks. After a successful swallow study, the patient may begin oral nutrition.
- The operative drain should be removed only after the patient starts an oral diet without clinical evidence of an anastomotic leak.

- The feeding jejunostomy tube should be left in place to supplement nutrition until the patient reliably demonstrates adequate oral intake to maintain nourishment.[4]

OUTCOMES

- Reflux esophagitis and anastomotic strictures are present in up to 40% of patients undergoing proximal gastrectomy.[6]
- The overall survival for patients undergoing proximal gastrectomy is similar to other gastric resections and is heavily dependent on tumor stage (5-year survivorship: stage I, 75% to 90%; stage II, 49%; stage III, 13% to 33%; stage IV, 11%).[7]

COMPLICATIONS

- If there is a small leak identified after the swallow study, replacement of an NG tube should almost never be considered. Keeping the patient NPO with enteral nutrition solves the majority of these leaks. Additional CT- or ultrasound-guided percutaneous drains should be considered if the surgical drain does not adequately drain the leak. A contrast esophagogastrogram should be repeated prior to initiating oral nutrition. An endoscopically placed covered stent may facilitate closure of a leak.
- If a large leak is identified on the initial contrast study, consider early reoperative intervention. Options can include wide drainage or conversion to an Ivor-Lewis or transhiatal esophagectomy. However, the majority of the time, simply widely draining the region and controlling abdominal sepsis is the primary focus of early reoperative surgery for leaks.

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Chapter **15**

Total Gastrectomy for Cancer

Vikas Dudeja Eugene A. Choi Waddah B. Al-Refaie

DEFINITION

- Total gastrectomy is removal of the stomach in its entirety including the gastroesophageal (GE) junction. This is typically performed for patients with proximal gastric cancer, including Siewert type II and III GE junction cancers,[1] in whom a subtotal gastrectomy with 5- to 6-cm proximal margin does not leave a reasonable gastric remnant. Rarely, diffuse involvement of stomach with malignant processes other than gastric adenocarcinoma may warrant a total gastrectomy. Even though proximal gastric resection is widely performed in Asia and select U.S. cancer centers for proximal gastric tumors, this procedure has not gained wide adoption in western centers.[2]

PATIENT HISTORY AND PHYSICAL FINDINGS

- **Presentation:** In the United States, most patients with gastric cancer are diagnosed at advanced stages. Weight loss, anorexia, dyspepsia, progressive dysphagia, and early satiety are the most common symptoms. Unfortunately, some of these symptoms (dyspepsia, nausea, anorexia) overlap with those of benign reflux disease and explain the late presentation of proximal gastric cancers in the United States. Poor oral intake because of cancer-induced anorexia and dysphagia contributes to patients' weight loss. As such, patients with more than 10% weight loss are at increased risk of perioperative complications. Thus, quantification of weight loss in the preoperative period provides a meaningful estimate of nutritional status and helps in pretherapy planning in terms of preoperative nutrition. Patients may also present with iron deficiency anemia due to occult blood loss.
- Evaluation of the performance status and frailty is important for the formulation of a treatment plan. Eastern Cooperative Oncology Group's (ECOG) performance status scale provides a standardized method to assess and compare performance status of the patient.[3] Patients with ECOG performance score of 0 to 1 are generally able to tolerate major oncologic resections. Those with a score of 2 may require individualized decision making, factoring comorbidities into the overall treatment plan. Patients with a score of 3 and above are unable to tolerate any major oncologic resection. Attention to pretherapy performance status and frailty are critical, as these two important yet underassessed parameters correlate well with the ability to tolerate various oncologic therapies, including major oncologic resection and systemic therapy.
- **Physical findings:** In early stages, the physical examination is essentially normal. However, surgeons need to look for signs of malnutrition. Patients with advanced-stage gastric cancer may present with supraclavicular lymphadenopathy, pleural effusion, abdominal mass, hepatomegaly, malignant ascites, or drop metastases in the form of "Blumer's shelf" appreciated on rectal examination. Presences of any of these physical findings suggest unresectability.

IMAGING AND OTHER DIAGNOSTIC STUDIES

- **Laboratory tests:** Baseline hemoglobin, platelet count, and complete metabolic profile should be obtained. Serum albumin and prealbumin are useful to guide assessment of nutritional status.
- **Diagnostic studies and staging evaluation:** The evaluation of any upper gastrointestinal symptomatology starts with an esophagogastroduodenoscopy (EGD), especially if gastric cancer is suspected. Endoscopy provides histopathologic diagnosis as well as gives information on location and extent of gastric tumor, GE junction involvement, presence of linitis plastica, and status of duodenal bulb (**FIG 1A,B**). Endoscopic

FIG 1 ● Endoscopy and EUS are critical for the diagnosis and staging of gastric cancer. **A.** Endoscopic findings in a 68-year-old male who presented with iron deficiency anemia and anorexia. An ulcerated adenocarcinoma of the proximal third of the stomach was discovered. Patient underwent R0 total gastrectomy with lymphadenectomy, and the final pathology report showed pT2 N0 (0/23) M0 disease. **B.** A retroflexed endoscopic view of T2 gastric adenocarcinoma in gastric fundus. **C.** EUS helps with accurate preoperative T staging of the lesion.

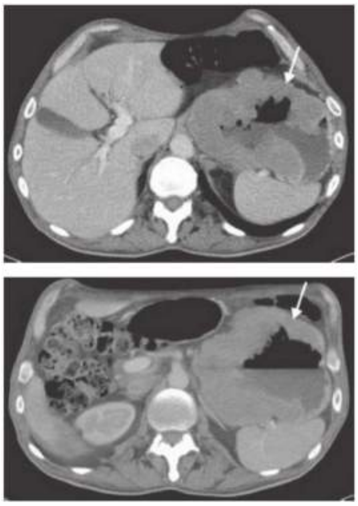

FIG 2 ● Cross-sectional imaging with CT or MRI evaluates for distant metastatic disease and bulky adenopathy. Abdominal CT scan in a patient with known high-grade neuroendocrine tumor. No liver metastases were noted. Note diffuse nodular heterogeneous thickening of the stomach *(white arrow)*.

ultrasound (EUS), performed at the time of or subsequent to diagnostic endoscopy, provides the most accurate estimation of the tumor depth (T stage) (**FIG 1C**) and can help in evaluation and needle biopsy of surrounding lymph nodes.[4] Furthermore, EUS provides information on the degree of distal esophageal involvement.

- Cross-sectional imaging of abdomen and pelvis, in the form of a computed tomography (CT) scan (**FIG 2**) with oral and intravenous (IV) contrast or magnetic resonance imaging (MRI), evaluates for presence of distant metastatic disease to the liver and bulky lymphadenopathy. Metastases to lungs should be evaluated by CT scan of the chest. The presence of bulky adenopathy has a prognostic value. However, it should not preclude resection unless patient presents with diffuse adenopathy involving the periportal area or mesenteric vessels. Positron emission tomography (PET)/CT scan has evolved as an additional radiographic staging modality to exclude the presence of distant metastatic disease (**FIG 3**).
- **Staging laparoscopy:** Peritoneal spread is part of the natural history of gastric cancer. Up to a third of the patients who have localized disease on staging evaluation have unsuspected hepatic and/or peritoneal disease.[5] Thus, staging laparoscopy can prevent a nontherapeutic laparotomy in the setting of M1 disease. The timing of staging laparoscopy may depend on the institutional preference with respect to neoadjuvant versus adjuvant therapy. We recommend neoadjuvant chemotherapy for patients with proximal gastric tumors and perform staging laparoscopy (with peritoneal cytology) before initiation of neoadjuvant therapy. We selectively place feeding jejunostomy during staging laparoscopy, especially in persons who are old, frail, have suboptimal performance status, or present with malnutrition. The patient then returns after completion of neoadjuvant chemotherapy for restaging and definitive surgical treatment (i.e., gastrectomy).
- **Peritoneal cytology:** The addition of peritoneal washing for cytology is an area of debate.[6,7] We use this diagnostic modality in patients at risk of undeclared metastatic disease or suboptimal performance status, as patients with positive peritoneal cytology have unfavorable overall prognosis compared to those with negative peritoneal cytology.

SURGICAL MANAGEMENT

- A complete margin-negative resection with an adequate lymphadenectomy is the most critical component of therapy for operable gastric cancer.

Preoperative Planning

- **Addressing preoperative malnutrition:** Patients with proximal gastric cancer are at an increased risk of being nutritionally compromised due to cancer-induced anorexia and dysphagia. These patients benefit from preoperative enteral nutrition through a jejunostomy tube placed preoperatively during the staging laparoscopy. The enteral nutrition through jejunostomy tube also helps with hydration and nutrition during neoadjuvant therapy. A consultation with a dietitian with regard to nutritional optimization is recommended.
- **Evaluation of the patient's ability to tolerate the surgery:** A careful review and optimization of underlying comorbidities (e.g., cardiac, pulmonary, diabetes) and perfor-

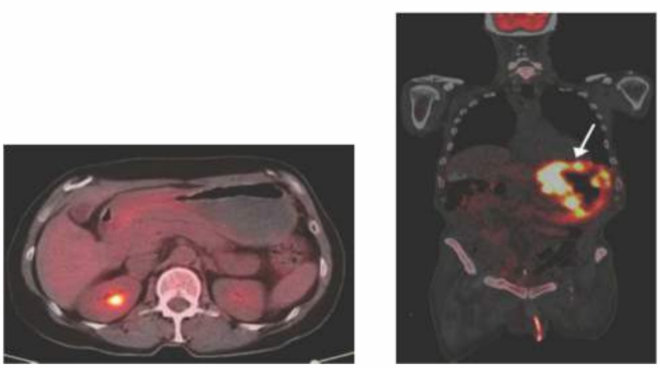

FIG 3 ● PET scan may help in the evaluation of disease spread. PET scan in a patient with known high-grade neuroendocrine tumor demonstrates hypermetabolic activity *(white arrow)* in the stomach but no other organ. This patient required total gastrectomy for complete disease clearance.

mance status should be considered in conjunction with other supporting specialties. A subset of high-risk individuals may benefit from preoperative admission to optimize nutrition, electrolyte imbalance, and performance status (e.g., physical therapy) in preparation for their oncologic resection.

- **Evaluation of response to neoadjuvant therapy:** At times, when neoadjuvant therapy is employed to increase rates of R0 resection or spare the GE junction, a repeat posttherapy preoperative EGD provides additional information on tumor response and the proximal extent of the tumor.
- **Preoperative antibiotics:** Patients should be given one dose of first- or second-generation cephalosporin for perioperative antibiotic prophylaxis.

Positioning

- In most patients, an upper midline incision provides optimal exposure for the procedure. The chest should be prepped into the operative field for the possibility of needing a thoracotomy for GE junction tumors. A sandbag can be placed under the left chest to facilitate thoracotomy.

STAGING LAPAROSCOPY

- Pneumoperitoneum is created by either an open technique or verse needle. A 30-degree scope is inserted at the umbilicus. One to two additional 5-mm ports on either side of the umbilicus are needed for optimal visualization, grasping of tissue, and biopsy of suspicious tissues. A complete survey of the peritoneal cavity is performed, including undersurface of the diaphragm, liver surface, spleen, lining of peritoneal cavity, pelvis, small bowel surface, and omentum for any metastatic disease. If any suspicious lesion is observed, it is biopsied and sent for frozen section. In the setting of biopsy-proven peritoneal disease, gastrectomy should not be performed and nonsurgical treatments should be initiated. However, at times, surgeons are faced with a situation to carefully and selectively consider palliative surgical procedures in the setting of metastatic disease, for example, bleeding or obstructing cancer not palliated by endoscopic means. These decisions need to be individualized based on the performance status of the patient, extent of metastatic burden, the projected survival, and the availability of adjunctive therapy such as endoluminal stenting.
- **Peritoneal cytology:** If the staging laparoscopy is negative for peritoneal spread, the procedure is continued. We perform peritoneal cytology in the patients who do not have gross peritoneal metastasis. For peritoneal cytology, 500 mL of normal saline is instilled into the abdominal cavity and allowed to dwell for 10 to 15 minutes. During this time, the patient's table is moved from left to right to expose the peritoneum to this fluid. After 10 to 15 minutes, the fluid is aspirated with a suction device, which has a mechanism to trap the fluid. The fluid is then sent to the pathology lab, and in those with positive peritoneal cytology, we favor not proceeding with resection.
- When a laparoscopic feeding jejunostomy is to be placed, it is imperative that the surgeon performing the staging laparoscopy and jejunostomy tube placement is cognizant of the need to construct a Roux limb for the restoration of gastrointestinal continuity at the time of definitive surgery. Thus, the loop of jejunum just distal to the ligament of Treitz, which would be used for fashioning the Roux limb, should not be used for the placement of jejunostomy tube.

EXPLORATORY LAPAROTOMY AND MOBILIZATION OF THE LIVER

- The abdomen is entered through a midline incision extending from the xiphoid process to just below the umbilicus. A bilateral subcostal incision, approximately 2 cm below the costal margin, also provides good exposure. During entry into the abdomen, the falciform ligament should be preserved as it can be used to buttress the duodenal closure. A careful exploration of the peritoneal cavity is performed to exclude the presence of subradiographic peritoneal or distant metastatic disease. The liver is carefully inspected and palpated for any suspicious nodules.
- For better access and visualization of the GE junction, we typically divide the left triangular ligament thus mobilizing the left lobe of the liver. Once mobilized, the left lobe of the liver can be folded on itself thus allowing better visualization of the GE junction and the right crus of the diaphragm.

MOBILIZATION OF THE GREATER CURVATURE OF THE STOMACH

- In this step, the attachments of the greater omentum to the transverse colon are divided in an avascular plane. The stomach and the greater omentum are reflected superiorly and the transverse colon is reflected inferiorly. The plane of fusion between the greater omentum and the transverse mesocolon is identified as a faint white line. This plane is entered by incising with electrocautery and, once properly developed, allows access to the lesser sac (**FIG 4**). This plane of separation is then developed toward both proximal and distal parts of the transverse colon thus completely separating the greater omentum from the transverse colon and mobilizing it with the specimen.

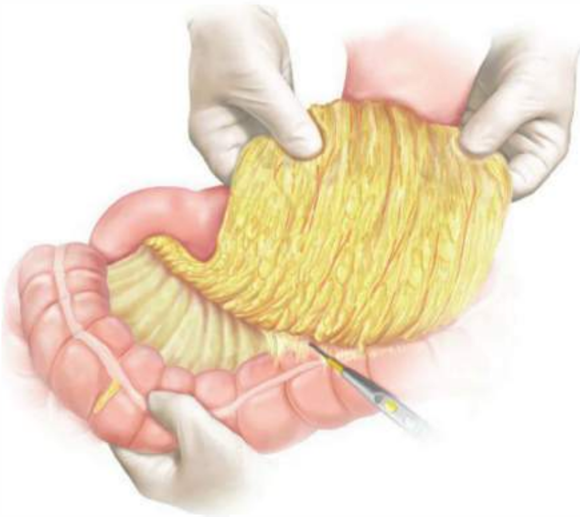

FIG 4 ● Division of attachments of greater omentum to the transverse colon. Incision of avascular fusion plane of greater omentum with the transverse colon/mesocolon separates greater omentum from the transverse colon and provides access to lesser sac.

FIG 6 ● Dissection of the infrapyloric nodal packet at the level of right gastroepiploic vessels.

- The hepatic flexure of the colon is mobilized by division of the avascular attachment of the hepatic flexure to the retroperitoneum. The separation of the greater omentum from the transverse mesocolon is carried toward the hepatic flexure. This exposes the gastrocolic trunk, which is formed by the confluence of right gastroepiploic vein with middle colic vein and drains into the superior mesenteric vein. The right gastroepiploic vein is divided at its junction with the gastrocolic trunk (FIG 5). Alternatively, the gastrocolic trunk can be divided with a single fire of a vascular stapler. At this stage, the right gastroepiploic artery is divided at its origin from the gastroduodenal artery at the infraduodenal level. We recommend additional time spent when performing this dissection in obese patients given the potential difficulty in identifying this artery. Infrapyloric nodes, located adjacent at the origin of gastroduodenal artery, are mobilized with the specimen (FIG 6).
- Toward the left, the greater curvature of the stomach is mobilized up to the GE junction by division of the short gastric vessels. These vessels are divided carefully to avoid troublesome bleeding or iatrogenic splenic injury that may lead to splenectomy (FIG 7).

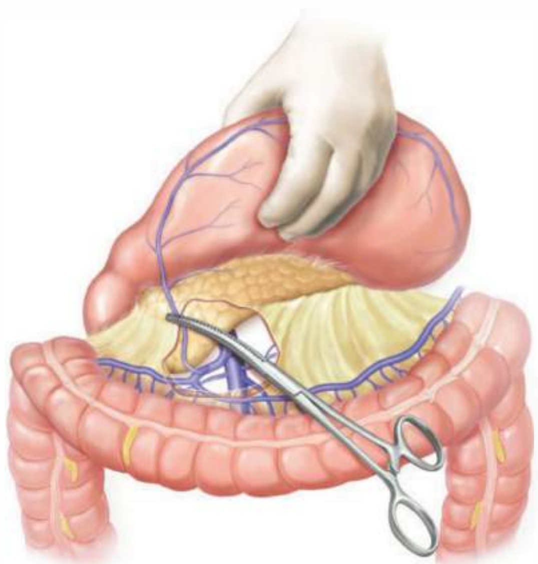

FIG 5 ● Ligation of right gastroepiploic vein at its confluence with colonic veins. Alternatively, the gastrocolic trunk can be divided with the single fire of a vascular stapler.

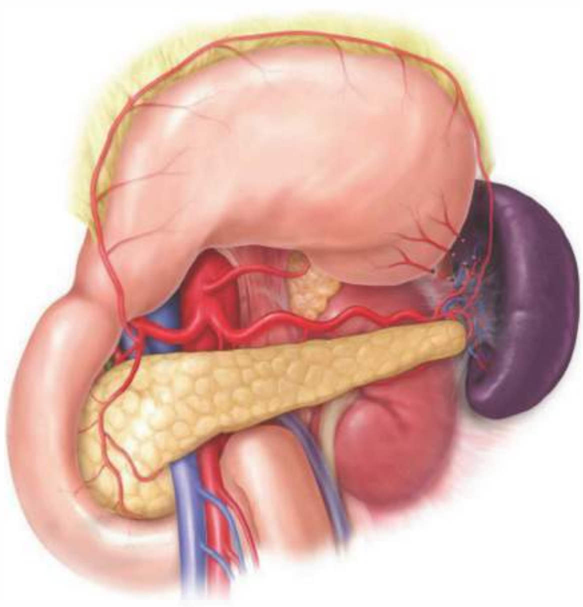

FIG 7 ● Division of short gastric arteries. Short gastric arteries are divided between ligatures or using energy devices. Care is taken to avoid iatrogenic splenic injury.

MOBILIZATION OF THE LESSER CURVATURE OF THE STOMACH

- Now, the lesser curvature is mobilized by dividing the lesser omentum as close to the liver as possible (**FIG 8**). Care is taken to identify the presence of a replaced or accessory left hepatic artery. This dissection is carried toward the portal triad. The right gastric artery arising from the common hepatic artery is divided carefully, mobilizing the lymphatic tissue toward the specimen. At this point, duodenum is circumferentially dissected about 2 to 3 cm distal to the pylorus, encircled with a Penrose drain and divided with a stapler (**FIG 9**). Care is taken not to injure the bile duct, hepatic artery, and portal vein while encircling the duodenum. The stapled duodenal line could be oversewn with 3-0 silk Lambert sutures and buttressed with a healthy piece of falciform ligament (Moossa's patch). However, in the setting of extensive inflammation around the periduodenal area (e.g., in the setting of chronic scarring due to duodenal ulcer), consideration should be given to dividing the duodenal stump in between two straight bowel clamps and suture closure of the duodenal stump.
- Next, the gastrectomy specimen, which is disconnected distally, and the right gastric and right gastroepiploic vessels have been divided, is lifted upward. The left gastric artery is identified, suture ligated, and divided at its origin (**FIG 10**). The lymph–areolar tissue with the left gastric artery is mobilized with the specimen.

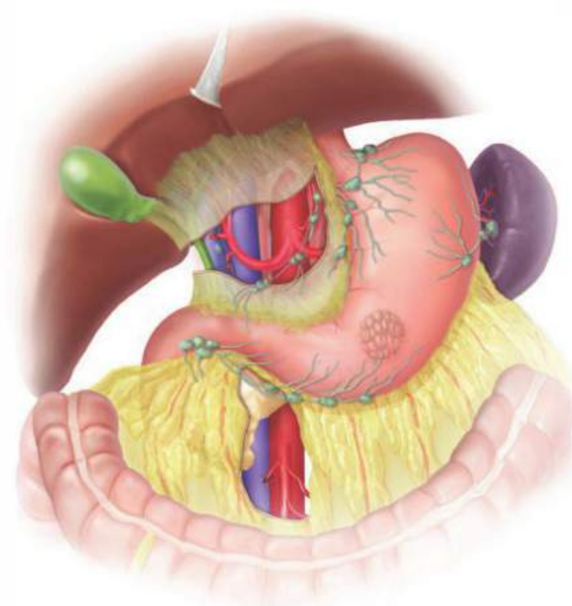

FIG 8 ● Division of lesser omentum. Lesser omentum is divided as close to the liver as possible. Presence of a replaced or accessory left hepatic artery arising from the left gastric artery is carefully sought for.

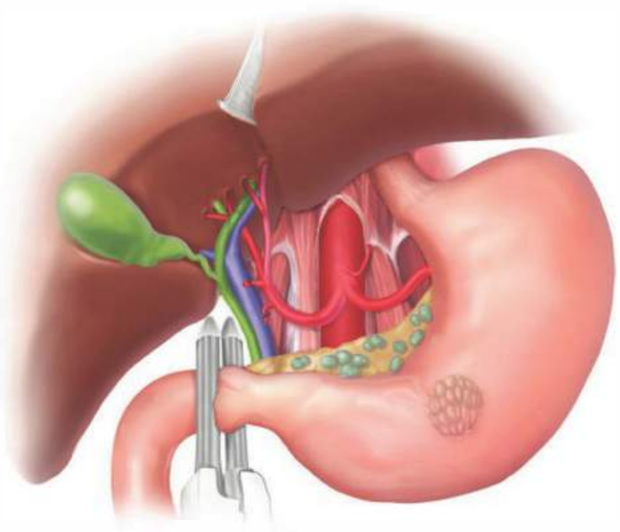

FIG 9 ● Division of the duodenum. Duodenum is circumferentially dissected, encircled with a Penrose, and divided with GIA stapler blue or green load.

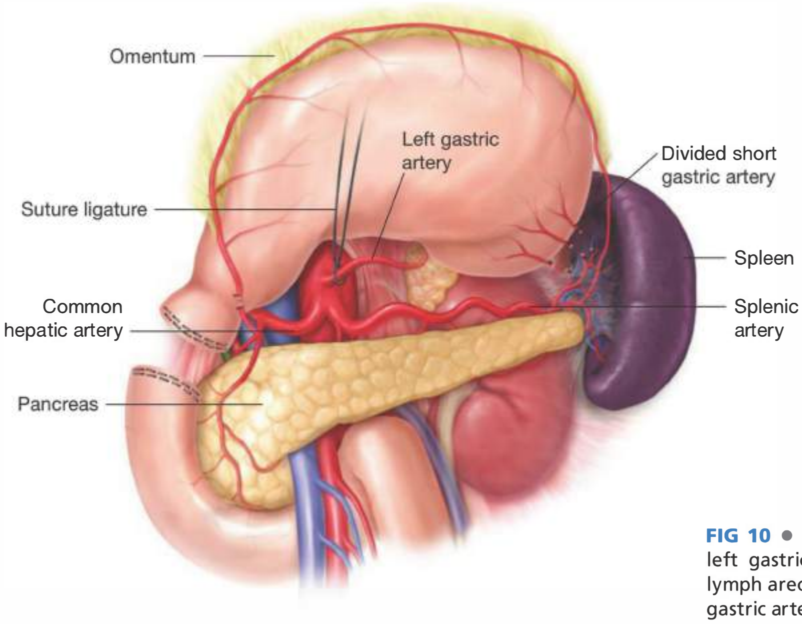

FIG 10 ● Division of the left gastric artery. The left gastric artery is divided at its origin. The lymph areolar tissue around the origin of the left gastric artery is mobilized with the specimen.

ESOPHAGEAL TRANSECTION

- After the division of the left gastric pedicle, the dissection continues upward, along the lesser curvature and the ascending branch of the left gastric artery. The peritoneum anterior to the GE junction is divided. The lymphoareolar tissue along and anterior to the upper part of the lesser curvature and the right aspect of abdominal esophagus is mobilized to the left with the specimen. At this point, the gastrectomy specimen is only anchored at the esophagus. Enough intrathoracic esophagus should be freed so that a proximal margin of 4 to 5 cm from the tumor can be obtained and an anastomosis can be fashioned without tension. At an appropriate point, the esophagus is divided between noncrushing clamps (**FIG 11**). We do not preserve the vagus nerve and both anterior and posterior vagi are divided with the esophagus. This allows for additional mobilization of the distal esophagus into the abdomen.

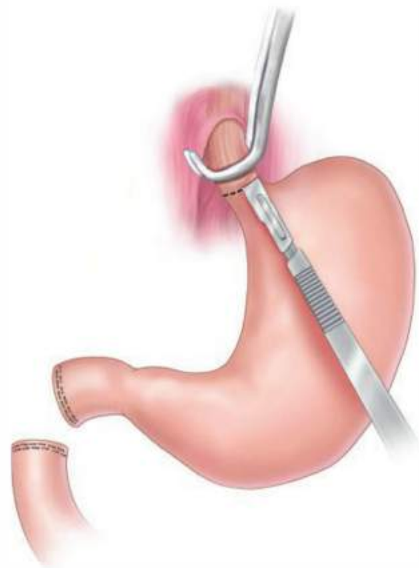

FIG 11 ● Division of esophagus. Esophagus is divided at least 5 cm proximal to the most proximal extent of the gastric tumor.

SPECIMEN PROCESSING

- The operating surgeon is encouraged to hand carry the specimen to the pathologist to orient him/her with the details of the resection and to perform frozen section assessments of the proximal and distal margins. We typically send the resected specimen in separate containers in the following manner: (1) stomach with a marking stitch on proximal end, (2) greater omentum, (3) infrapyloric nodal packet, and (4) lesser curvature nodal packet with a long stitch on the left gastric artery.
- Once the frozen section of the proximal margin comes back negative for malignancy, we proceed with restoration of intestinal continuity.

LYMPHADENECTOMY

- The extent of lymphadenectomy in patients with operable gastric cancer is an area of controversy. Western trials[8,9] did not demonstrate the same survival advantage of D2 lymphadenectomy over D1 lymphadenectomy as demonstrated in eastern gastric cancer surgery trials. However, it has been suggested that the excess mortality in the D2 lymphadenectomy arm in the Dutch gastric cancer trial[8] and the Medical Research Council Trial[9] was due to the distal pancreatectomy and splenectomy. Thus, at this time, we typically perform a pancreas–spleen-preserving D1 lymphadenectomy; that is, taking the right gastric, right gastroepiploic artery, and left gastric arteries at their origin. We acknowledge that the addition of a celiac axis dissection is an area of controversy.

RESTORATION OF INTESTINAL CONTINUITY

- After total gastrectomy, the intestinal continuity is restored by Roux-en-Y esophagojejunostomy. The length of the Roux limb from the esophagojejunal anastomosis to jejunojejunal anastomosis should be 40 to 60 cm to avoid biliary reflux esophagitis.
- **Construction of the Roux limb:** While the pathology team is performing their frozen section on the gastric margin, we simultaneously proceed with the reconstruction. A loop of jejunum distal to the ligament of Treitz that will reach the transected esophagus without any tension is identified. Jejunum at this point is divided with a blue gastrointestinal anastomosis (GIA) stapler. The staple line on the end of the Roux limb is oversewn with 3-0 silk stitches in Lambert fashion. The Roux limb needs to be at least 40 cm (i.e., from its beginning at the level of anastomosis with esophagus to the jejunojejunostomy). A defect is created in the transverse mesocolon to the left of the middle colic vessels (**FIG 12**). We then test that the Roux limb can easily reach the esophagus in retrocolic manner without tension. Our preference is to first perform the stapled side-to-side anastomosis between the biliopancreatic limb and the jejunum. Our rationale behind this order is to allow for an easier reconstruction of this anastomosis away from the mesenteric defect, which is typically the case once the Roux limb has been passed through the mesocolic defect and esophago-jejunostomy has been done. Stay sutures are placed between the biliopancreatic limb and the jejunum and enterotomies for insertion of the limbs of stapler are made. One limb of the blue GIA stapler is introduced into the biliopancreatic limb and the other in the jejunum. The blue load is fired, and the common enterotomy is either closed in a hand-sewn fashion or with a single fire of GIA or thoracoabdominal (TA) stapler.
- **Esophagojejunal anastomosis:** Next, the Roux limb is passed through the mesocolic defect to the left of middle colic vessels, and esophagojejunal anastomosis is performed. The esophagojejunal anastomosis can be fashioned either in hand-sewn or stapled fashion. We favor the hand-sewn anastomosis as it is consistent with our academic mission of training residents in complex intestinal anastomosis techniques. Also, we find the hand-sewn anastomosis more controlled with respect to placement of sutures.
- **Hand-sewn anastomosis:** Two seromuscular stay sutures, passing through the 3 o'clock and 9 o'clock position on the esophagus and antimesenteric aspect of Roux limb, are placed to keep esophagus and the Roux limb together while the anastomosis is being created. We prefer single-layer end-to-side anastomosis. An enterotomy is made on the antimesenteric border of the Roux limb with the help of the electrocautery. The opening in the jejunum is kept smaller than that of the esophagus because the jejunal opening tends to stretch and become bigger. A stay stitch on the anterior lip of the esophagus helps to keep it open thus facilitating the anastomosis. First, the posterior layer of equally spaced interrupted full-thickness 3-0 silk (or absorbable) sutures are placed (**FIG 13A**). Special attention should be given to the corner stitches. All the sutures should be placed before tying. Once the posterior layer is complete, the anterior layer is then performed with the placement of interrupted 3-0 silk (or absorbable) sutures (**FIG 13B**). The knots on the anterior-layer sutures can be extraluminal. Before completion of the anterior layer, a nasogastric (NG) tube is passed into the Roux limb and a small piece of Gelfoam is placed in the lumen to help with hemostasis and to prevent inadvertent placement of anterior stitches through the posterior wall. The jejunum could be tacked to the diaphragm to reduce the tension on the anastomosis from the weight of the Roux limb.

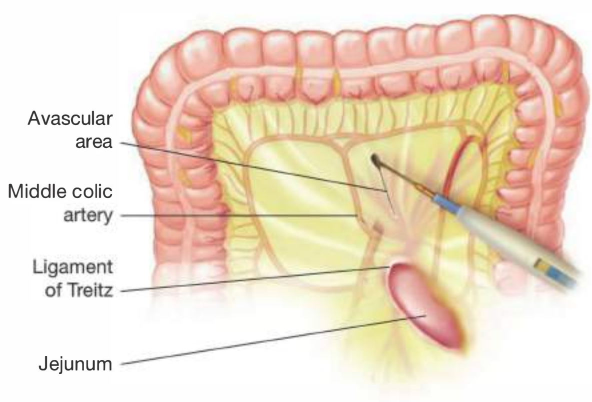

FIG 12 ● Creation of the defect in mesocolon. A defect is created in the mesocolon to the left of middle colic vessels. The Roux limb is passed through this defect in a retrocolic fashion.

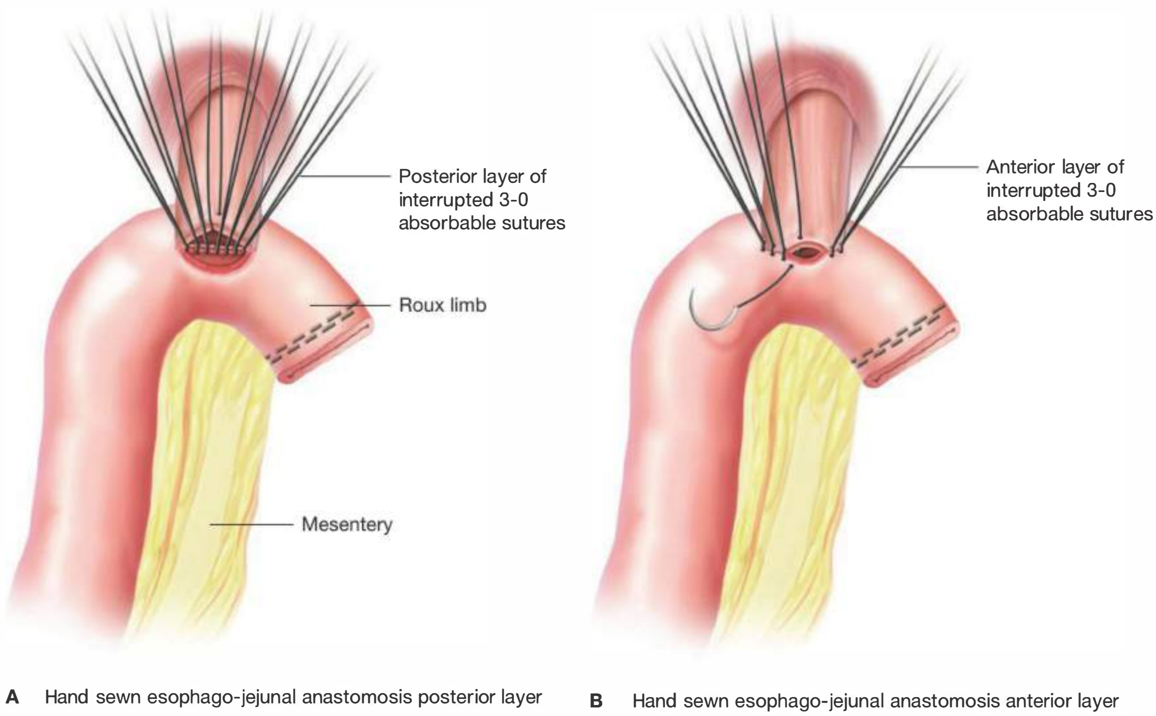

FIG 13 ● Hand-sewn esophagojejunal anastomosis. An end-to-side anastomosis is created between the esophagus and the Roux limb. An enterotomy, smaller than the opening in the esophagus, is made in the antimesenteric border of the Roux limb. First, the **(A)** posterior layer of interrupted absorbable sutures is placed followed by **(B)** anterior layer of sutures.

- **Stapled anastomosis:** For stapled anastomosis (FIG 14), an end-to-end anastomosis (EEA) stapler is used. First, the size of the esophageal opening is measured by using calibrated sizers and the EEA stapler is chosen on the basis of this measurement. Esophagus can also be gently dilated using a Foley, which is inserted into the esophagus and then withdrawn gently with balloon inflated. In general, a 25-mm EEA stapler is used for the esophagojejunostomy. A purse string is placed at the end of esophagus with a 2-0 Prolene (FIG 14A). The anvil of the EEA stapler is now introduced into the esophagus and the purse string is tied (FIG 14B). Next, the EEA stapler is introduced into the Roux limb preferably through the end of the jejunum or through an opening created in the Roux limb and directed toward the antimesenteric border of the Roux limb (FIG 14C). The pin of the EEA stapler is now opened with anticlockwise rotation of the knob and brought out through the point on the antimesenteric border of the Roux limb where the anastomosis is planned. This pin is attached to the anvil, stapler closed, and fired. The operator of the stapler should familiarize himself/herself to the operation of the stapler as these may differ from one company to the other. The doughnuts are checked for completeness and integrity. If the stapler was inserted through the blind end of the jejunum, this can be stapled close after the anastomosis is created.
- Although we do not routinely employ the following additional step, some surgeons assess the integrity of the anastomosis using an instilled methylene blue or air into the esophagus (through a tube in the esophagus) while the Roux limb is clamped.

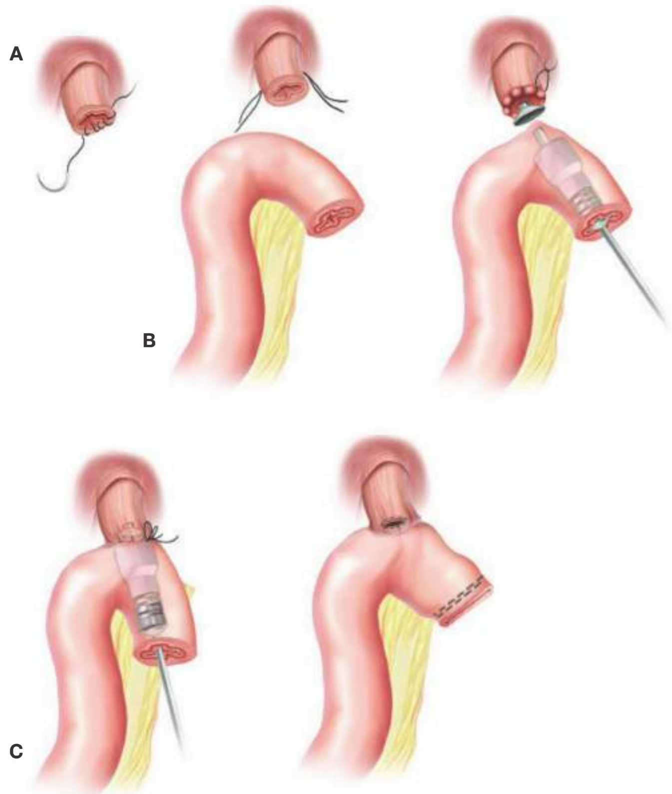

FIG 14 ● Stapled esophagojejunal anastomosis. **A.** Purse string is placed at the end of esophagus with a 2-0 Prolene. **B.** The anvil of the EEA stapler is introduced into the esophagus and the purse string is tied. **C.** The EEA stapler is introduced into the Roux limb through the end of the jejunum and directed toward the antimesenteric border of the Roux limb. The pin of the EEA stapler is now opened with anticlockwise rotation of the knob and brought out through the point on the antimesenteric border of the Roux limb where the anastomosis is planned. This pin is attached to the anvil, stapler closed, and fired. The doughnuts are checked for completeness and integrity.

CLOSURE

- After the restoration of gastrointestinal continuity, a feeding jejunostomy is placed distal to the jejunojejunal anastomosis. The patient may already have a feeding jejunostomy if one was placed during staging laparoscopy before neoadjuvant therapy.
- Prior to abdominal wall closure, we typically ensure absence of kinks, twists, or tension in the reconstructed intestinal continuity.

PEARLS AND PITFALLS

Mobilization of the greater curvature	■ Short gastric vessels should be carefully divided to avoid troublesome bleeding or iatrogenic splenic injury leading to inadvertent splenectomy.
Dissection of the infrapyloric region	■ The origin of the right gastroepiploic artery from the gastroduodenal artery should be carefully dissected, especially in the obese patients, due to difficulty in identifying this vessel.
Dissection of the GE junction	■ Adequate length of the esophagus should be dissected to yield a tension-free esophagojejunal anastomosis.
Construction of esophagojejunal anastomosis	■ The esophagojejunal sutures should be full thickness to ensure a robust anastomosis.
Feeding jejunostomy tube	■ If the feeding jejunostomy tube is placed during the staging laparoscopy, the surgeon should be cognizant of the need of constructing a Roux limb for the restoration of gastrointestinal continuity at the time of definitive surgery. Thus, the loop of jejunum just distal to the ligament of Treitz, which would be used for fashioning the Roux limb, should not be used for the placement of jejunostomy tube.

POSTOPERATIVE CARE

- Similar to other major abdominal operations, patients who undergo total gastrectomy require close attention to hemodynamics, optimization of fluid and electrolyte status, pain management, and pulmonary toilet.
- We increasingly use pain blocks (epidural, paravertebral blocks) in the care of these patients.
- NG tube is typically left to suction and is removed on postoperative days 3 to 4. If NG tube accidentally comes out, it should not be replaced due to the concern for anastomotic disruption. If NG tube needs to be replaced, it should be done under fluoroscopic guidance.
- If patient does not demonstrate any symptoms and signs of anastomotic leak by days 5 to 7, then they can be started on a clear liquid diet and then advanced to a postgastrectomy diet based on return of bowel function. Postgastrectomy diet consists of six small meals instead of three large meals. Most patients with time are able to liberalize the food choices as well as portion size.

OUTCOMES

- Although older data from gastric cancer trials quote an 8% in-hospital mortality for patients with total gastrectomy,[2] in recent series, in-hospital mortality of 1% to 2%, anastomotic leak rate of 1% to 3%, and duodenal stump leakage of less than 1% have been reported.[10,11] The cancer-specific outcomes depend on the stage of gastric cancer. Stage-specific 5-year survival of 57% to 71% for stage I, 33% to 45% for stage II, 14% to 20% for stage III, and 4% for stage IV M0 (AJCC 1988) has been reported[12] in the era prior to widespread acceptance of adjuvant or perioperative therapies. In a landmark study evaluating the role of adjuvant therapy in the treatment of stage Ib to IV resectable gastric cancer, addition of chemoradiation to surgery alone improved the 3-year overall and relapse-free survival from 41% to 50% and 31% to 48%, respectively. Similarly, perioperative chemotherapy without radiation for gastric cancer leads to improvement of overall 5-year survival from 23% to 36%.[13,14]

COMPLICATIONS

- **Early surgical complications:** Given the magnitude of surgery, total gastrectomy is associated with multiple systemic complications such as pulmonary embolism, pneumonia, atelectasis, myocardial infarction, and deep venous thrombosis. The diagnosis and management of these complications is no different from that after other major operations. Complications related to technical, physiologic, and anatomic aspect of total gastrectomy are described below.
  - **Anastomotic leak**
    - Presentation: Leak rates of 2% to 8% have been reported for esophagojejunal anastomosis. The type of reconstruction (stapled vs. hand sewn) has not been shown to influence this complication. This complication presents around postoperative days 6 to 9 and is heralded by unexplained fevers, tachycardia, and systemic inflammatory response.
    - Investigation: When suspected, a gastrografin swallow (followed by use of barium if needed) is used to evaluate for a leak. A CT scan with oral and IV contrast to evaluate for intraabdominal collections should be obtained.
    - Management: Initial management consists of NPO, IV antibiotics, nutrition, either enteral through feeding jejunostomy or parenteral, and drainage of any intraabdominal collection. Surgeons are increasingly using placement of a stent to help seal operative anastomotic leaks. Presence of feeding jejunostomy, which can help support the patient through enteral feeding, is very helpful in this situation. The resolution of the leak can be monitored by weekly gastrografin study. Operative exploration and repair is rarely required.
  - **Postoperative intraluminal bleeding**
    - Presentation: Bleeding from the anastomosis may present as sanguineous drainage from NG tube, melena, and/or drop in hematocrit or hemodynamic alteration.
    - Management: Most bleeding episodes resolve in response to conservative management with limited transfusion and correction of coagulopathy. Rarely, upper endoscopy with identification of bleeding site and its control with electrocautery or clips is required. We typically use endoscopic intervention as a last resort because of the fear of potential perforation.
  - **Postoperative extraluminal bleeding**
    - Presentation: Extraluminal bleeding presents in the early postoperative period as hemodynamic instability and falling hemoglobin. Although many etiologies are likely, unrecognized injury to the spleen, in the form of capsular tears or unligated short gastric arteries, is the most common reason for significant extraluminal bleed.
    - Management: If splenic injury is recognized during the gastrectomy, then splenic capsular tears can be managed by topical hemostatic preparation. Bleeding short gastric vessels can be managed with the use of surgical clip placement or use of energy devices. Uncontrolled bleeding may warrant a splenectomy. Postoperative bleeding that was not recognized during the procedure and is unresponsive to hemodynamic support with correction of coagulation parameters mandates return to the operating room with correction of underlying cause.
  - **Duodenal stump breakdown**
    - Presentation: Duodenal stump leak presents as signs and symptoms suggestive of intraabdominal sepsis such as fever, tachycardia, increasing abdominal pain, and leukocytosis.[15] An abdominal and pelvic CT scan with oral and IV contrast reveals an intraabdominal collection in the vicinity of duodenum requiring a percutaneous drain placement. If the drain output is bilious, it heightens the suspicion of duodenal fistula, which is confirmed by performing a drain study once the drain output does not decrease with time. Duodenal suture line failure can also present much more acutely in form of duodenal stump blowout if there is a downstream obstruction. The fistula may be an end fistula when it forms at the duodenal staple line or a lateral fistula when duodenum perforates laterally.
    - Management: Duodenal fistula is a difficult problem due to high volume loss of biliary and pancreatic secretions. Management involves supportive treatment with parenteral nutrition, correction of electrolyte abnormalities, antibiotics in early phase, and control of drainage with

special attention to skin care. Supportive treatment for as long as 6 weeks may be attempted. If resolution of duodenal fistula is not achieved, a percutaneous transhepatic tube can be advanced through the bile duct and into the duodenum to allow for retrograde drainage and control. Surgical management includes the take down of fistula, and duodenal reconstruction with Roux-en-Y end-to-side duodenojejunostomy. If the duodenal blowout presents as acute abdomen, then exploratory laparotomy, placement of a lateral tube duodenostomy, and wide drainage of right upper quadrant is required.

- **Delayed complications**
  - **Nutritional deficiencies**
    - Postgastrectomy diet: Patients postgastrectomy need to be started on postgastrectomy diet, which involves taking six small meals a day due to the loss of storage capacity of the stomach. With time, most patients can liberalize the volume and type of foods they consume. Some patients might be able to tolerate a diet similar to what they consumed preoperatively.
    - Iron supplementation: Postgastrectomy patients need to be on iron supplementation as the duodenum is the primary site of iron absorption and is bypassed. Also, the loss of gastric acidity impairs the conversion of ferric iron to the more absorbable ferrous form; 150 mg to 300 mg per day of elemental iron in three divided doses is recommended.
    - Vitamin B_{12} supplementation: Patients with total gastrectomy will develop vitamin B_{12} deficiency if not supplemented. Reduction in intrinsic factor and loss of gastric acidity impairs its absorption. Oral vitamin B_{12} (up to 100 μg per day) or monthly intramuscular vitamin B_{12} is recommended.
    - Supplementation of folate, calcium, and vitamin D is also recommended.
  - **Anastomotic stricture**
    - Presentation: Patients may present with dysphagia either early in postoperative period or many years after the initial operation.
    - Management: The differential diagnosis for anastomotic stricture includes postoperative edema, fibrosis/scarring, and local cancer recurrence. The diagnostic workup starts with contrast study followed by endoscopy with biopsy. Dysphagia secondary to edema will resolve with no interventions. Benign strictures can be managed by endoscopic or fluoroscopic balloon dilation. There is an increasing role of self-expanding metal stent for this condition. If the stricture is due to recurrent cancer, then the patient should be restaged and managed accordingly.

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Chapter 16 Gastrostomy

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DEFINITION

- A gastrostomy tube (G-tube) is a transcutaneous tube that is positioned in the lumen of the stomach. The primary functions of the G-tube are enteral access for nutrition and gastric decompression. They can be temporary or permanent depending on the patient's underlying pathology and clinical needs.
- A G-tube can be placed with an open, laparoscopic, endoscopic, or image-guided percutaneous approach.

PATIENT HISTORY AND PHYSICAL FINDINGS

- The history and physical exam should focus on the indication for enteral access, hemodynamic stability of the patient, current functional status of the gastrointestinal (GI) tract, and previous GI or upper abdominal surgeries.
- Indications for G-tube include feeding access and gastric decompression. They also play a role as an additional method of gastropexy following antireflux procedures or to prevent gastric torsion.
- Patients who are hemodynamically unstable should not undergo elective G-tube placement. In these scenarios, gastric access can be maintained through a nasogastric route.
- Assessing the status of the GI tract is essential for operative planning and patient benefit.
  - If the G-tube is to be used for feeding, the patient should have a functional GI tract distal to the stomach and without evidence of mechanical bowel obstruction, adynamic ileus, GI ischemia, or peritonitis.
  - Safe access to the stomach via the oropharynx and esophagus needs to be verified prior to proceeding with percutaneous endoscopic gastrostomy (PEG) tube placement. If this route is obstructed or otherwise unsafe, an open, laparoscopic, or image-guided percutaneous technique should be used.
  - In patients with esophageal pathology that may necessitate an esophagectomy, a G-tube should be avoided because the stomach may be used as a conduit for reconstruction following esophagectomy. In this scenario, a feeding jejunostomy is our preferred route of enteral nutrition.
- A thorough surgical history is imperative prior to G-tube placement. Patients with a history of previous upper abdominal or gastric surgery will be at higher risk for inadvertent colon or small bowel injury during PEG tube placement. An extensive abdominal surgical history may prohibit safe laparoscopic or endoscopic G-tube placement and thus an open technique may be the safest route.

IMAGING AND OTHER DIAGNOSTIC STUDIES

- Specific imaging or other diagnostic studies are generally unnecessary for G-tube placement. However, it is often the case that patients have had a plethora of upper abdominal imaging for other reasons that may provide valuable information or clues to previous unknown surgical procedures or unexpected anatomic findings.
- For PEG tube placement, it is important to look for structures, particularly the liver and transverse colon, which may be resting anterior to the stomach along the line of the proposed G-tube tract. In patients with increased risk of abdominal adhesions (i.e., previous operations, history of peritonitis) and radiographic evidence of abdominal structures lying between the abdominal wall and stomach, PEG placement should be avoided in favor of a laparoscopic or an open approach.

SURGICAL MANAGEMENT

Preoperative Planning

- The patient should be NPO for a minimum of 6 hours prior to the procedure.
- Antibiotics should be given within 30 minutes of incision to reduce the incidence of abdominal wall infection around the tube site. First-generation cephalosporins are our preference when not contraindicated by a patient's known allergies.
- For patients undergoing a PEG tube placement, the patients should be provided an antiseptic mouth rinse to reduce oral flora being carried into the abdominal wall soft tissues.

Positioning

- For endoscopic or surgical G-tube placement, the patient should be positioned supine.
- For laparoscopic placement, the patient should be supine with the right arm tucked to allow adequate room for the surgeon and assistant to both work comfortably on the right side.

PERCUTANEOUS ENDOSCOPIC GASTROSTOMY TUBE PLACEMENT

Equipment

- There are several PEG kits available. These vary depending on technique (push or pull) and tube size (20 French [Fr] or 28 Fr). Most of these kits come with everything needed for placement, including prep and sterile drapes. We use the Bard Ponsky PEG kit, 20 Fr.
- A standard adult or pediatric endoscope is required, preferably with an external display so that both operating surgeons can see the endoscopic view.

Endoscopy and Tube Site Selection by Transillumination

- With an endoscopist at the patient's head and surgeon scrubbed at the patient's abdomen, the room lights are dimmed and the endoscopist introduces the endoscope into the stomach.

- A quick look around the entire stomach is performed to rule out occult gastric pathology.
- The endoscopist should fully insufflate the stomach.
- The endoscopist should advance the polypectomy snare to the end of the scope then withdraw 2 cm so that it is ready for the ensuing steps.
- Transillumination will allow the surgeon to locate the appropriate place on the abdominal wall for the G-tube to be placed. This is done by retracting the scope into the body of the stomach several centimeters distal to the gastroesophageal junction and then directing it toward the anterior stomach.
  - Some endoscopic light sources offer a transilluminate feature that temporarily increases the light intensity to enhance visualization through the abdominal wall by the surgeon.
  - Palpation is sometimes required to compress the tissue between the stomach and skin to better reveal the light.
  - It is often necessary to darken the room to visualize the light.
- Carefully palpate multiple areas and choose the spot with the brightest area of transillumination (**FIG 1**).
- Ensure that the sight is at least 2 to 3 cm from the left costal margin for patient comfort.
- Mark the spot with a marking pen or press the needleless tip of a Luer lock syringe into the skin to leave an indentation mark.
- Insertion of a fine 25-gauge or 27-gauge needle, as used for infusion of local anesthesia, may be used to best identify the perfect placement position and tube track.

Optional Technique for Site Selection

- For additional assurance that there is no intervening bowel between the tube site chosen by transillumination and the stomach, the following technique can be used.[1]
  - Using a 10-mL syringe with several milliliters of saline and a small-gauge needle, advance the needle perpendicularly through the abdominal wall at the spot previously chosen, keeping the plunger drawn back.

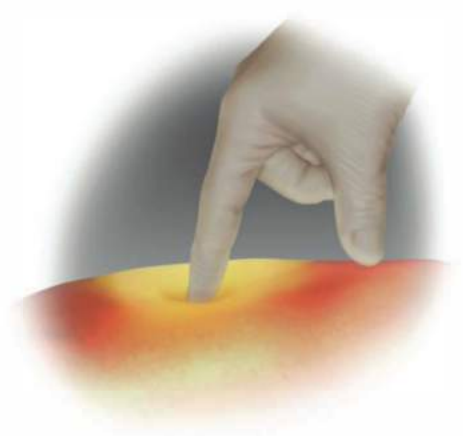


FIG 1 ● Transillumination of the abdominal wall.

- Watch the saline in the syringe for air bubbles. If the initial presentation of bubbles is seen at the same time the endoscopist sees the needle from inside the stomach, you can safely assume you have not passed through any bowel before entering the stomach.
- If you see bubbles before the endoscopist sees the needle from inside the stomach, you may be passing through bowel and thus should choose another point of entry and repeat (**FIG 2**).
- During this process, it is important to limit the force applied to the abdominal wall as this may compress a portion of an unexpected piece of bowel lying along the proposed track.

Tube Placement

- Infiltrate the site chosen with local anesthetic and make an approximately 0.5-cm skin incision with a no. 11 blade.
- The endoscopist should advance the previously positioned polypectomy snare and center the loop over the area of the mucosa that was identified during abdominal wall site selection. This type of synchronization and planning not only facilitates a timely procedure but also avoids visceral movement once the best site is selected (**FIG 3**).
- The needle with the angiocath is then placed through the abdominal wall at the designated site and advanced into the stomach under direct visualization into the loop created by the polypectomy snare. The needle is then removed while the angiocath is left in place (**FIG 4A**).
- The snare is left loose.
- The looped wire or the stiffer guidewire (see "Push Technique") is advanced through the angiocath.
- After several centimeters are passed through the snare, the snare loop is tightened around the wire (**FIG 4B**).
- The scope is then completely withdrawn while the polypectomy snare is held snug around the wire, pulling the wire through the abdominal wall. This leaves the wire passing through the abdominal wall via the angiocath, into the stomach, through the esophagus, and out of the mouth.
- At this point, there are two techniques available—"push" and "pull"—that can be chosen based on available supplies and surgeon's preference.

Pull Technique

- The looped wire that was pulled through the stomach to the mouth is connected to the looped wire at the tapered external end of the PEG tube (**FIG 5**).
- The surgeon then pulls the suture from the abdominal wall end, advancing the PEG tube through the esophagus into the stomach. The endoscopist should follow the tube down to visualize from within the stomach. To save time, the polypectomy snare can be cinched around half of the button of the PEG tube to allow the scope to easily follow the tube while it is being pulled by the surgeon (**FIG 6**).

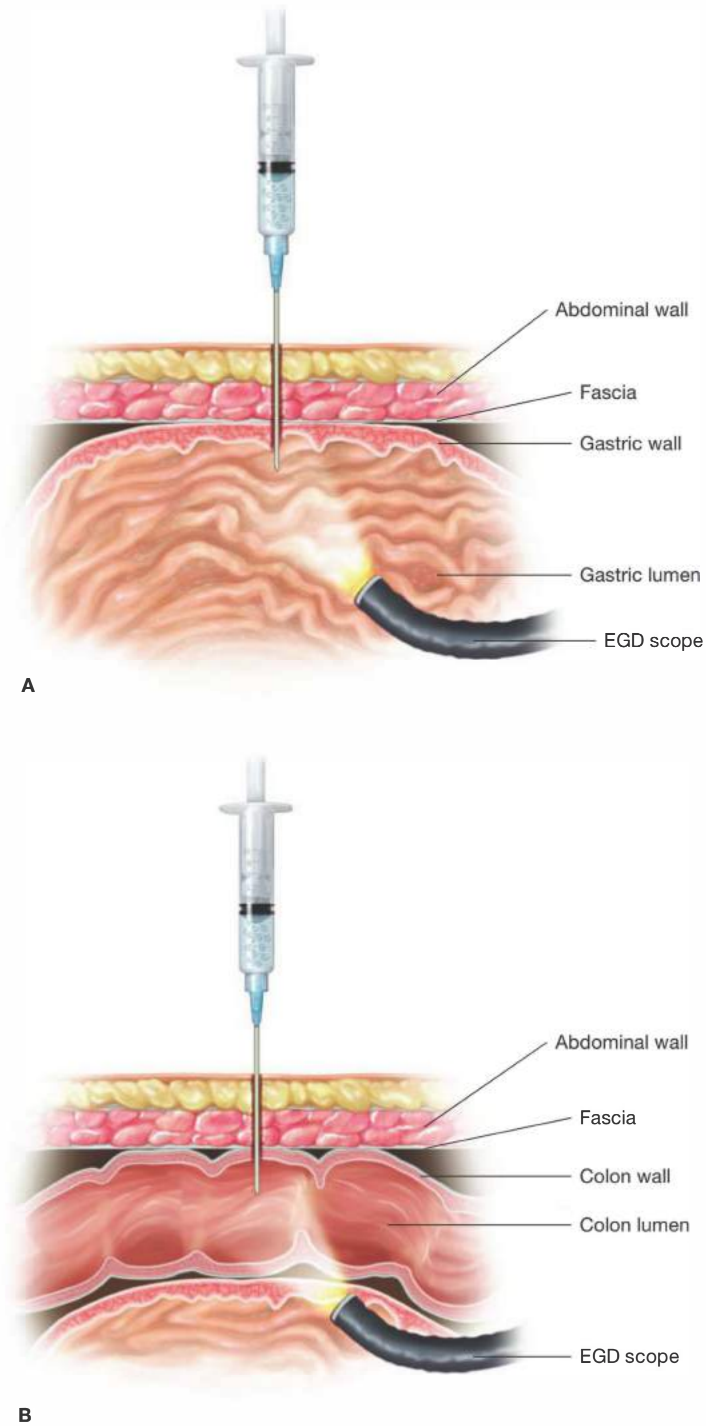


FIG 2 ● **A.** Bubbles are seen at the same time as the endoscopist sees the needle, confirming intragastric positioning without intervening bowel. **B.** Bubbles are seen *before* the needle is seen by the endoscopist, suggesting bowel between the stomach and abdominal wall.

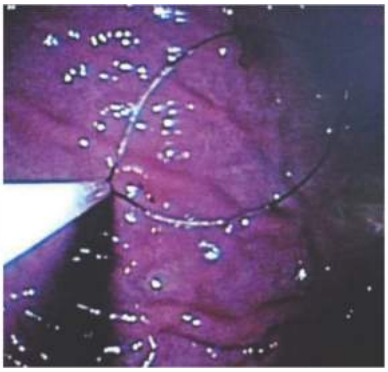


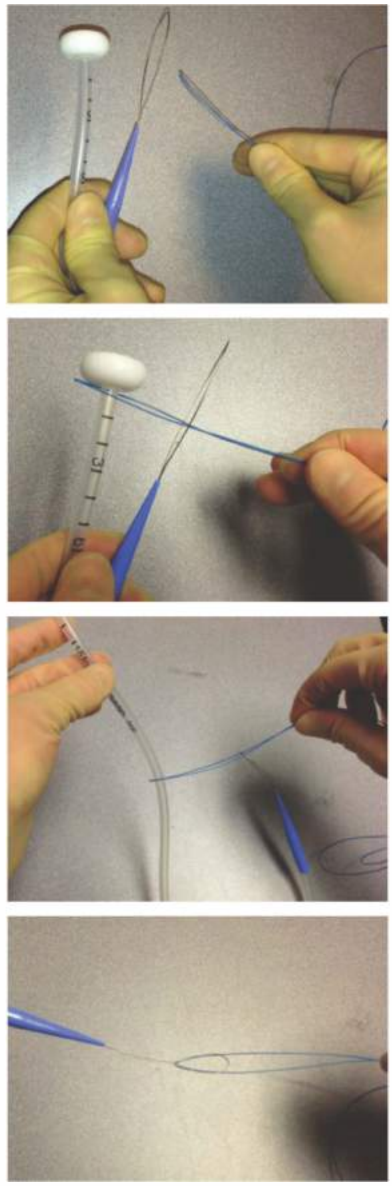
FIG 3 ● The snare is positioned against the mucosa where the needle is intended to pass.

- When the tapered end of the PEG tube begins to come through the abdominal wall, additional force directed perpendicular to the abdominal wall is required to pull the tube through (**FIG 7**).
- The tube should be pulled until the button is resting loosely against the gastric mucosa.

A

B

FIG 4 ● **A.** The needle and angiocath are advanced into the stomach in the center of the snare by the surgeon. The needle is removed. **B.** The wire is passed through the angiocath into the stomach and through the center of the snare. The snare is then tightened around the wire.



A

B

C

D

FIG 5 ● With the looped wire exiting the patient's mouth, the tapered end of the PEG tube is secured to the wire. There is often a wire loop on the PEG to facilitate this attachment. Pass the wire through the loop **(A)** and around the button end of the tube **(B)**. Pull the rest of the tube through the wire **(C)** so that they are now secured together **(D)**.

- The endoscopist should confirm position of the button to rule out bleeding while the surgeon notes the thickness of the abdominal wall when securing the bolster.

Push Technique

- This technique requires a stiffer guidewire to be used.
- The G-tube is inserted over the wire by the endoscopist and advanced while tension is held on the wire by both the surgeon and endoscopist.

FIG 6 ● The snare can be tightened around half of the PEG flange to facilitate prompt scope reentry into the stomach.

- The tube is then pushed until the surgeon is able to grasp the tapered end as it emerges through the skin.
- The surgeon then pulls the tube until the button rests loosely against the gastric mucosa, as described earlier.

Securing the Tube

- The outer bolster included in the kit is then applied to the external portion of the tube and directed toward the skin.

FIG 7 ● Once the tapered end of the PEG is seen exiting through the abdominal wall, a steady pull directed toward the ceiling by the surgeon is required to advance the PEG tube to its final position.

- The bolster should rest about 2 to 3 mm above the skin.
- Avoid compressing the abdominal and gastric wall between the bolster and button (FIG 8). This can cause ischemic necrosis to these tissues, potentially leading to abdominal wall infection, tube extrusion, or the stomach falling away from the abdominal wall.
- The kit manufacturers often recommend and provide antibiotic ointment to be applied to the interface of the tube as it enters the skin to decrease the formation of an abdominal wall infection.
- The tube is then cut to the appropriate length and an adapter is secured to the end to allow a sealed connection for feeding, drainage, or to secure the cap to prevent leakage.
- We connect a collection bag during the immediate postoperative period to allow the GI tract to be decompressed of any gas that was insufflated during the procedure and to decrease the risk of reflux during emergence from sedation.

FIG 8 ● The bolster is advanced so that it is just touching and depressing the skin.

OPEN GASTROSTOMY TUBE

Equipment

- A standard laparotomy setup should be used.
- For the G-tube, a 22-Fr Foley catheter or the G-tube from a laparoscopic G-tube kit can be used. There are commercially available G-tubes that allow simultaneous gastric decompression and jejunal feeding, which may be beneficial in some scenarios.

Incision

- When done as a single procedure, a 4-cm upper midline incision to expose the stomach should be used (FIG 9).
- Just beneath the linea alba, the extraperitoneal fat and the falciform ligament should be retracted to the right to assist with visualization of the left upper quadrant.
- A small wound protector functions well as a retractor and limits the subcutaneous tissues exposure to contamination from the gastric flora.

Gastrotomy and Tube Placement

- The location of the gastrotomy should be on the anterior surface of the midportion of the stomach, close to the greater curve (FIG 10). Mark this point with the cautery or a surgical marking pen.
- Using a 3-0 absorbable monofilament suture on a taper needle, sew a circular purse string around the gastrotomy site with a diameter of about 1 cm. Place a second purse string around the first one concentrically taking care to create a purse string diameter of approximately 2 cm. This allows the gastric wall to partially intussuscept, creating nice track for the tube (FIG 11).

FIG 9 ● Open G-tube incision.

- Next, grasp the left linea alba at the exposed incision with an atraumatic clamp and elevate the left abdominal wall. Pick a point through the middle of the left rectus muscle where the tube will exit the abdominal wall. Make sure that this is at least two fingerbreadths below the left costal margin and at the approximate level of the gastrotomy. Make a 5-mm incision in the overlying skin and pass a fine clamp through the rectus from the peritoneum through the 5-mm incision in the skin. Grasp the end of the catheter and bring it through the abdominal wall (**FIG 12**). Care should be taken during this process to avoid injury to the balloon on the tip of the catheter and its integrity should be checked at this point by infusing sterile water (*not* saline) into the balloon.

FIG 10 ● Preferred location of gastrostomy on anterior surface of the stomach.

FIG 11 ● Using nonabsorbable suture, a double purse-string stitch is placed around the enterotomy site. The inner circle should be about 1 cm in diameter and the outer should be about 2 cm in diameter.

- Using the point of a cautery device, make a small gastrotomy in the center of the purse string and confirm entry into the stomach. Do not dilate the gastrotomy (**FIG 13**).
- Place the catheter through the gastrotomy into the stomach. Starting with the inner stitch, tie the two purse-string sutures down around the catheter. Inflate the balloon with 10 mL of water. Do not secure too tight as to close off the catheter or cause ischemia to the gastric wall (**FIG 14**).

Fixation (Optional)

- In some scenarios, the stomach or gastric remnant in patients with a history of a gastric bypass may not reach the abdominal wall; in this case, fixation should be avoided. When this is the case, it is advantageous to pass the tube through a small portion of omentum prior to insertion through the gastrotomy so that the omentum is readily able to begin forming a healthy track between the abdominal wall and the gastric lumen.

FIG 12 ● The left linea alba is grasped and retracted medially. A skin incision is made at the G-tube site and a Kelly clamp is passed through the abdominal wall and out through the skin incision. The enteral end of the G-tube is then pulled through the abdominal wall.

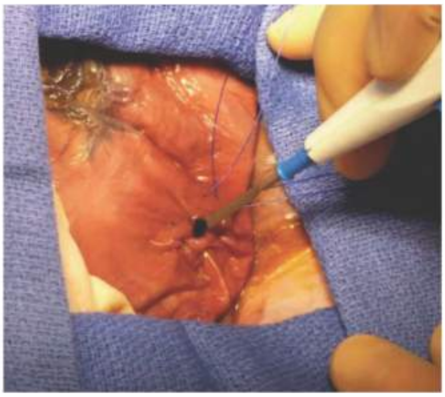


FIG 13 ● Cautery is used to create a gastrotomy at the center of the purse string.

- When fixation is desired, the goal is to secure the stomach to the abdominal wall at the point where the tube passes through the rectus. This seals the tract made by the tube and helps to prevent gastric content spillage into the peritoneal cavity.
- Using a 3-0 absorbable suture on a taper needle, place four separate stitches through the seromuscular layer of the stomach and peritoneum of the abdominal wall. This should be done four times around the point where the tube enters the abdominal wall. Start with the lateral (furthest) stitch first, then superior, inferior, and finally medial. Secure each suture after it is placed and do not tie them until the end. Once all four sutures have been placed, tie them down in the order they were placed while relaxing on the retraction of the left abdominal wall.
- Before tying, ensure that the stomach is not on too much tension or twisted in any way.

Closure

- Close the abdomen in standard fashion.
- Secure the tube to the skin with a 3-0 nylon suture to prevent the tube from being dislodged.
- If a manufactured G-tube was used, the supplied bolster may be used to secure the tube along with a nylon suture. Make sure that the bolster is not too tight to prevent abdominal wall or gastric wall ischemia. The bolster should rest without tension 2 to 3 mm above the skin (**FIG 8**).
- We connect a collection bag during the immediate postoperative period to allow the GI tract to be decompressed of any gas that was insufflated during the procedure and to decrease the risk of reflux during emergence from sedation.

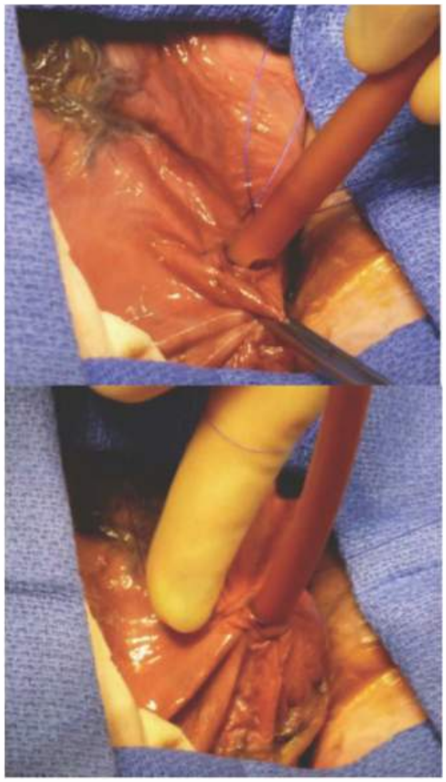


FIG 14 ● The tube is inserted into the stomach through the gastrotomy and the purse strings are tied, starting with the inner circle.

LAPAROSCOPIC GASTROSTOMY TUBE

Equipment and Port Placement

- Several commercial laparoscopic G-tube kits are available. We use the Flexiflo Lap G™ by Abbot Nutrition. This section will describe G-tube placement using this kit. The steps described can be modified for other kits and the package inserts for each kit should be read as they often pertain pertinent pearls for success.
- A standard laparoscopic setup including a 5-mm 0-degree or 30-degree laparoscope and a single 5-mm port is used.
- The procedure can be accomplished with only one periumbilical port for the camera so long as there are no adhesions that need to be taken down and the stomach can be insufflated by anesthesia via an orogastric tube. If these conditions cannot be met, additional ports may be needed to lyse adhesions and/or manipulate the stomach. The ports should triangulate toward the stomach in the left upper quadrant (**FIG 15**).
- The T-fasteners used in this procedure aid in providing traction for the stomach while the tract is being dilated and the G-tube is being placed. This is very helpful when only a single laparoscopic port is used for the

FIG 15 ● Port placement for laparoscopic G-tube.

camera and no additional laparoscopic instruments are used. However, if an additional instrument port has to be placed for adhesions or stomach manipulation as mentioned earlier, the T-fasteners can be eliminated from the procedure and the extra instrument port can provide the traction on the stomach during the dilation and tube placement steps.

Tube Placement

- Once laparoscopic access has been gained and all necessary adhesions have been cleared, anesthesia should insufflate the stomach via an orogastric tube. Pick a site in the left upper quadrant where the G-tube should enter the abdomen. The entry point should be at least two fingerbreadths below the left costal margin. The surgeon should palpate in this general area while watching the laparoscopic screen to find the place where the depressed abdominal wall lines up with the stomach. Avoid placing the tube too close to the gastroesophageal junction or antrum to avoid obstruction. The anterior surface of the midbody closer to the great curvature is the preferred location (**FIG 10**).
- Mark the tube site on the skin and then mark points 2 cm in four directions around the tube site for the T-fasteners.
- Starting with the most superior mark, insert the needle with the loaded T-fastener through the abdominal wall angled slightly toward the center mark. Once the needle is seen in the peritoneal cavity, direct it to point around the proposed gastrostomy site that corresponds to the skin location. Advance the needle with the loaded T-fastener into the stomach up the double-line marking. Press the plunger on the needle to deploy the T-fastener (**FIG 16**). Place a clamp on the T-fastener tail approximately 1 to 2 cm from the skin.
- Repeat the step to deploy the remaining three T-fasteners. Ask anesthesia to remove some air from the stomach so that the stomach begins to fall away from the abdominal wall. The anterior wall of the stomach should be visible with the four T-fasteners entering in

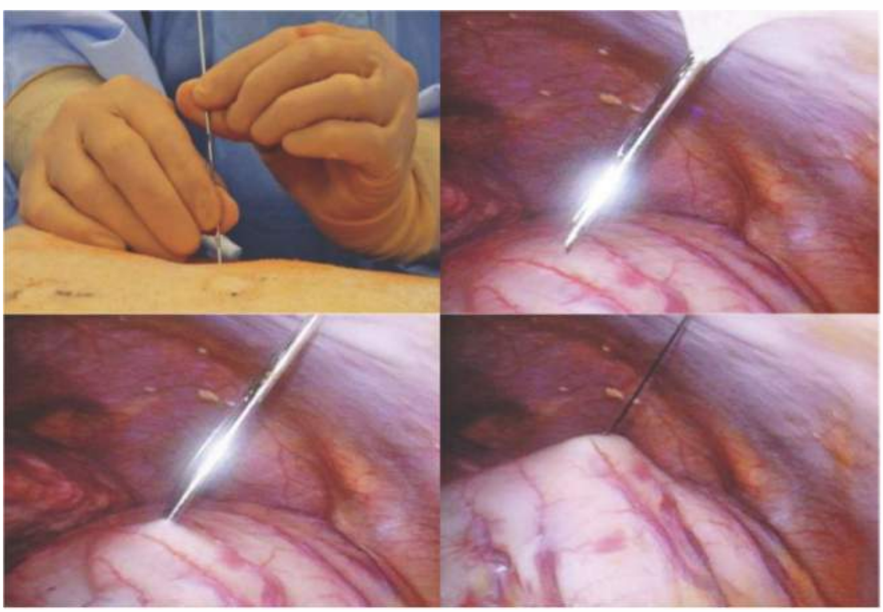


FIG 16 ● The sequence of steps for T-fastener placement is shown here. Note the insertion of the needle to the double black bar marking before deployment of the T-fastener.

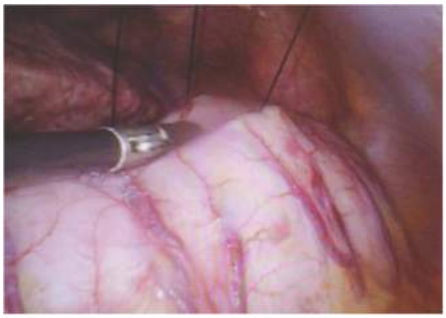


FIG 17 ● Final view after all T-fasteners have been placed.

an approximate diamond shape (**FIG 17**). The center of diamond will be the tube insertion site.

- Make a 5-mm skin incision at the chosen tube site and direct the 18-gauge needle with a 40-mL slip-tipped syringe through the abdominal wall and into the peritoneal cavity. Under direct visualization with the laparoscope, direct the needle into the stomach through the point at the center of the diamond created by the T-fasteners (**FIG 18**). The T-fasteners can be used to manipulate the stomach to guide entry of the needle. Insufflate air to be absolutely certain that the tip of the needle is intraluminal.
- Pass the supplied wire into the stomach and remove the needle.
- Using the supplied serial dilators, dilate the tract through the abdominal and gastric wall. The stomach should be just off the abdominal wall during this step so that the dilators can be seen exiting the abdominal wall and passing into the stomach. A back-and-forth twisting motion can help when advancing the dilators through the tissue (**FIG 19**).
- Once the track is sufficiently dilated, insert the smallest dilator through the tube and guide the tube over the wire into the stomach (**FIG 20**).

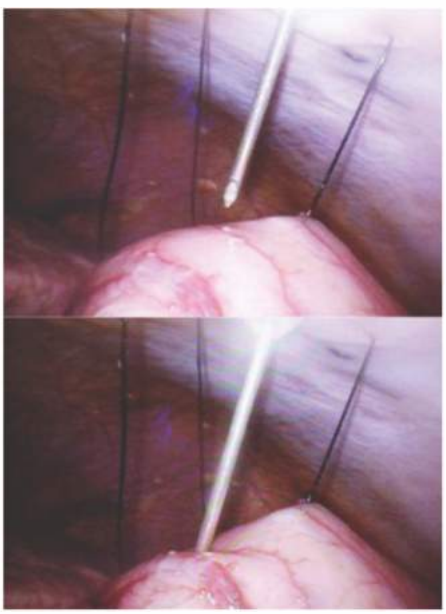


FIG 18 ● The large-bore needle is directed into the stomach through the center of the T-fasteners.

FIG 19 ● The dilator is passed over the wire though the abdominal wall and into the stomach.

FIG 20 ● The smallest dilator is inserted into the G-tube and two are guided over the wire through the tract and into the stomach. The wire and dilator are removed together leaving the tube in place.

- Remove the wire and dilator together. Inflate the balloon port with 18 to 20 mL of water and pull back the tube back so the stomach rests against the abdominal wall. The outer flange should be advanced so that it rests just on the skin. Too much squeeze between the outer flange and intraluminal balloon can result in gastric and/or abdominal wall necrosis (**FIG 8**).
- In a similar manner, gently pull the T-fasteners individually so that the stomach rests just on the abdominal wall and crimp them into position using a needle driver. This will leave small cotton bolsters against the skin that may be removed by cutting the sutures below the bolsters 2 weeks after the procedure (**FIG 21**).

FIG 21 ● The T-fasteners are gently retracted so that the stomach is secured against the abdominal wall and crimped into place.

PEARLS AND PITFALLS

Indications	▪ Be certain that a G-tube best fits the needs of the patient. Frequently, physicians may request a G-tube when in reality the patient needs a jejunostomy tube (J-tube) or vice versa.
Preprocedure planning	▪ Review previous upper abdominal procedures or history of peritonitis that may have scarred another piece of bowel along the proposed track of the G-tube. ▪ Be prepared to sufficiently darken the room for transillumination.
Patient position	▪ Position the patient supine with the entire abdomen exposed to be prepped once a suitable site is identified for tube placement.
Tube site selection	▪ The skin incision should be at least 2 cm inferior to the costal margin. ▪ The gastrotomy site should nicely line up without tension with the site for the tube to course through the abdominal wall.
PEG	▪ Enter slowly with the needle watching for any bubbles in the syringe before the tip of the needle is seen by the endoscopist, which would indicate the traverse of another hollow viscus.
Laparoscopic G-tube	▪ Position the patient supine with the right arm tucked to allow a comfortable working space for the surgeon and the laparoscopic assistant on the right side of the patient.
Open G-tube	▪ Place the second purse-string suture at least 1 cm outside the first so that the gastric wall will intussuscept into the gastric lumen thereby creating a secure track around the tube.
Securing the tube	▪ Do not secure the bolster on the tube too tightly against the skin as it may result in necrosis of the skin or the gastric wall.
Postprocedure care	▪ Leave the tube to gravity drainage initially to decompress any excess gas within the proximal GI tract and to reduce the risk of reflux upon emergence of sedation. ▪ An abdominal binder is helpful for securing the tube and preventing premature or inadvertent removal during patient movement or in a patient with impaired mental status.

POSTOPERATIVE CARE

- For gastric decompression, the tube should be left to gravity drainage via a collection bag. The gastric tube should never be hooked up to low wall suction. The tube does not have a sump port and if suction is applied, it will adhere to the posterior gastric wall and cause suction necrosis, bleeding, and/or perforation.
- Tube feedings may be started the evening of the procedure at a low rate, usually about 10 mL per hour. If the patient tolerates this, he or she can advance by 10 mL per hour every 4 hours until the nutritional goal is reached.
- Care should be taken to avoid the tube catching or pulling while the patient is moving or if the patient's neurologic status is such that he or she can grasp and pull the tube. An abdominal binder or gauze dressing can be used to cover the tube. Hand mittens can be used in the high-risk patient.
- The patient and their caregiver should receive education regarding proper tube care and simple troubleshooting.
- For patients going home with a G-tube for gastric decompression, they should be taught how and when to intermittently vent the tube. This will allow them to not have to keep the tube attached to a drainage bag at all times.

OUTCOMES

- Not applicable

COMPLICATIONS

- Clogged tube
  - A clogged tube can be flushed clear in essentially every case with a small syringe. Due to the laws of hydraulics, the smaller the diameter of the syringe the more pressure that can be generated. We recommend the smallest syringe that will tightly fit into the opening in the tube. When a Foley catheter is used as the G-tube, the entire end of a 3-mL syringe will fit snugly and will often clear the obstruction when flushed with water. Carbonated acidic beverages such as Coke™ may also aid in clearing an obstruction and should be allowed to stay in the tube for an hour or more before attempting to flush the tube.
- Dislodged tube
  - It is imperative that patients and caregivers are taught to reinsert the tube immediately if they become dislodged so that the tract does not close. If they are unable to reinsert, then they should immediately go to an emergency department where a smaller catheter could be temporarily advanced into place preserving the tract, which could be later dilated and the proper tube placed.
  - If a tube is reinserted easily without resistance and flushing with water causes no discomfort, the tube may be used per the patient's routine without a confirmational radiologic study.
  - However, if the replacement is complicated or if there is discomfort with flushing, the tube position should be checked to ensure proper positioning.
- Fractured tube
  - If a tube is fractured with or without leakage, it may be temporarily patched with waterproof occlusive tape such as electrical tape or Duct® tape. The tube should be electively exchanged for a new tube during a regular clinic appointment. If the tube is new or in complex scenarios, it may need to be exchanged over a glide wire by a gastroenterologist, interventional radiologist, or a surgeon.
- Abdominal wall abscess
  - Tube site infections rarely lead to significant abscess formation, but if this occurs, it should be treated with incision and drainage leaving the wound open as with any infected open wound. The tube may need to be removed to allow the infection to heal.
- Tube placed through another piece of bowel
  - If the tube has penetrated the colon or small bowel, a surgical consult is indicated.
    - If the tube remains essential to the patient's care, then proceed to operating room (OR) for laparoscopic or open abdominal exploration with repair of the injury and placement of an open G-tube.
    - If the tube has been in place and functional for months but is no longer necessary, the tube may be removed realizing there is a potential need for repair of the gastric to colon or small bowel fistula. It has been our experience that most of these gastroenteric fistulas will close on their own or prove to be asymptomatic and inconsequential.
- Gastric outlet obstruction
  - Gastric outlet obstruction is most frequently associated with an overinflated balloon. When this is suspected, decreasing the amount of fluid in the balloon and being certain that the balloon is up against the gastric wall instead of free floating within the gastric lumen where it could be passed through the pylorus are important aspects to consider.

REFERENCE

1. Foutch GP, Talbert GA, Waring JP, et al. Percutaneous endoscopic gastrostomy in patients with prior abdominal surgery: virtues of the safe tract. *Am J Gastroenterol*. 1988;83:147.

Chapter 17 Feeding Jejunostomy

John Daniel Hunter, III John Roland Porterfield, Jr.

DEFINITION

- A jejunostomy tube (J-tube) is a flexible soft tube that connects the intraluminal jejunum with the outside world through the abdominal wall. The main function is to provide long-term access to the proximal gastrointestinal (GI) tract for enteral nutrition when oral intake is not possible or inadequate.
- A J-tube can be placed through an open or a laparoscopic approach. Often, they are placed in conjunction with a larger operation when it is anticipated that the patient will not progress to adequate oral intake in a timely fashion during the early postoperative course. The J-tube affords the advantage of early enteral nutrition even when the upper GI tract cannot be used.

PATIENT HISTORY AND PHYSICAL FINDINGS

- The history and physical exam should focus on the indication for enteral access J-tube, hemodynamic stability of the patient, current functional status of the GI tract, and previous surgeries.
- Patients who are hemodynamically unstable generally should not undergo elective J-tube placement.
- The patient should be assessed for a functional GI tract distal to the ligament of Treitz (LOT) and should not have evidence of mechanical bowel obstruction, adynamic ileus, GI ischemia, or peritonitis.
- A thorough surgical history is imperative prior to J-tube placement. Preexisting tubes, drains, mesh from previous hernia repairs, or stomas may require alternative planning. An extensive abdominal surgical history may prohibit safe laparoscopic J-tube placement and an open technique may be employed.

IMAGING AND OTHER DIAGNOSTIC STUDIES

- Radiologic workup is generally not necessary for J-tube placement. However, it is often the case that patients have had a plethora of upper abdominal imaging for other reasons that may provide valuable information or clues to previous unknown surgical procedures or unexpected anatomic findings.

SURGICAL MANAGEMENT

Preoperative Planning

- The patient should be NPO for a minimum of 6 hours prior to the procedure.
- Antibiotics should be given within 30 minutes of incision to reduce the incidence of abdominal wall infection around the tube site. First-generation cephalosporins are our preference when not contraindicated by the patient's known allergies.
- Generally, the jejunostomy feeding tube will exit the patient's abdomen in the left upper quadrant (LUQ). As mentioned previously, preexisting tubes, drains, implanted mesh, and stomas may require tube site adjustment.

Positioning

- For an open J-tube, the patient should be placed in the supine position. Usually, this procedure is done in addition to a larger procedure and thus the patient is already positioned accordingly.
- For a laparoscopic J-tube, the patient should be positioned supine with the right arm tucked to allow for adequate room for the surgeon and assistant to both work comfortably on the right side.
- It is important to be certain the patient is secured to the bed for intraoperative bed tilting, which may assist with exposure of the proximal jejunum.

OPEN JEJUNOSTOMY TUBE PLACEMENT

Equipment

- The type of tube used for the feeding jejunostomy is decided upon by the surgeon to optimize the longevity, comfort, and function for the patient. There are many commercially available tubes that vary widely in features, availability, and cost.
- If a tube is being placed as part of a larger procedure and will likely be removed within 6 to 8 weeks, a standard 14-French (Fr) "red rubber Robinson" catheter is economical, time tested, and very functional.
- The most important tube characteristics are that it should be soft, pliable, and preferentially not containing a balloon unless it is a small balloon, less than 5 mL, and specifically designed to be placed within the jejunum. Balloon catheters within the small bowel are a frequent cause of recurrent bowel obstructions and should be avoided.
- The enteral end should be free of sharp edges that could damage the mucosa or promote migration or perforation. The holes should be of adequate size to allow feedings to pass through with minimal risk of clogging. The external portion should be tapered up to allow standard feeding pump tubing to be attached.
- At our institution, a 12- to 18-Fr "red rubber Robinson" catheter is often used. Extra holes can be cut into the distal portion to allow tube feeds to flow with less resistance. These holes may be created by folding the tube over and cutting the corner of the fold (**FIG 1**). Alternatively, the tube from a laparoscopic jejunostomy kit can be used (Flexiflo Lap J™ laparoscopic jejunostomy kit by Abbott Nutrition).

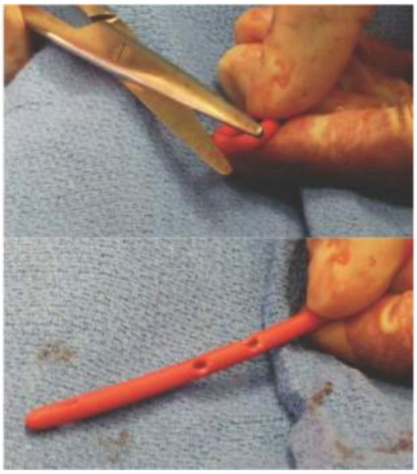


FIG 1 ● Cutting extra holes in a red Robinson tube will reduce resistance of flow to the tube feeds.

Incision

- If the open J-tube placement is being done as a stand-alone operation, the incision should be centered in the midline at the level of the LOT.
- The supraumbilical vertical midline incision should be carried through the linea alba with enough length to locate the LOT, mobilize 20 to 30 cm of jejunum, and allow for fixation of the jejunal segment to the peritoneum of the abdominal wall around the tube exit site. If there are minimal adhesions, this incision may be kept relatively small, 5 to 7 cm, and the majority of the operation can be done on eviscerated jejunum (FIG 2).
- A limitation of an incision that is too small is that it may prove difficult to fix the bowel to the abdominal wall through the small incision. Exposure of this step should not be compromised in anyway to avoid lengthening the incision.

Mobilization of Jejunum

- Once the peritoneal cavity has been entered, the omentum and transverse colon are retracted cephalad to expose the small bowel. A segment of small bowel is chosen in the LUQ and traced proximally until the LOT is identified.
- Once the LOT is identified, the small bowel is examined all the way to the ileocecal valve to ensure no occult pathology, obstruction, or torsion is present.
- The tube insertion site is chosen where the tube will pass through the abdominal wall. This will generally be in the LUQ. The surgeon must ensure the chosen segment of jejunum will reach the parietal surface of the abdominal wall without any tension or torsion. Lysis of adhesions may be needed to make sure the jejunum can reach the abdominal wall without tension.
- Placement of atraumatic clamps on the left side of the fascia allows the abdominal wall to be retracted anteriorly for exposure of tube placement. While keeping retraction, a strong fine clamp is passed from inside the abdomen through the point chosen in the abdominal wall. A 3-mm skin incision, at the clamp exit site, is created and the tube is grasped and the distal end is pulled through the abdominal wall into the peritoneal cavity. Both ends of the tube are clamped together and positioned out of the way (FIG 3).

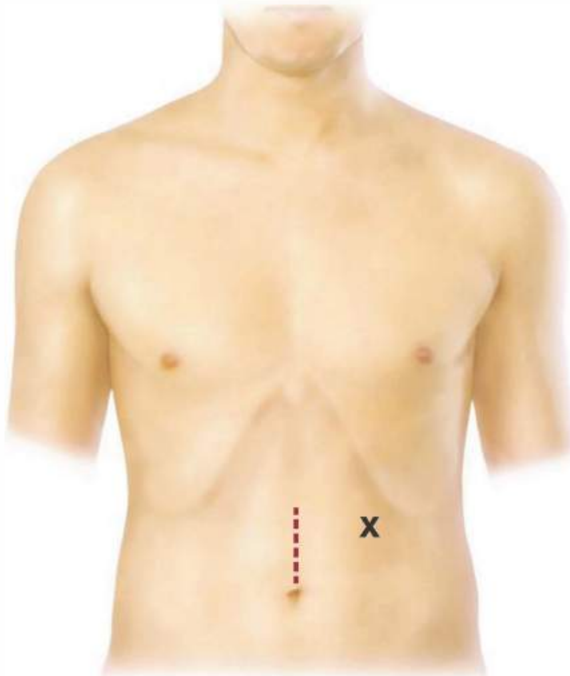


FIG 2 ● Open incision diagram with tube exit site marked.

Enterotomy and Placement of the Jejunostomy Tube

- A segment of jejunum approximately 30 cm from the LOT is chosen as the site for the J-tube placement. This portion of jejunum can be eviscerated for the next steps if a smaller incision has been used. Using a 3-0 nonabsorbable or absorbable suture, place an approximately 4-mm purse-string suture in a box formation on the antimesenteric side of the small bowel (FIG 4). A double purse-string stitch may be used for additional security (FIG 5).
- At this point, it is essential to note the proximal and distal ends of the jejunum and to ensure the orientation is maintained through the entire procedure.
- Using cautery, create a small enterotomy in the center of the purse-string suture. It is helpful to grasp the bowel by the mesentery during this step. Inadvertent cautery injury to the opposite side of the small bowel can be avoided by cutting the serosa and muscularis with the cautery but "popping" into the lumen with a fine clamp (FIG 5).
- Place the distal end of the feeding tube through the enterotomy into the lumen and direct it distally. The catheter is advanced until at least 10 cm is intraluminal. It can be advanced further if there is an excessive amount of tubing left externally (FIG 6).
- Tie down the purse-string suture, taking care not to overtighten and occlude the tube (FIG 7).

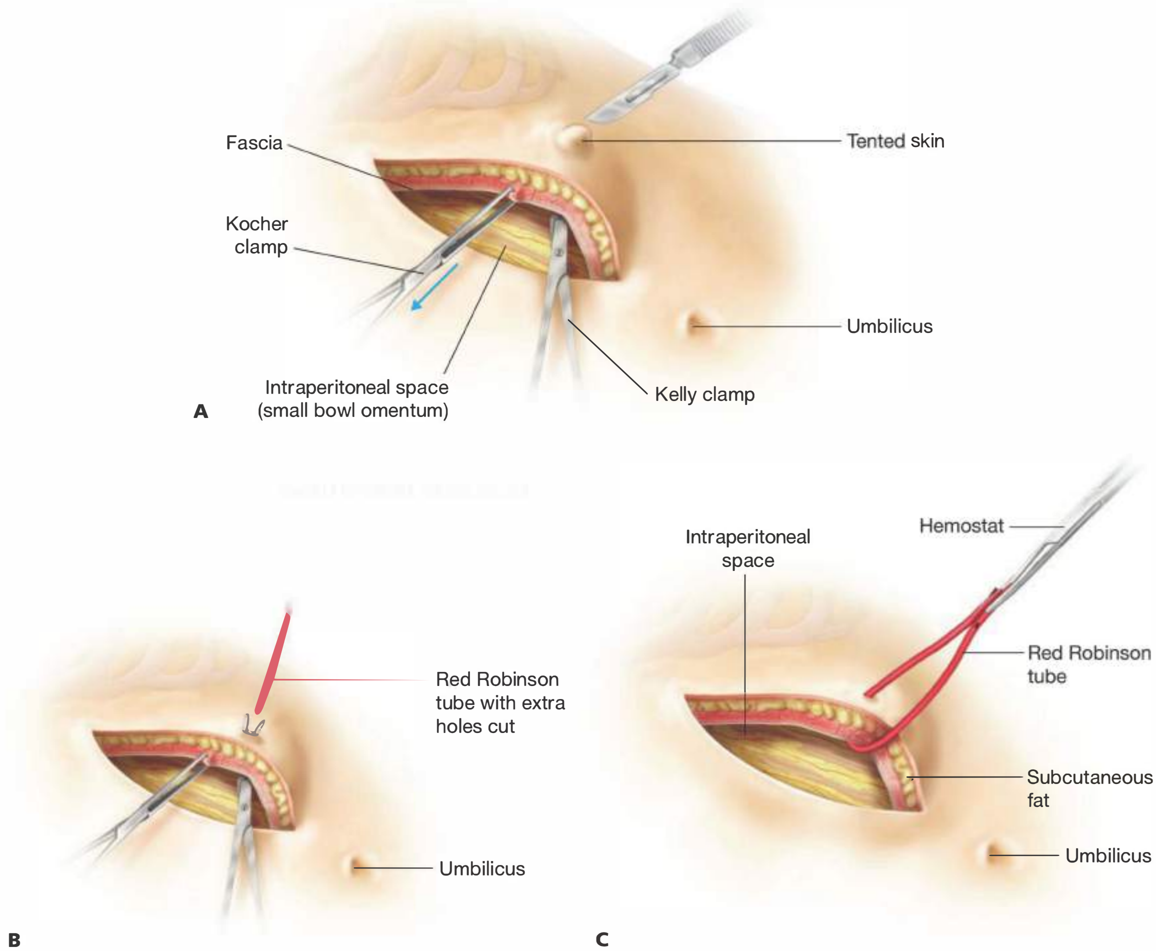


FIG 3 ● Facial retraction anterior and midline with stab incision being made for the feeding tube.

FIG 4 ● Placement of purse-string stitch on antimesenteric jejunum.

FIG 5 ● The enterotomy is made with a cautery and then a hemostat is used to "pop" into the lumen. Note the double purse-string stitch used.

- The tube entry sight is then imbricated using a three-point triangular technique (**FIG 8**).
- Next, a Witzel tunnel is created. Starting at the enterotomy, the small bowel is imbricated over the feeding tube using interrupted 3-0 absorbable suture on a taper needle (**FIG 9**) for a distance of about 5 cm. These are seromuscular bites spaced approximately 5 to 10 mm apart, ensuring the tube is not exposed. Care should be taken not to place the bites too far from the tube, as this will draw more bowel into the Witzel tunnel and narrow the jejunal lumen (**FIG 10**).
- The jejunal segment must now be secured to the parietal peritoneum. This will allow the formation of a tract so that if the tube is inadvertently removed, it can be replaced without reentering the abdomen. This should be done in a way that the bowel is flush with the abdominal wall. Four "tacking" sutures of absorbable 3-0 suture can be placed around the tube exit site. The first is placed lateral to the tube, away from the operating surgeon. A seromuscular bite is taken and then a bite of peritoneum is taken at the corresponding location in the abdominal wall (**FIG 11**). Start with the lateral (furthest) suture first, then superior, inferior, and finally medial. Secure each suture with a clamp after it is placed and do not tie until they are all appropriately placed.
- Once all four sutures have been placed, it is best to tie them in the order they were placed (**FIG 12**). An additional tacking suture may be placed 5 to 10 cm distally to secure a longer segment of bowel to the abdominal wall. This may help prevent torsion on the bowel around a single fixed point. The small bowel should now be adherent to the LUQ abdominal wall (**FIG 13**).
- The external portion of the tube should be secured to the skin using a 2-0 nonabsorbable monofilament suture (**FIG 14**).
- The abdomen is then closed in layers.
- The tube may be capped or placed to gravity drainage via a bag. Covering the tube with a dressing and tape or abdominal binder will help prevent it from being inadvertently dislodged during patient movement.

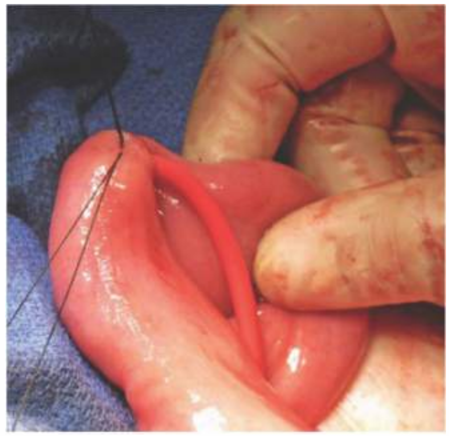


FIG 7 ● Tying down purse string to secure the feeding tube.

FIG 6 ● Directing end of feeding tube into distal jejunum.

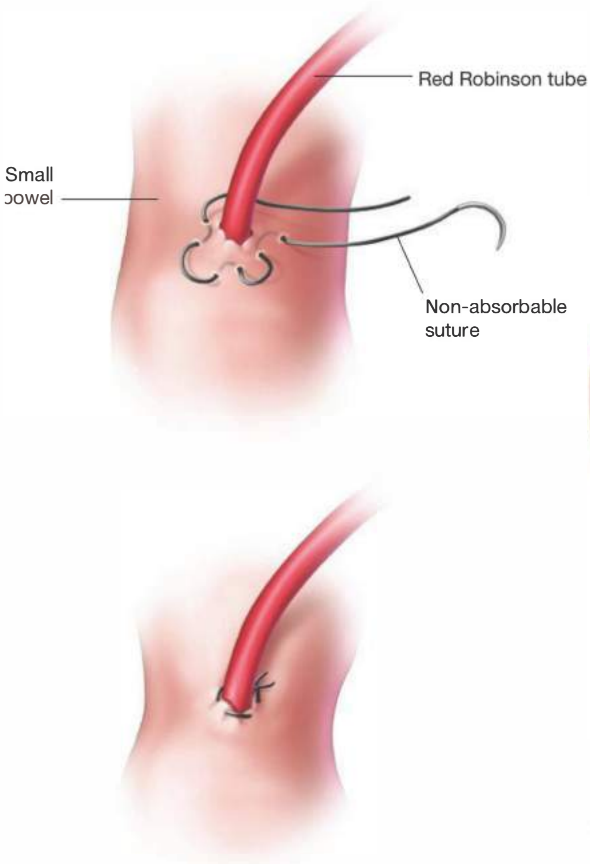


FIG 8 ● Triangle stitch to imbricate the tube entry site.

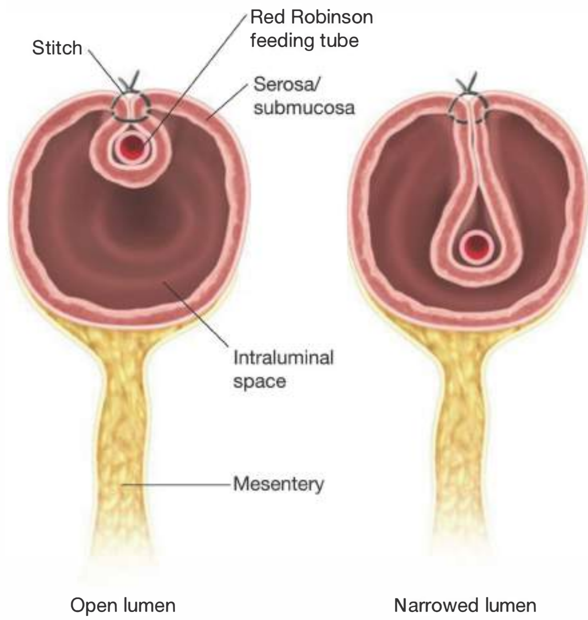


FIG 10 ● Cross section of Witzel tunnel. The **left** shows the correct placement of sutures with adequate lumen diameter. The **right** shows a narrowed lumen from suture bites placed too far from the tube.

FIG 9 ● Creation of the Witzel tunnel.

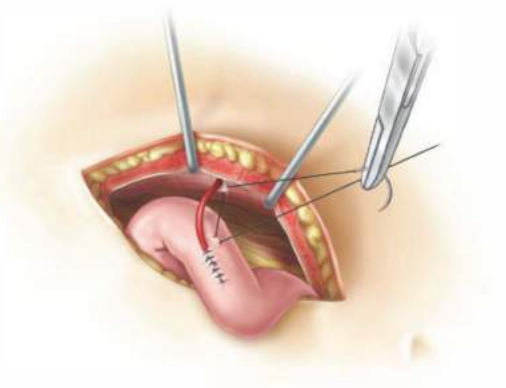


FIG 11 ● Placement of first tacking suture.

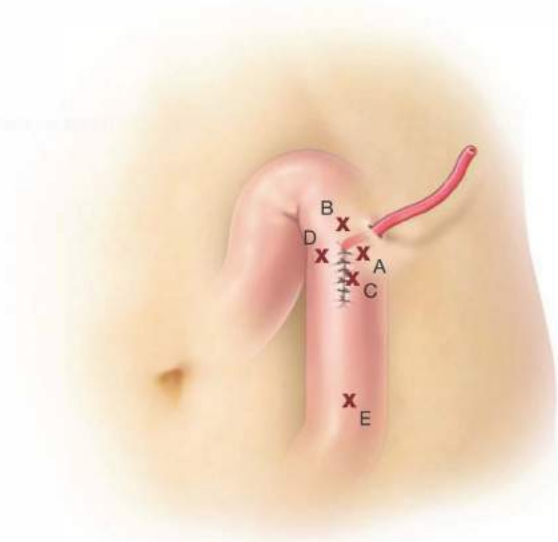


FIG 12 ● Final appearance of bowel attached to the abdominal wall. The sutures should be placed in order from *A* to *E*.

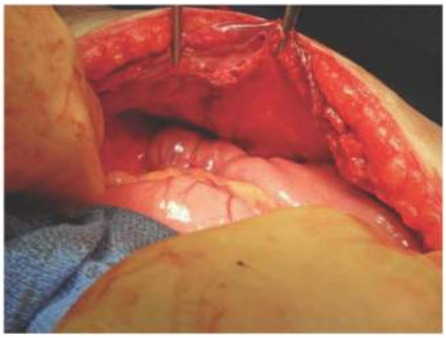


FIG 13 ● Final view of small bowel fixed to abdominal wall after the four tacking sutures have been placed. Note the feeding tube is not visible.

FIG 14 ● Securing the external portion of the tube to the abdominal wall.

LAPAROSCOPIC JEJUNOSTOMY

Equipment and Port Placement

- Several commercially available laparoscopic jejunostomy kits are available. We use the Flexiflo Lap J™ laparoscopic jejunostomy kit by Abbott Nutrition. This section will describe J-tube placement using this kit. The steps described can be modified for other kits, and the package inserts for each kit should be read as they often contain pertinent pearls for success.
- A standard laparoscopic setup including a 5-mm 0-degree or 30-degree laparoscope and two to three 5-mm ports is used.
- Port placement should triangulate toward the proposed tube exit site in the LUQ (FIG 15). The J-tube site should be at least two fingerbreadths below the left costal margin at approximately the midclavicular line.

Jejunal Mobilization and Tube Placement

- Once the ports are placed, the abdomen should be inspected to rule out occult pathology or evidence of a distal obstruction.
- The upper port should be used to retract the colon and omentum cephalad. The middle port is used for the camera. The lower port should be used to expose the small bowel.

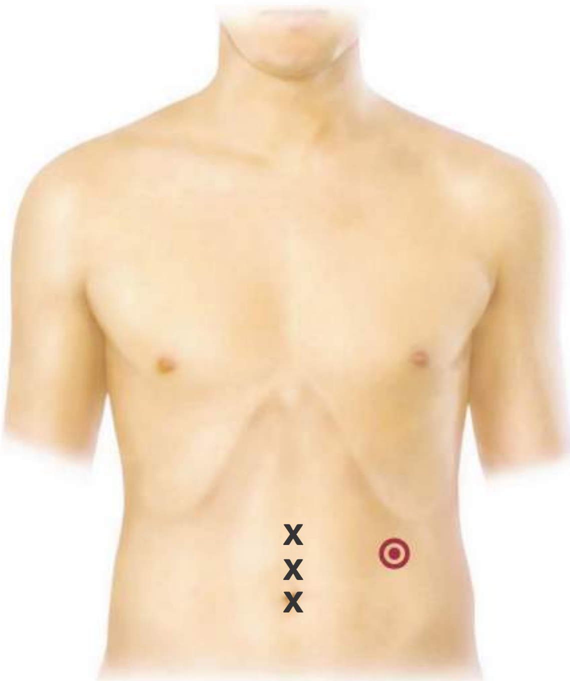


FIG 15 ● Port placement diagram for laparoscopic J-tube. The tube site is represented by the target.

- To identify the LOT, the transverse colon is retracted anteriorly as the patient is placed in Trendelenburg position and the mesentery of the transverse colon is followed toward its origin. The proximal most portion of the jejunum can be seen exiting the retroperitoneum at the LOT. Alternatively, if this exposure is unable to be obtained, the small bowel may be followed in the LUQ until the LOT is reached (FIG 16).
- Once the proximal jejunum is convincingly identified, it should be traced distally 20 to 30 cm to identify the tube site. Once the tube site is identified, it is essential to keep the proper orientation of the bowel throughout the completion of the procedure.
- The tube site on the abdominal wall should be chosen by identifying the area on the inner abdominal wall where the selected jejunal segment most easily reaches. The bowel should be free of tension at this point. The point on the abdominal wall should also be at least 2 cm below the costal margin. Placement of a fine needle through the abdominal wall into the peritoneal cavity often facilitates identifying and maintaining the best placement (FIG 17).
- The T-fasteners supplied in the kit are placed next. They are placed in a diamond configuration around the tube entry site, marked with the fine needle. They should be placed 2 cm from the needle at the skin level, pass through the fascia, and exit approximately 1 cm from the needle in the peritoneal cavity (FIG 18).
- To start, the assistant grasps the chosen segment of jejunum and pulls it to the tube site, holding it in proper orientation. The first T-fastener is passed through the superior point of the diamond. Once intraabdominal, the needle/T-fastener is advanced through the bowel wall. It is easy to inadvertently pass the needle through the "back wall" of the bowel at this point. The assistant should orient the bowel so that the mesenteric side is as far from the needle as possible during placement.
- The needle should be advanced to the 2-cm (double) mark and then deployed (FIG 19). Pull back on the fastener to ensure the bowel catches, retract it to the abdominal wall, and then apply a clamp to the external portion of the suture to keep the bowel in position.
- The next three T-fasteners are placed in a similar manner. The far lateral one should be deployed after the superior one, followed by the inferior, and then finally the medial fastener.

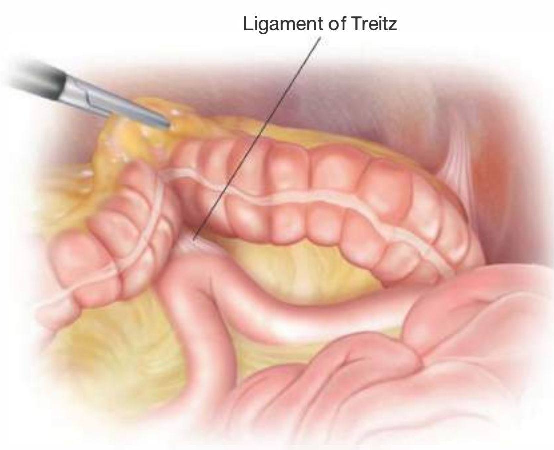


FIG 16 ● The small bowel is followed in the LUQ to the LOT.

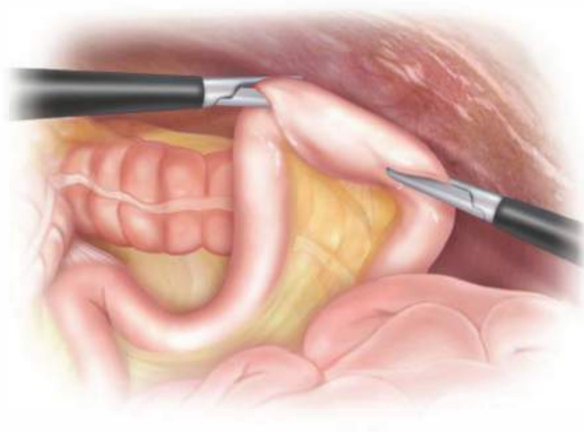


FIG 17 ● There should be no tension when the small bowel is retracted toward the chosen area on the abdominal wall. A needle can be placed through the abdominal wall to easily mark the area from the peritoneal cavity.

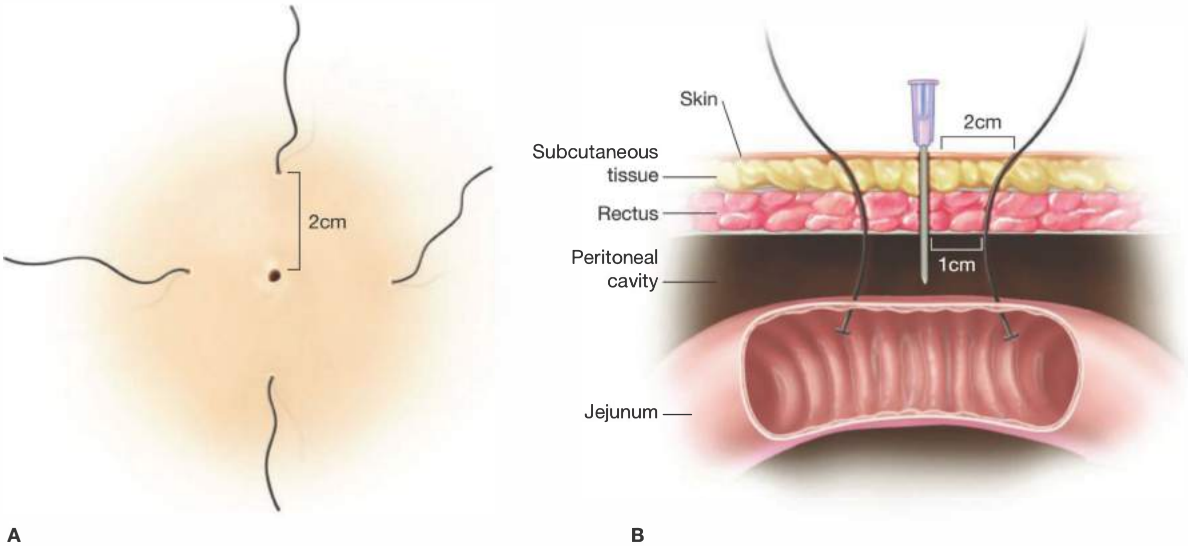


FIG 18 ● **A.** Diamond configuration of T-fasteners around the tube entry site as seen on the abdominal wall. **B.** Cross-sectional view of trajectory of T-fasteners as they pass through the abdominal wall. Note they enter 2 cm from the tube site at the skin and exit 1 cm from the tube site at the peritoneum.

- At this point, the antimesenteric side of the bowel should be almost flush with abdominal wall in four places (**FIG 20**). A small gap should be left for the next step.
- The 18-gauge needle is then advanced into the small bowel in the center of the four T-fasteners. Saline, air, or a brief insufflation with carbon dioxide from the laparoscopic insufflator will ensure that the needle is intraluminal. A fluid wave should be seen passing though the bowel. If the needle is submucosal, a local infiltration of saline in the bowel wall will be seen, but it will not pass as a fluid wave within the bowel.
- The wire is then advanced through the needle into the bowel while the assistant uses a blunt grasper to direct the wire into the distal limb of the jejunum. The wire can coil in the bowel easily during this step. This may be avoided if the assistant stretches the distal limb as the wire is passed (**FIG 21**).

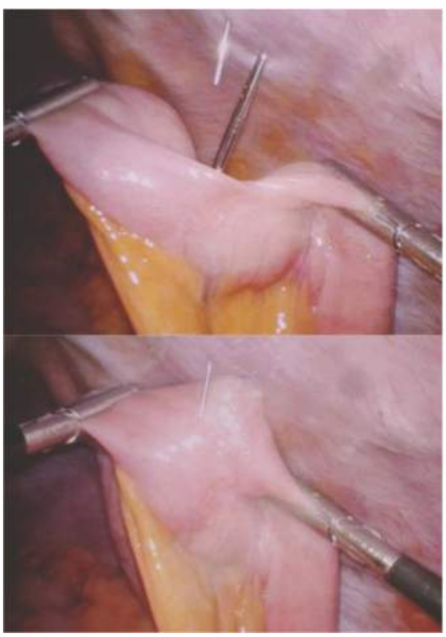


FIG 19 ● The needle is advanced into the small bowel up to the double marking and the T-fastener is then deployed. Gentle traction after deployment will ensure the T-fastener has engaged the bowel properly.

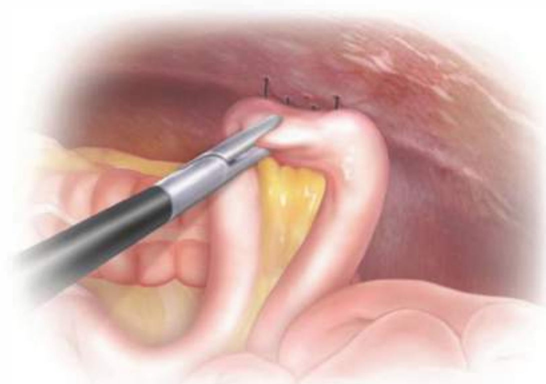


FIG 20 ● A view of the bowel after all four T-fasteners have been placed. Note the small gap to allow visualization during placement of the J-tube.

FIG 21 ● As the wire is being advanced, the assistant can provide gentle traction on the distal bowel to allow the wire to pass easily.

- The needle is then removed.
- Pull up on the fasteners gently so that the jejunal segment is anchored to the abdominal wall. Pull just enough that the bowel makes contact with the wall. The wire should not be visible at this point.
- A skin nick is made at the wire entry site, and the dilator along with the peel-away sheath is passed over the wire, through the abdominal wall, and into the distal limb of the small bowel (FIG 22).
- Care must be taken during this step so that the opposite side of the small bowel is not perforated and that the dilator and sheath should easily follow the path of a gently curved wire.
- The wire and dilator are then removed.
- The J-tube is passed in to the distal limb through the peel-away sheath. The tube should be at least 10 cm into the jejunum. Avoid leaving too much of the tube externally to reduce the risk of it being inadvertently pulled out.
- While an assistant holds the tube in place at the skin, the sheath is cracked and removed by peeling it apart slowly, making certain that the J-tube remains in proper position (FIG 23).
- Inject 10 mL of saline or air through the small port to ensure the tube is patent. This also again allows for conformation that the tube is in fact intraluminal. A fluoroscopy study could be used with similar contrast to that used for a cholangiogram if there is any question regarding the intraluminal nature of the tube.

FIG 22 ● The dilator and sheath are passed over the wire, through the abdominal wall, and into the jejunal lumen.

- At this point, the fasteners, which were pulled up and held gently to anchor the jejunal segment to the abdominal wall, may be secured. Crimping the fasteners on the suture just above the skin bolsters secures them in place (FIG 24). Care must be taken to avoid these fasteners being pulled too tight as this could lead to erosion through the bowel. The tube should not be visible at this point from inside the abdominal cavity.

FIG 23 ● After the dilator and wire are removed, the J-tube is passed through the sheath and into the jejunum. The sheath is then peeled away while the tube is held in place.

- With the T-fasteners entering the skin 2 cm from the tube, there is plenty of room to slide the flange down to the skin and secure it with one or multiple sutures. Be careful not to inadvertently pull the tube out at this step.
- A final evaluation with the laparoscope should reveal no tension or torsion on the bowel as it rests on the anterior abdominal wall.
- The trochar sites are closed in standard fashion and the procedure is complete.
- An abdominal dressing with tape or abdominal binder is placed over the tube to avoid it snagging during patient transport.

FIG 24 ● The T-fasteners are crimped into place at the skin level.

PEARLS AND PITFALLS

Indications	■ Be certain that a J-tube best fits the needs of the patient. Frequently, physicians may request a J-tube when in reality the patient needs a gastrostomy tube (G-tube) or vice versa.
Preprocedure planning	■ Review previous upper abdominal procedures or history of peritonitis that may have scarred another piece of bowel along the proposed track of the J-tube.
Patient position	■ Position the patient supine with the entire abdomen exposed and prepped and draped.
Open G-tube	■ Place the triangle suture and the imbricating sutures carefully to avoid excessively narrowing the lumen of the bowel.
Tube site selection	■ The tube site should be at least 2 cm inferior to the costal margin. ■ Keeping midline retraction on the fascia with clamps while making the incision through the abdominal wall will ensure that the tube does not get kinked as it traverses the abdominal wall once the fascia is closed.
Laparoscopic J-tube	■ Position the patient supine with the right arm tucked to allow a comfortable working space for the surgeon and the laparoscopic assistant on the right side of the patient. ■ Take special care to avoid penetration of the back wall of the jejunum with the needle. ■ Ensure, without question, that the wire and the tube pass intraluminally.
Securing the tube	■ Do not slide the bolster on the tube down tightly against the skin as it may necrose the skin or lead to pulling of the base of the tube through the jejunal wall and into the peritoneum.
Postprocedure care	■ An abdominal binder is helpful for securing the tube and preventing premature or inadvertent removal during patient movement or in a patient with impaired mental status.

POSTOPERATIVE CARE

- Tube feedings can be started the evening of the procedure at a "trophic" or low rate, usually about 10 mL per hour. If the patient tolerates this, they can be advanced by 10 mL per hour every 4 hours until the nutritional goal is reached.
- Care should be taken to avoid the tube catching or pulling while the patient is moving or if the patient's neurologic status is such that they can grab and pull the tube. An abdominal binder or gauze dressing can be used to cover the tube. Hand mittens can be used in the high-risk neurologic patient.
- The patient and his or her caregiver should receive education regarding proper tube care and simple troubleshooting.

OUTCOMES

- Not applicable

COMPLICATIONS

- Clogged tube
  - A clogged tube can be flushed in essentially every case with a small syringe. Due to the laws of hydraulics, the smaller the diameter of the syringe the more pressure. We recommend the smallest syringe that will tightly fit into the opening in the tube. Carbonated acidic beverages such as Coke™ may also aid in clearing an obstruction when they are allowed to sit within the tube for an hour or more.
- Dislodged tube
  - It is imperative that patients and caregivers are taught to reinsert the tube immediately if it becomes dislodged so that the tract does not close. If they are unable to reinsert, then they should immediately go to an emergency department where a smaller catheter could be temporarily advanced into place, preserving the tract that could be later dilated, and the proper tube placed.

- If a tube is reinserted easily without resistance and flushing with water causes no discomfort, the tube may be used per the patient's routine without a conformational radiologic study.
- However, if the replacement is complicated or if there is discomfort with flushing, the tube position should be checked to ensure proper positioning.
- For tubes that have been in place for more than 1 month, it is exceptionally unlikely that the tube would not reenter the same bowel and rest in the same functional position where it was dislodged from.

- Fractured tube
  - If a tube is fractured with or without leakage, it may be temporarily patched with a waterproof occlusive tape such as electrical tape or Duct® tape. This tube should be electively exchanged for a new tube during a regular clinic appointment. If the tube is new or in complex scenarios, it may need to be exchanged over a glidewire by a gastroenterologist, interventional radiologist, or a surgeon.
- Abdominal wall abscess
  - Tube site infections rarely lead to significant abscess formation, but if this occurs, it should be treated with incision and drainage, leaving the wound open as with any infected open wound.
- Small bowel obstruction
  - Small bowel obstruction is most frequently caused by a balloon on the J-tube or from torsion at the tube insertion site.
  - When an obstruction is evident, any fluid in a balloon should be removed and the bowel obstruction treated with nasogastric decompression as with any bowel obstruction.
  - If this does not resolve the obstruction, a computed tomography (CT) scan with oral contrast administered 2 hours prior to the study may be of assistance in assessing torsion of the bowel around the tube insertion site.
  - If torsion is confirmed, an operative exploration either in a laparoscopic or open approach is required to relieve the obstruction.

Chapter 18 Laparoscopic Gastric Bypass

Elizabeth A. Dovec Ronald H. Clements

DEFINITION

- Obesity is a medical condition in which excess body fat has accumulated to the extent that it may have an adverse effect on health, leading to reduced life expectancy and/or increased health problems.[1]
- The body mass index (BMI) is a measurement obtained by dividing a person's weight in kilograms by the square of the person's height in meters.[2]
  - BMI greater than or equal to 30 kg/m^2 is *obesity*.
  - BMI greater than or equal to 35 to 39.9 kg/m^2 is *severe obesity*.
  - BMI greater than or equal to 40 to 49.9 kg/m^2 is *morbid obesity*.
  - BMI greater than or equal to 50 kg/m^2 is *super obesity*.
- Obesity is a leading preventable cause of death worldwide, with increasing prevalence in adults and children. Obesity is one of the most serious public health problems of the 21st century.[3]
- The World Health Organization (WHO) predicts that overweight and obesity may soon replace more traditional public health concerns such as malnutrition and infectious diseases as the most significant cause of poor health.[4] Before the 20th century, obesity was rare[5]; however, in 1997, the WHO formally recognized obesity as a global epidemic.[6] As of 2008, the WHO estimates that at least 500 million adults (>10%) are obese.[7]

PATIENT HISTORY AND PHYSICAL FINDINGS

- Patients should undergo comprehensive preoperative evaluation and have multidisciplinary support, with attention to psychological issues and dietary intake, for optimum outcome.
- A thorough history should be performed prior to treatment, including a detailed past medical and surgical history, present medications and allergies, family history, social history, and discussions at previous attempts at weight loss.
- Obesity-related comorbidities include, but are not limited to, hypertension, dyslipidemia/hyperlipidemia, diabetes mellitus, obstructive sleep apnea, chronic obstructive pulmonary disease (COPD), congestive heart failure (CHF), coronary artery disease (CAD), vascular disease, renal failure, urinary stress incontinence, polycystic ovarian syndrome (PCOS), back pain, joint pain, pseudotumor cerebri, and anxiety/depression.

SURGICAL MANAGEMENT

- The goals of the surgical treatment of obesity include
  - Improving health
  - Improving quality of life
  - Increasing the life span
- The American Society of Metabolic and Bariatric Surgery (ASMBS) and National Institutes of Health (NIH) have reached several conclusions about bariatric surgery and formulated a consensus statement. These organizations agree that bariatric surgery is the most effective treatment for morbid obesity.
- Gastric bypass has been the gold standard in the treatment of the morbidly obese (BMI of ≥40 kg/m^2) and severely obese (≥35 to 39.9 kg/m^2) patients with obesity-associated comorbidities. It is the most frequently performed bariatric procedure in the United States.
- A Roux-en-Y gastric bypass is a restrictive and malabsorptive procedure.

Preoperative Planning

- Preoperative education is a vital part to the success of the patient. Patients must be instructed on what to expect both preoperatively and postoperatively.
- All patients at our program undergo a surgical evaluation, medical clearances, insurance requirements, psychological evaluation, nutrition education, online information seminars, and attend a support group prior to their surgery.
- A detailed bariatric diet guideline packet is provided to all patients describing each diet phase. Documented understanding of the dietary expectations is imperative.
- All medications are reviewed and anticoagulation discontinuation is discussed, as applicable.
- Instruction on early ambulation beginning the afternoon of surgery and continuing every 1 or 2 hours while awake thereafter
- Sequential compression devices (SCDs) are on and verified to be functioning prior to the induction of anesthesia. Routine prophylactic subcutaneous anticoagulation administration is not done unless the patient has a known prior thromboembolic event or the procedure is expected to take longer than 2 hours.

Positioning

- The patient is placed on the table in supine position. After satisfactory anesthesia had been administered, the patient is first secured to the bed. A thick, wide strap is placed tightly above the knees and padded well. Two pads are placed under the patient's heels. A footboard is pushed firmly to the patient's feet allowing the feet to turn out slightly but being cognizant not to bow the knees (**FIG 1**).
- The left arm is left out at a 75-degree angle and secured to the arm board with a gauze wrap. If the patient's body habitus allows, the right arm is ideally tucked at the side. The bed is positioned down as low as possible.
- A standing stage is placed on the patient's right side to be used by the operating surgeon. The assisting surgeon stands on the patient's left side.
- A 34-Fr gastric lavage tube is placed in the patient's stomach and allowed to drain. A glove may be placed at the end of the lavage tube to prevent spillage of gastric contents. No other devices except the gastric lavage tube and endotracheal tube should be in the patient's mouth.

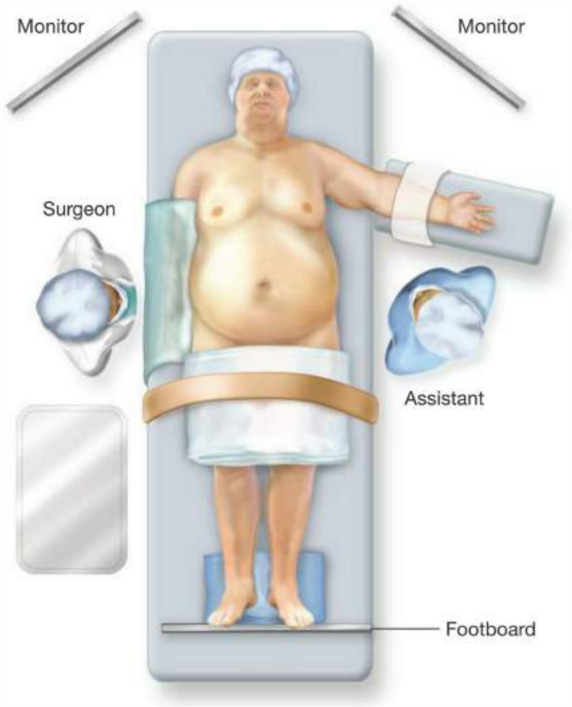


FIG 1 ● Patient positioning.

PLACEMENT OF INCISIONS

- Sixteen centimeters is measured down in the left paramedian position. The skin and underlying fascia is injected with local anesthetic, and a 10-mm visual port is inserted through the left rectus sheath, identifying all layers of the abdominal wall. Pneumoperitoneum is then established. An inspection of the abdomen and pelvis is then performed ensuring there was no injury from the initial trocar placement.
- The remaining five ports are then placed. The first 5-mm trocar is placed just inferior to the xiphoid process and to the left of the falciform for liver retraction. A second 5-mm trocar is placed approximately 2 cm to the right and inferior to the first 5-mm trocar placement. This 5-mm right paramedian port is also placed to the left of the falciform. A 12-mm right paramedian trocar is placed to the left of the falciform approximately one handbreadth from the second 5-mm trocar. A 5-mm left subcostal trocar is placed 2 cm below the costal margin. A final 5-mm trocar is placed 1 or 2 cm below the level of the initial port, as far lateral as possible (FIG 2).

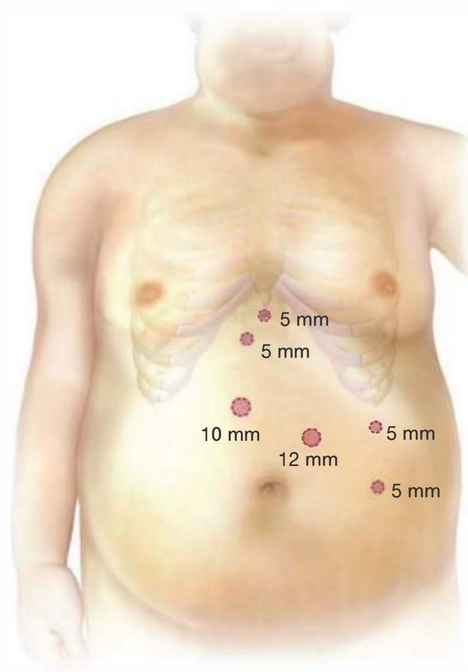


FIG 2 ● Port placement.

LIVER BIOPSY

- A needle biopsy of the liver is obtained because blood tests do not accurately predict the presence, absence, or degree of histologic changes due to fatty liver disease. The liver is elevated by two bowel graspers placed through the left lateral ports to ensure the biopsy needle does not go through the liver and cause injury to underlying structures. Two core biopsies are obtained from the left lateral segment of the liver for pathologic examination for the diagnosis and staging of nonalcoholic fatty liver disease (NAFLD) and nonalcoholic steatohepatitis (NASH).

LIVER RETRACTION

- The patient is placed in full reversed Trendelenburg position. The liver is retracted with a locking Allis grasper clamp placed through the subxiphoid 5-mm port and secured to the diaphragm just anterior to the gastroesophageal (GE) junction (**FIG 3**).

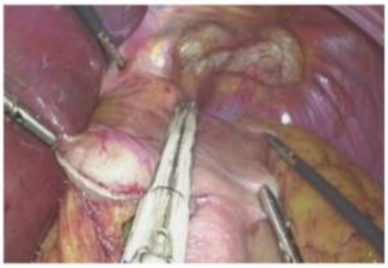


FIG 3 ● Liver retraction and vertical 60-mm stapler.

GASTRIC POUCH CREATION

- With the gastric lavage tube retracted into the esophagus by the anesthetist, the angle of His is exposed and dissected with an ultrasonic dissector.
- Identification, dissection, and primary posterior repair of a hiatal hernia is done at this time, if necessary. Five centimeters is measured down from the GE junction along the lesser curve where the lesser sac is entered immediately adjacent to the lesser curve of the stomach using the ultrasonic dissector to divide branches of the left gastric artery.
- A 45-mm laparoscopic stapling device with appropriate-sized staples is oriented transversely to the lesser curve and fired.
- The 34-Fr gastric lavage tube is advanced to abut this newly placed horizontal staple line. Additional firings of laparoscopic stapling devices are placed parallel to the lavage tube. Complete transaction of the stomach and hemostasis are ensured by inspecting the entire staple line. Once divided, the gastric lavage tube is retracted back into the esophagus.
- The retrogastric and pancreatic adhesions are freed using the ultrasonic dissector to increase pouch mobility (**FIG 4**).

FIG 4 ● Completed pouch.

IDENTIFICATION OF THE LIGAMENT OF TREITZ

- The table is taken out of reversed Trendelenburg and placed in the supine position. The omentum is retracted cephalad, exposing the transverse mesocolon, which is also elevated and retracted cephalad. The proximal jejunum is retracted to expose the ligament of Treitz and the inferior mesenteric vein (**FIG 5**).

FIG 5 ● Identification of the ligament of Treitz.

CREATION OF THE BILIOPANCREATIC LIMB

- Starting at the ligament of Treitz, a marked grasper in the surgeon's right hand is used to measure 40 cm distally (FIG 6).
- The jejunum is divided with a white 60-mm laparoscopic stapling device, with care being taken not to undercut the biliopancreatic or Roux limb mesentery.
- If necessary, further mesenteric division can be accomplished with an ultrasonic dissector.

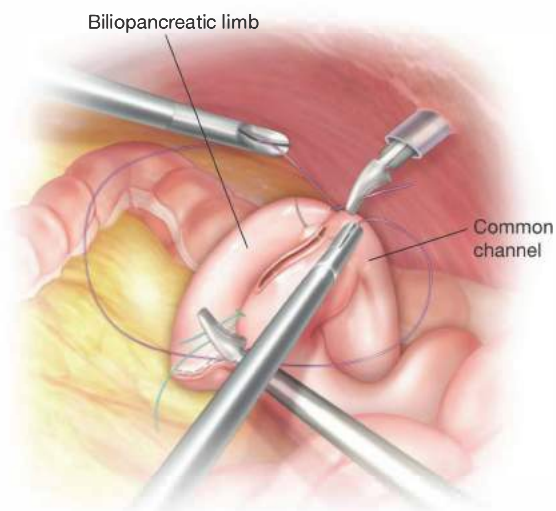
FIG 6 ● Measurement of the biliopancreatic limb.

JEJUNOJEJUNOSTOMY CREATION

- A 2-0 undyed absorbable suture is placed on the tip of the distal jejunum to later identify the Roux limb (FIG 7). The Roux limb is measured using the previous technique with a marked grasper in the surgeon's right hand. A 95-cm Roux limb is created if the patient's BMI is less than 50. A 150-cm Roux limb is created if the patient's BMI is greater than 50.
- The site chosen for the anastomosis is brought into apposition to the proximal jejunum with the cut end of the biliopancreatic limb oriented toward the patient's right side and cephalad to the distal Roux limb.
- A pretied, 24-cm long, 2-0 absorbable suture is placed through the Roux limb and biliopancreatic limb approximately 3 cm from the biliopancreatic tip. This suture will later be used for enterotomy closure.
- A pretied, 26-cm long, 2-0 nonabsorbable suture is placed through the Roux limb and biliopancreatic limb approximately 1 cm from the biliopancreatic tip. This suture will later be used for mesenteric closure.
- An ultrasonic dissector is used to make enterotomies in the biliopancreatic and Roux limbs.

FIG 7 ● Roux limb identification suture.

- A white 60-mm laparoscopic stapling device is placed into the enterotomies to construct a side-to-side jejunojejunostomy. Hemostasis of the staple line is assured.
- The assistant distracts the absorbable and nonabsorbable sutures to orient the enterotomy into a slit rather than a circle. The enterotomy is closed by running the absorbable suture in two layers (FIG 8).



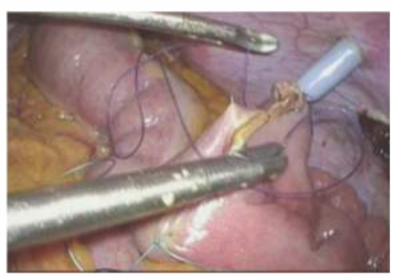


FIG 8 ● Closure of enterotomy defect before starting to sew.

CLOSURE OF MESENTERIC DEFECT

- The mesenteric defect is closed in a running, locking fashion with the previously placed 2-0 nonabsorbable suture (**FIG 9**).

FIG 9 ● Closure of mesenteric defect.

DIVISION OF GREATER OMENTUM

- The omentum is divided vertically, toward the direction of the liver retractor, with the ultrasonic dissector to facilitate bringing the Roux limb up to the gastric pouch. This step can be omitted if the omentum is thin or if the Roux limb is placed in the retrocolic retrogastric position.

CREATION OF GASTROJEJUNOSTOMY

- With the Roux limb in the left upper quadrant, a pretied, 26-cm long, 2-0 absorbable suture is placed between the antimesenteric side of jejunum and posterior wall of the gastric pouch approximately 2 cm from the tip of the Roux limb. The patient is placed in full reversed Trendelenburg position.
- An interrupted, undyed, 2-0 absorbable suture is placed 1.5 cm from the running suture on the antimesenteric side of the Roux limb and posterior wall of the gastric pouch.
- An adequate gastrotomy is created just posterior to the transverse staple line of the gastric pouch using an ultrasonic device.
- An adequate enterotomy is created by entering the Roux limb. Care should be taken not to injure the posterior wall of the jejunum.
- A side-to-side gastrojejunostomy is created by placing the cassette side of the stapler into the stomach and the anvil side into the jejunum. The assistant orients the tip of Roux limb so that it is in line with the stapler as it is inserted to the 20-mm mark. The stapler is closed and fired (**FIG 10**).
- While the assistant continues to hold the tip of the Roux limb in approximation with the gastric pouch, the surgeon places a 2-0 absorbable stitch between the Roux limb and the gastric pouch just beyond the apex of the gastrojejunostomy staple line to suspend the jejunum to the pouch.
- The assistant distracts the absorbable and nonabsorbable sutures to orient the gastrojejunostomy into a slit

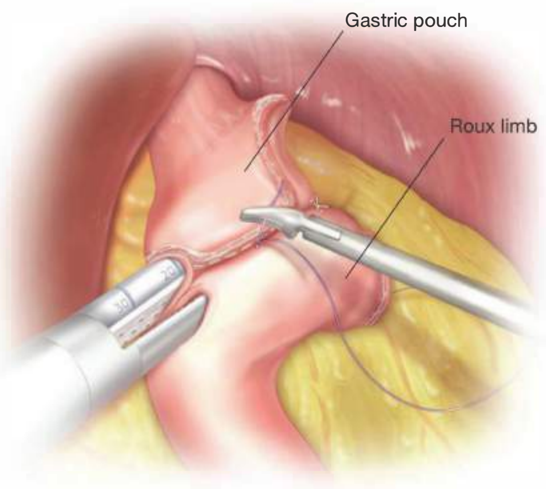


FIG 10 ● Stapling the gastrojejunostomy.

rather than a circle. The first layer of the gastrojejunostomy is closed using the previously placed, pretied 2-0 absorbable suture in a running fashion. The 34-Fr gastric lavage tube is then passed across the gastrojejunostomy to prevent suturing the back wall and to calibrate the opening. After locking the final suture on the first row, the same suture is used to place a second layer running back toward the knot. The anesthetist periodically moves the lavage tube to prevent sewing it into place. The gastric lavage tube is completely removed upon completion of the second layer, and the suture is tied to its tail (FIG 11).

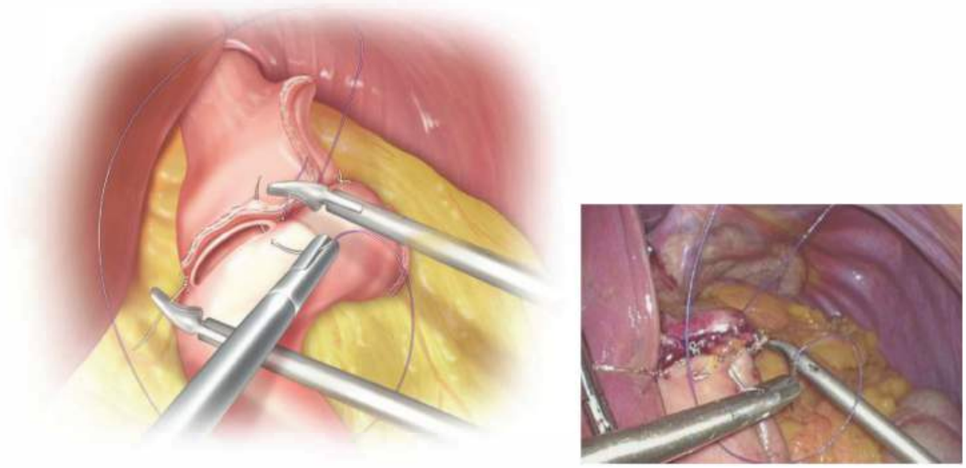


FIG 11 ● Closure of gastrojejunostomy.

CLOSURE OF PETERSEN DEFECT

- The mesenteries of the biliopancreatic, Roux limb, and transverse mesocolon are all secured with a 2-0 nonabsorbable suture to obliterate a potential hernia site at Petersen defect.

UPPER ENDOSCOPY LEAK TEST

- The Roux limb is occluded with a bowel clamp approximately 2 cm distal to the gastrojejunostomy. The assistant retracts the distal gastric remnant and omentum to keep the gastrojejunostomy in view. With the patient placed in Trendelenburg position, the gastric pouch, gastrojejunostomy, and tip of the Roux limb are submerged under saline (FIG 12).
- An endoscope is passed across the gastrojejunostomy to ensure its integrity, hemostasis, and patency. The scope is withdrawn into the pouch, which is inflated

FIG 12 ● Placement of bowel clamp. Submerged anastomosis with light transilluminating the jejunum.

with air from the endoscope. The submerged areas are inspected for bubbling, which, if present, are identified and repaired with 2-0 absorbable suture. The test is then repeated until there is no further leaking observed. The length of the gastric pouch is confirmed by measuring the distance between the gastrojejunostomy and the Z line. The endoscope is removed, saline is aspirated from the abdominal cavity, all instruments are removed, and the trocars are removed under direct visualization to ensure hemostasis.

SKIN CLOSURE

- No fascial sutures are placed in the 10- and 12-mm trocar sites, because radially dilating trocars are used and they are both placed off the midline.
- The skin is closed with 4-0 absorbable monofilament suture in a subcuticular fashion. A waterproof sterile adhesive is placed to close the epidermis.

PEARLS AND PITFALLS

Pearls:
- The use of sterile adhesive allows the patient to shower and have no dressings to change.
- Patients are maintained on proton pump inhibitor therapy for 30 days to reduce the risk of early marginal ulceration.
- Initially, all medications should be administered in the crushed or elixir form.
- Extended-release medications (XR, XL, ER, or EC) often cannot be crushed, broken, or opened and will need to be changed by their prescribing provider to an immediate release or alternate form that can be crushed or opened.
- Daily supplements with an adult strength chewable or liquid multivitamin and at least 1,200 mg of calcium citrate with vitamin D are recommended.
- Long-term dietary goals should include 50 to 80 g of protein per day.

Pitfalls:
- Liquid calories and sweets can cause late dumping syndrome.
- Snacking should be avoided to prevent developing a pattern of eating called "grazing."
- Pregnancy is not recommended in the first 18 months after surgery.
- Birth control pills alone may not be effective for birth control after surgery. Patients are instructed to speak with their gynecologist regarding other methods of birth control.
- Patient's fertility may increase after surgery and weight loss.

POSTOPERATIVE CARE

- Diet
  - Patients remain NPO the night of surgery and are advanced to noncarbonated, low caloric, bariatric clear liquid diet on postoperative day (POD) 1 if they are not tachycardic, tachypneic, or experiencing excessive pain. If the patient tolerates this step, they are advanced to a pureed diet upon discharge home.
- Activity
  - It is imperative that the patient walk on the evening of the operation, because we only use SCDs for deep venous thrombosis (DVT) prophylaxis.

OUTCOMES

- The long-term average weight loss after a Roux-en-Y gastric bypass is 60% to 70% excess body weight (EBW).
- There is usually rapid resolution of comorbidities such as diabetes mellitus, sleep apnea, hyperlipidemia, and GE reflux disease.

COMPLICATIONS

- Early serious complications (<30 days) include gastrointestinal bleeding, bowel obstruction, anastomotic leak, intraabdominal abscess, DVT, pulmonary embolism (PE), wound infection, and mortality; all of which should be less than 1% in experienced centers.
- Late complications (>30 days) include bowel obstruction, anastomotic stenosis, marginal ulceration, gastrointestinal bleeding, cholelithiasis, internal herniation, gastro–gastro fistula, vitamin deficiencies, and mortality.

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Chapter 19

Laparoscopic Sleeve Gastrectomy

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DEFINITION

- Sleeve gastrectomy or partial vertical gastrectomy is defined as the creation of tubular, sleeve-shaped, lesser curve–based stomach by resection of the greater curvature of the gastric body and fundus.
- Laparoscopic sleeve gastrectomy (LSG) has been an increasingly popular procedure due to its relative technical simplicity and excellent safety and efficacy profile. With an increased number of insurers now covering the sleeve gastrectomy, the number of LSG performed in the United States has grown rapidly in the last several years.
- LSG was initially performed as the first stage of the biliopancreatic diversion–duodenal switch procedure. However, beginning in 2008, LSG has been performed as a stand-alone bariatric operation, and short- and medium-term follow-up have documented its safety and efficacy.
- In 2010, a Current Procedural Terminology (CPT) code was assigned to the procedure and, more recently, the American Society for Metabolic and Bariatric Surgery has issued a statement with 3- and 5-year data and robust experience acknowledging LSG as an approved primary bariatric procedure.

PATIENT HISTORY AND PHYSICAL FINDINGS

- A complete history and physical examination should be obtained, with particular attention given to history or identification of metabolic disorders such as diabetes, dyslipidemia, and fatty liver disease; cardiovascular disease; obstructive sleep apnea; venous thromboembolism as well as a history of previous abdominal operations.
- Per National Institutes of Health (NIH) consensus guidelines, bariatric surgery is indicated for patients with a body mass index (BMI) greater than 40 or a BMI greater than 35 with obesity-associated comorbidities. Insurers and payers, though, may have other stipulations.
- A detailed nutritional history, including prior attempts at weight loss through dietary, exercise, and medical programs, and psychologic/psychiatric history should be obtained.
- Multidisciplinary evaluation with registered dietitians, psychologists, and medical physicians is critical prior to consideration for any bariatric surgery.

IMAGING AND OTHER DIAGNOSTIC STUDIES

- In the absence of history or physical findings suggestive of upper gastrointestinal (GI) pathology, preprocedural imaging is not mandatory.
- However, symptoms such as dysphagia, early satiety, or odynophagia should prompt further radiologic or endoscopic evaluation.
- In our practice, some find a preoperative barium swallow helpful to rule out gross esophageal motility disorder; assess for hiatal hernias; and exclude mass lesions, stricture, diverticula, and other anatomic abnormalities. Others get a swallow study only if the history and symptoms raise any concerns.
- Subsequent upper endoscopy can then be selectively used to follow up any concerning findings from the swallow study.
- When esophageal dysmotility is suspected based on history or swallow study, preoperative esophageal manometry is obtained.

SURGICAL MANAGEMENT

Preoperative Planning

- Preoperative laboratory, pulmonary, and cardiac evaluation are performed as indicated by patient history, age, and comorbidities as with other major abdominal surgery.
- Patients should be encouraged to lose as much weight as possible leading up to surgery. We place our patients on a low caloric diet 2 to 3 weeks before surgery in order to decrease the volume and rigidity of the left lobe of the liver, facilitate laparoscopic exposure, and allow for a less technically demanding and safer operation.
- Appropriate antibiotic and venous thromboembolism prophylaxis should be administered in a timely fashion.

Positioning

- The patient is positioned supine or in the split-leg position according to the surgeon's preference. Specialized bariatric beds are available to accommodate the super obese and allow for ergonomic positioning of the patient. The arms and legs should be well secured along with a footboard to allow steep reverse Trendelenburg to facilitate visualization of the left upper quadrant intraoperatively. An orogastric tube should be placed to decompress the stomach after endotracheal intubation.

PORT PLACEMENT

- Initial peritoneal access is obtained using the surgeon's preferred method. Pneumoperitoneum is created, and subsequent ports are placed under direct visualization. Many geometric arrangements for port placement will allow adequate exposure for the operation. In general, five ports in the upper abdomen will allow adequate access and visualization for the operation. These will usually include two working ports for the operating surgeon and ports for the camera, liver retractor, and assistant. At least one 12- or 15-mm trocar is required to allow introduction of a stapler. Two example diagrams of port placement are shown in **FIG 1**.

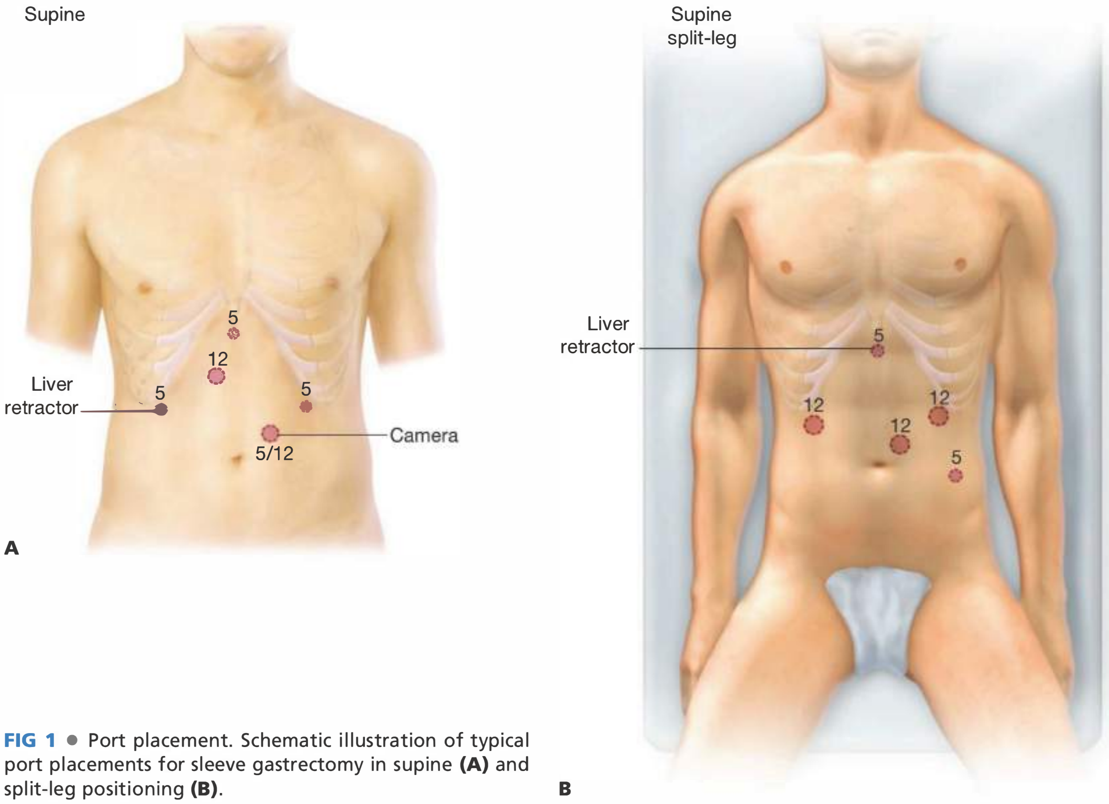


FIG 1 ● Port placement. Schematic illustration of typical port placements for sleeve gastrectomy in supine **(A)** and split-leg positioning **(B)**.

MOBILIZATION OF THE STOMACH

- After exploration of the peritoneal cavity, the patient is placed into steep reverse Trendelenburg position to drop away the intestines and omentum, and a liver retractor is placed to expose the stomach and hiatus.
- The pylorus is identified and the distal margin of the sleeve is measured within 2 to 6 cm proximal to the pylorus (**FIG 2A,B**). The greater curvature of the stomach is mobilized by transecting the gastrocolic ligament and short gastric vessels. An ultrasonic or bipolar vessel-sealing device speeds this dissection (**FIG 3**). Proximally, the vessels are divided up to the highest short gastric, a reliable landmark which often dives posteriorly toward the pancreas (**FIG 4**). We find that complete mobilization of the angle of His from the left crus of the diaphragm and freeing of any lesser sac adhesions to the pancreas or posterior gastric space facilitates subsequent formation of the gastric sleeve. These adhesions are often avascular and can be taken sharply. Complete mobilization to allow adequate resection of the fundus is believed to be a critical step of sleeve gastrectomy.[1]
- The surgeon should look for a hiatal hernia and fix it should it be readily evident. We do not promote the routine dissection of the hiatus to identify a "hiatal hernia" that is not readily apparent.

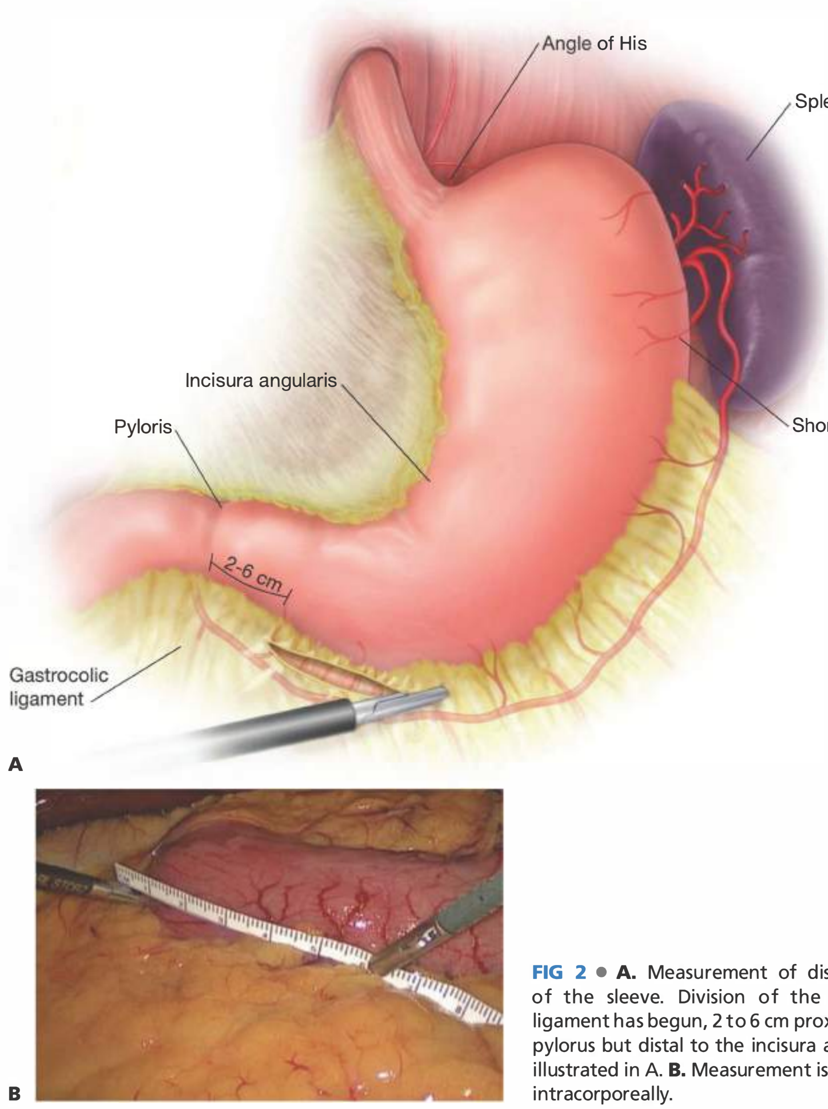


FIG 2 ● **A.** Measurement of distal margin of the sleeve. Division of the gastrocolic ligament has begun, 2 to 6 cm proximal to the pylorus but distal to the incisura angularis as illustrated in A. **B.** Measurement is performed intracorporeally.

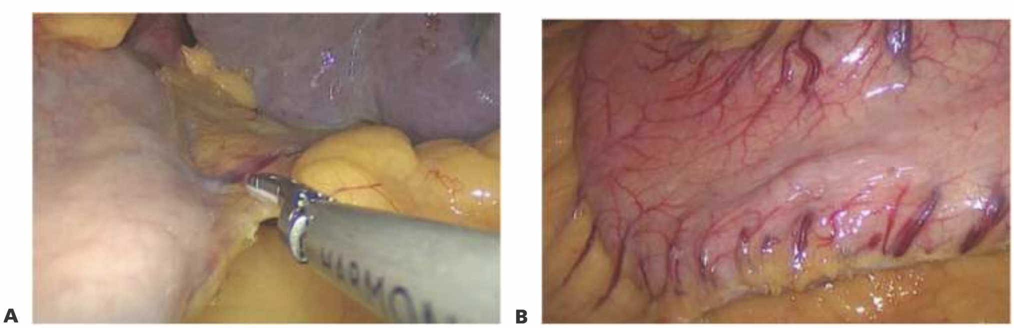
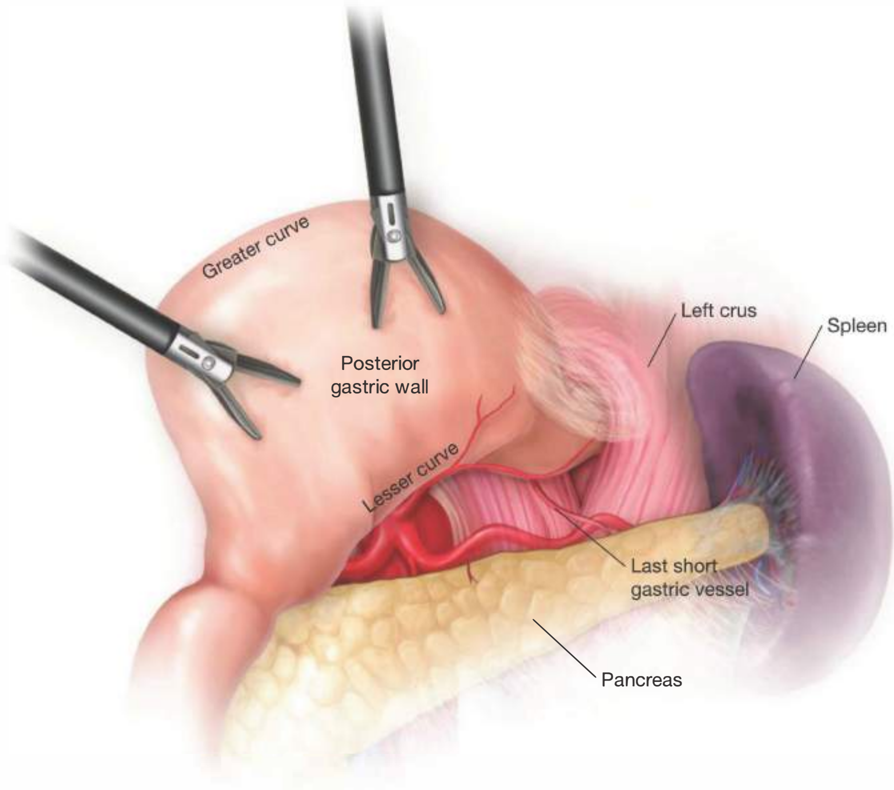


FIG 3 ● Division of short gastrics and gastrocolic ligament. **A.** The gastrocolic ligament and short gastric vessels are divided using an ultrasonic dissector. **B.** Final view of the distal margin of the dissection as previously measured from the pylorus is shown.

A



B

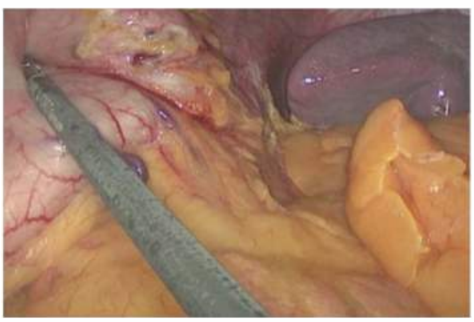


FIG 4 ● **A.** Complete mobilization of gastric fundus from the diaphragm and lesser sac. The last short gastric vessel often dives posterior and into the pancreas and is a reliable anatomic landmark. **B.** The gastric fundus is fully mobilized up to the left crus of the diaphragm, and lesser sac adhesions are dissected to facilitate subsequent stapling.

CREATION OF THE GASTRIC SLEEVE

- Accurate and safe formation of the gastric sleeve is performed using a bougie introduced into the oropharynx, down the lesser curvature, and into the gastric antrum as a guide (FIG 5). Choice of size and type of bougie remains a surgeon's preference. The recent sleeve consensus statement recommended use of a 32- to 36-Fr bougie.[1] Various Maloney dilators or flexible endoscopes may be used as a bougie. Our practice is to use the therapeutic endoscope (36 Fr in caliber) to size the sleeve, which we find helpful to later perform a provocative leak test and examine our staple line endoluminally.
- With the chosen bougie in place, and after confirmation that no other intragastric tubes (e.g., orogastric tubes, temperature probes) remain in place, transection of the greater curvature of the stomach begins 2 to 6 cm proximal to the pylorus using a linear cutting stapler. It is critical to avoid narrowing of the sleeve, particularly at the incisura angularis, and to take equal portions of

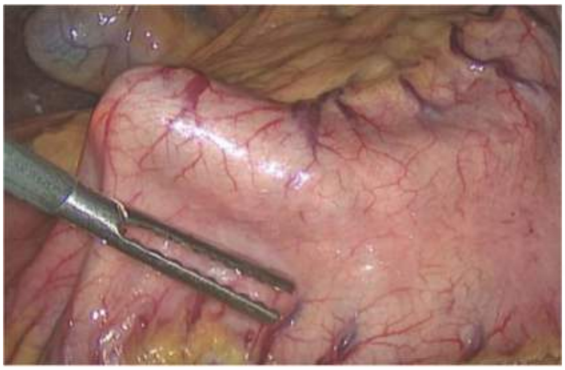


FIG 5 ● Placement of intragastric bougie. A bougie is placed along the lesser curvature into the antrum to guide formation of the sleeve. This illustration shows the use of an endoscope, which is easily manipulated to match the contour of the lesser curvature.

the anterior and posterior walls of the stomach to avoid "spiraling" the sleeve (**FIG 6**).

- The gastric sleeve formation is completed with subsequent fires of the linear stapler along the bougie, thus resecting the greater curvature of the stomach. With each staple fire, continued care is made to assure that equal amounts of anterior and posterior gastric wall are resected (**FIG 7**). It is often helpful to have the assistant maintain lateral traction on the lateral aspect of the stomach and, at times, toward the posterior aspect. The final staple line should veer off the gastroesophageal junction as this area is particularly susceptible to leaks.[1] In **FIG 8**, a laparoscopic and endoscopic view of the completed sleeve is shown.
- Staple loads should be chosen as appropriate for the thickness of the tissue. The gastric wall is generally thickest on the initial distal staple line at the antrum. The use of staple line reinforcement is controversial. There is some evidence that staple line reinforcement may decrease the incidence of bleeding complications; however, any impact on leak rates is less clear. Several absorbable and permanent staple line buttressing materials are available. Some oversew an unreinforced staple line routinely, which should be performed with the bougie in place to prevent narrowing of the gastric conduit if it is done. Others prefer not to use reinforcements, or to routinely oversew, due to concerns of excessive material where staple lines cross, the added expense, and unclear benefit or potential harms from those practices.

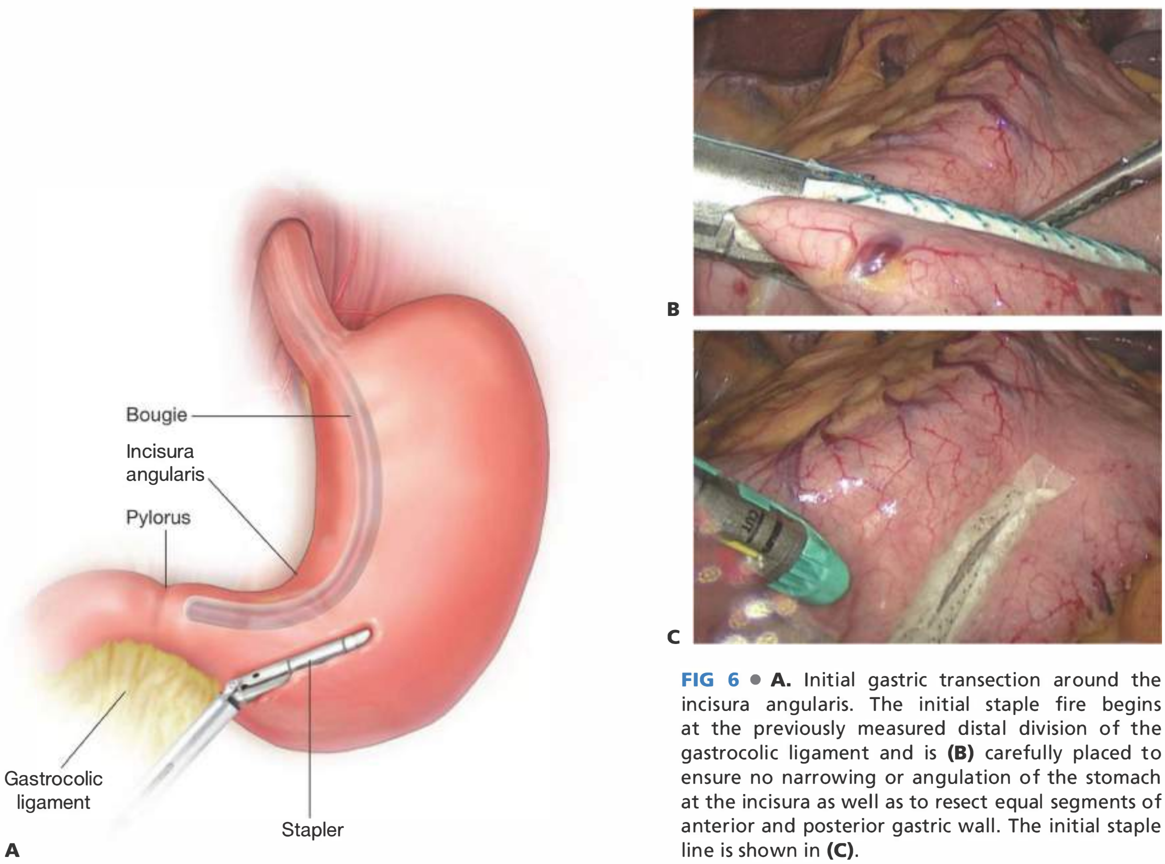
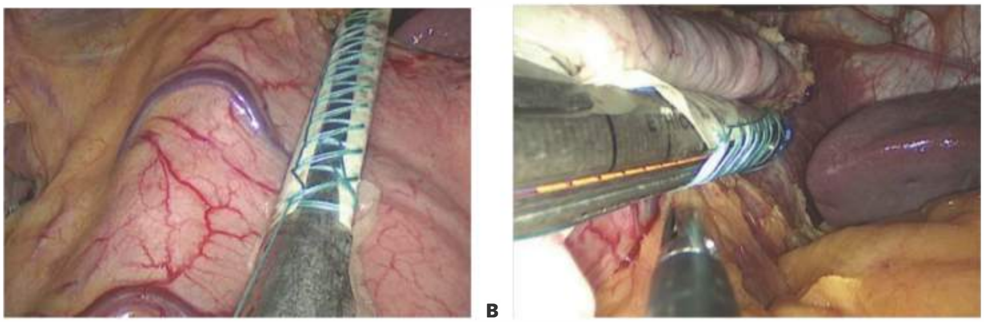
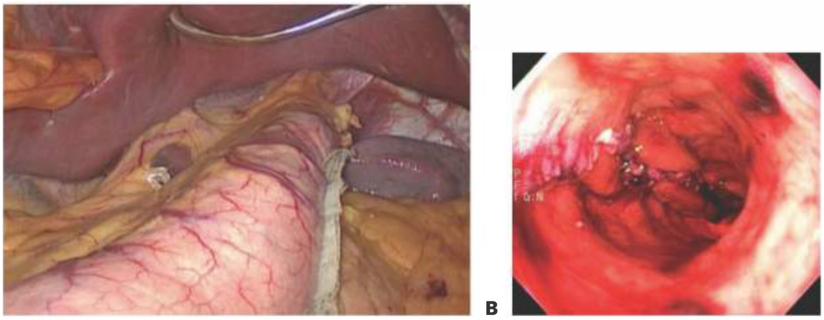


FIG 6 ● **A.** Initial gastric transection around the incisura angularis. The initial staple fire begins at the previously measured distal division of the gastrocolic ligament and is **(B)** carefully placed to ensure no narrowing or angulation of the stomach at the incisura as well as to resect equal segments of anterior and posterior gastric wall. The initial staple line is shown in **(C)**.



A B

FIG 7 ● Transection of greater curvature of stomach. Subsequent gastric transection is performed parallel to the lesser curvature, along the bougie, and aimed toward the angle of His. In these photographs, staple line buttressing material is used. The placement of the stapler is examined anteriorly **(A)** and posteriorly **(B)** to ensure equal alignment of the gastric walls.



A B

FIG 8 ● Laparoscopic **(A)** and endoscopic **(B)** view of completed sleeve gastrectomy.

PROVOCATIVE LEAK TEST

- A provocative leak test can be performed after the sleeve is created, either with gas or liquid dye. Our practice is to submerge the staple line in saline irrigation while insufflating the sleeve with carbon dioxide (CO_2) via the indwelling endoscope and clamping the distal stomach. A laparoscopic assessment for evidence of leaks or bubbles is done, and simultaneously, an endoluminal examination is performed to exclude intraluminal bleeding and to assess the gastric conduit for any narrowing or kinking. Alternatively, insufflation or instillation with distention via a nasogastric or other device can be done with CO_2, air, or colored liquid; however, oxygen alone should not be used.
- Hemostasis of the staple line and divided greater curvature vessels is ensured. Although some surgeons choose to recreate the gastrocolic ligament by suturing the omentum to the staple line in an effort to prevent torsion of the sleeve, we do not routinely do that. The gastrectomy specimen is removed, which can usually be accomplished using a protective bag without enlarging any incisions. The bougie, liver retractor, and trocars are removed under direct vision; pneumoperitoneum is released; and closure is performed of the extraction site with a fascial closure device.

PEARLS AND PITFALLS

- Secure positioning of the patients extremities with a footboard is imperative to allow steep reverse Trendelenburg to optimize laparoscopic visualization.
- During division of the gastrocolic ligament and short gastrics, care should be taken to avoid injury to the gastroepiploic vessels and spleen.
- It is important to assure that the proximal fundus is completely mobilized by dissecting up to the left crus and taking the highest short gastric vessel.
- Freeing of lesser sac adhesions to the pancreas and posterior gastric stomach and release of the angle of His from the left crus give additional mobility of the greater curve to allow precise placement of the stapler for greater curvature resection.
- A 32- to 40-Fr bougie should be placed along the lesser curvature of the stomach to aid in sizing of the gastric sleeve.
- Care should be taken to avoid narrowing the gastric conduit, particularly at the incisura angularis.
- Accurate placement of each stapler ensuring equal resection of the anterior and posterior gastric walls is critical to avoid spiraling of the sleeve, which could result in postoperative obstruction.

POSTOPERATIVE CARE

- Postoperative care is similar to other bariatric patients. Early postoperative ambulation, adequate postoperative analgesia, and frequent pulmonary toilet are important to help avoid pulmonary and thrombotic complications. Appropriate perioperative antibiotics and venous thromboembolic prophylaxis are continued. We keep our patients NPO on the first postoperative evening, but allow oral intake of important medications.
- The use of routine postoperative upper GI series is of debatable value. It is our practice to routinely obtain a Gastrografin and barium swallow examination on postoperative day 1 (**FIG 9**). We find this study helpful not only to exclude leak or obstruction but also to obtain a baseline study of each patient's anatomy for future reference.
- Following the swallow study, the patient is started on a clear liquid diet and oral analgesics. We discharge our patients on either postoperative day 1 or 2. We maintain our patients on a liquid diet for 9 to 14 days and then introduce soft foods. Multivitamin supplementation is started on discharge, and we keep our patients on acid suppression in the perioperative period.

FIG 9 ● Postoperative barium study of a sleeve gastrectomy.

OUTCOMES

- Early data shows that the LSG is a safe and effective bariatric and metabolic operation, with outcomes positioned between the adjustable gastric band and Roux-en-Y gastric bypass (GBP).[2] Weight loss and improvements in comorbid conditions such as diabetes, sleep apnea, hyperlipidemia, and hypertension with LSG are significantly better than the gastric band, but do not quite reach the levels seen after GBP.
- Similarly, rates of perioperative complications for the sleeve gastrectomy lie between the band and the bypass. Overall, the incidence of death, serious complication, readmission, and reoperation in the early postoperative period are equivalent for the LSG and the bypass and higher than for the gastric band. Most studies have also shown a trend toward decreased rates of specific complications for the LSG compared to the bypass—for example, obstruction, stricture, and anastomotic ulcer.[2,3] Although promising, good quality data are still lacking on the long-term effectiveness and safety of the LSG.

COMPLICATIONS

- The most frequent complications after LSG are bleeding, urinary tract infections, superficial site infections, and deep venous thromboses (DVTs). They are similar to other bariatric operations in their incidence, diagnosis, and treatment.
- A few LSG-specific complications merit further discussion. Leaks occur overall at a similar incidence as the GBP. Sleeve leaks can occur both early and late and are most often found at the proximal staple line near the angle of His. Principles and treatment of LSG leaks are similar to other abdominal leaks, including control of sepsis with wide drainage and antibiotics and nutritional optimization. Treatment of leaks after sleeve gastrectomy can be particularly challenging, as the intact pylorus and gastric conduit itself often create a relative distal obstruction and enteral access for nutritional supplementation is more problematic. However, unique to management of LSG leaks is the use of covered stents, which can be placed endoscopically and can be useful to control leaks in combination with intraabdominal drainage.

- Although extremely infrequent, obstruction after sleeve gastrectomy can occur, and unlike the GBP, they are not due to internal hernia, as the intestinal spaces are not disturbed, but more commonly due to narrowing or twisting of the gastric conduit. Again, upper endoscopy can be particularly helpful for diagnosing this problem and treatment with endoscopic dilation.
- Severe gastroesophageal reflux has also been described following LSG. Management should include fluoroscopic and endoscopic imaging of the sleeve to assess and treat any defined obstruction. Recalcitrant reflux may even require reoperation with sleeve conversion to Roux-en-Y GBP.

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Chapter **20** Laparoscopic Gastric Band

Darren S. Tishler Pavlos K. Papasavas

DEFINITION

- The laparoscopic adjustable gastric band (LAGB) is a Food and Drug Administration (FDA)–approved, implantable medical device for the treatment of morbid obesity and obesity-related medical comorbidities. The adjustable gastric band (AGB) consists of an adjustable saline-filled annular balloon, a segment of tubing, and a subcutaneous access port (**FIG 1**). This simple hydraulic system is placed around the upper portion of the stomach, just distal to the gastroesophageal (GE) junction, to create a small (approximately 30 mL) stomach pouch. The subcutaneous port is placed on the abdominal wall fascia and allows for the band stoma area to be adjusted by the addition or removal of saline solution using a noncoring needle. The AGB restricts the amount the stomach can accommodate to varying degrees, depending on the fluid volume in the band. The AGB helps to slow the progression of food from the small upper pouch to the distal stomach as well as possibly stimulating the production of gastric peptides and neuronal pathway signals related to satiety.
- The AGB differs from other bariatric procedures in three main ways: It is adjustable, reversible, and involves no cutting or stapling of the stomach.
- The AGB is an exclusively restrictive procedure, unlike other malabsorptive procedures such as the Roux-en-Y gastric bypass (RYGB) (see Part 2, Chapter 18) and the duodenal switch.
- Patients who undergo AGB are at a low risk for developing major nutritional and vitamin deficiencies. Although medication pill size can be a factor, the AGB does not have any effect on the absorption of medications and other nutritional supplements.

FIG 1 ● AGB system.

PATIENT HISTORY AND PHYSICAL FINDINGS

- No validated algorithm exists to prescribe the most appropriate bariatric procedure.
- Although the AGB is indicated for patients with body mass index (BMI) of 30 to 40 kg/m^2 with medical comorbidities or BMI greater than 40 kg/m^2 with or without medical comorbidities, best results are often obtained in patients with lower BMI.
- AGB typically produces best results in patients who are ambulatory and capable of performing regular aerobic activity.
- In patients who fail to achieve adequate weight loss with AGB, the two most common factors are lack of exercise and depression. These issues, when present, need to be addressed both prior to surgery and during the requisite aftercare.
- Ideal patients for AGB have an understanding of the importance of regular follow-up visits for band adjustments. Several studies have demonstrated an association between number of aftercare visits and weight loss. Patients require, on average, six to eight visits in the first year to achieve optimal results with the AGB procedure.[1]
- Although patients with long-standing severe gastroesophageal reflux disease (GERD) symptoms may improve immediately after the placement of an AGB, long-term tolerance of restrictive procedures can be a problem in this subset of patients.
- Allergies must be assessed, as some patients could rarely experience adverse reactions to the materials in the band.
- In patients with a history of autoimmune disease, gastric banding procedures are contraindicated at this time by the FDA.[2] However, several studies have demonstrated both safety and efficacy of gastric banding in this patient population.[3] Contraindications to adjustable gastric banding are listed in Table 1.

Table 1: Contraindications to Adjustable Gastric Band Placement

Absolute Contraindications	Relative Contraindications
• Uncontrolled psychiatric disease • Current substance or alcohol abuse • Current history of anorexia or bulimia • Achalasia • Prior GE junction surgery (fundoplication, Heller myotomy)	• Cigarette smoking • Severe GERD • Gastroparesis • Esophageal dysmotility • Autoimmune disease • Prior bariatric surgery

GE, gastroesophageal; GERD, gastroesophageal reflux disease.

IMAGING AND OTHER DIAGNOSTIC STUDIES

- **Barium upper gastrointestinal (UGI) fluoroscopic evaluation** is obtained in all of our patients prior to restrictive procedures to rule out the possibility of a hiatal hernia and as a screening tool for functional and structural esophageal disorders.
- **Routine diagnostic endoscopy** is not required in all patients prior to placement of the AGB. However, it can be of use in patients with an abnormal UGI study to confirm findings of esophageal or upper gastric abnormalities or other unusual anatomy (i.e., diverticulum, paraesophageal hernia, Schatzki's ring).
- **Esophageal function testing** is a useful adjunct in patients with a suspected esophageal motility disorder. Patients with significant esophageal dysmotility or conditions such as achalasia and diffuse esophageal spasm should not be considered for adjustable gastric banding due to the high risk of long-term band intolerance.

SURGICAL MANAGEMENT

Preoperative Planning

- LAGB should be performed at a multidisciplinary bariatric surgery program or center.
- The surgeon must be comfortable with laparoscopic intracorporal suturing and procedures of the GE junction. Familiarity and preferably comfort with other bariatric surgical procedures is required.
- Informed consent for the procedure should include a comprehensive discussion of alternative bariatric surgical procedures, need for long-term follow-up and adjustments, and discussion of risks (Table 2).
- A preoperative very low calorie diet (VLCD) is used to deplete hepatic glycogen stores and reduce liver volume to facilitate UGI exposure. Surgery is postponed for patients with rapid weight gain just prior to the scheduled procedure.

Positioning

- The patient is positioned supine with both arms extended. A footboard and thigh straps are used to secure the patient to the operating table.
- Reverse Trendelenburg position helps to expose the upper abdomen, and steep positioning is often needed for patients with a large amount of omentum and upper abdominal fat.
- The stomach is decompressed immediately after intubation with an orogastric tube. Deep muscle relaxation aids the exposure of the GE junction.
- The surgeon stands to the patient's right with an assistant to the left.
- During the setup for the procedure, the scrub assistant will prepare the band per the manufacturer recommendations to flush any air from the system.
- Prophylactic antibiotics are given immediately prior to incision. In addition, mechanical and pharmacologic deep vein thrombosis (DVT) prophylaxis is used.

Table 2: Risks of Adjustable Gastric Banding

General/systemic	Infection, bleeding, venous thromboembolism, death Dehydration, inadequate weight loss, weight regain, nutritional deficiencies
Device related	Device intolerance Prolapse Erosion Dysphagia/reflux/vomiting/regurgitation Port leakage/tubing disconnection

ENTRY TO ABDOMEN AND EXPOSURE

- Laparoscopic exposure to the abdomen is obtained using an optically guided trocar in the left paramedian position approximately 3 to 5 cm below the costal margin. Either a 30-degree, 45-degree, or deflectable-tip camera is used.
- Additional trocars are placed with a 12- or 15-mm trocar to accommodate the AGB insertion into the abdomen. Precise positioning of trocars ensures appropriate angle for the placement of the AGB around the upper stomach (**FIG 2**).
- A Nathanson or similar liver retractor is placed just above the GE junction to retract the left lobe of the liver. Upward (anterior) traction on the liver retractor helps to visualize the phrenoesophageal ligament and proximal gastric anatomy. A solid and strong mounting clamp for the retractor greatly enhances the exposure. In some cases, an assistant pulling anteriorly on the retractor can facilitate exposure on a patient with both hepatomegaly and a large amount of fat around the GE junction.

TECHNIQUES

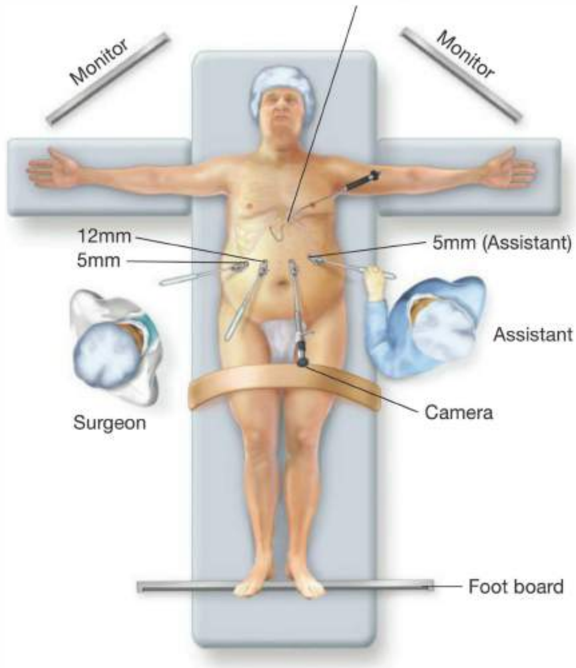


FIG 2 ● Positioning and trocar placement. Careful placement of the trocars facilitates proper placement and orientation of the AGB.

DISSECTION

- The hepatogastric ligament (pars flaccida) is opened using hook electrocautery or ultrasonic shears. Care must be taken to not injure a replaced or accessory hepatic artery.
- The anterior GE (Belsey's) fat pad is either lifted from the proximal stomach or removed altogether. There are often small branch vessels arising from the left gastric artery within this fat.
- The angle of His (junction of greater curvature of stomach and esophagus) is minimally dissected to free the stomach from the diaphragm. This can be performed either bluntly or with hook electrocautery. Inferior traction on the fundus by the assistant facilitates this exposure (**FIG 3**).
- If a small hiatal hernia is seen, it should be repaired anteriorly after reduction and gentle mediastinal dissection. Larger hiatal hernias may require a traditional posterior repair.
- A small incision is made with electrocautery low down on the right crux of the diaphragm, at the point where a small band of fat crosses the crux (**FIG 4**). Care must be taken to identify the vena cava prior to this dissection. Exposure of this region is facilitated by the assistant providing gentle lateral (leftward) retraction of the lesser curvature of the stomach.

FIG 3 ● Dissection of angle of His.

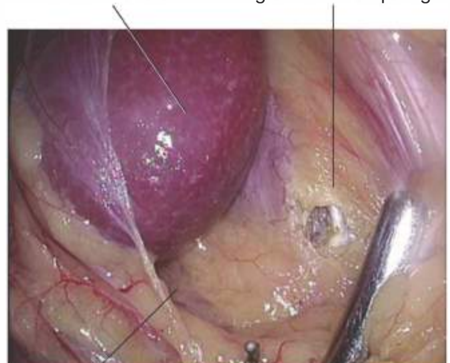
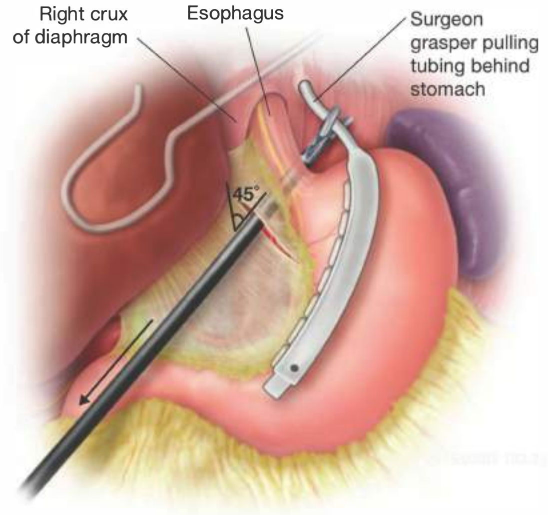


FIG 4 ● Exposure of right crux of diaphragm. Note lateral retraction of lesser curvature of stomach.

PLACEMENT OF ADJUSTABLE GASTRIC BAND

- Either a long blunt grasper or specialized curved instrument is passed behind the upper portion of the stomach from right to left at a 45-degree angle to the long axis of the body (**FIG 5**). There should be no resistance to the passage of this instrument and it should be observed exiting exactly at the point where the angle of His dissection was made. Care must be taken to not perforate the stomach or esophagus posteriorly during this step of the procedure.
- The band is grasped and brought behind the stomach using the grasper just placed behind the stomach. The orientation of the band for placement (band first or tubing first) is determined based on which brand of band is selected.
- The AGB is buckled per manufacturer instructions (**FIG 6**). The band should sit loosely on the stomach when buckled and be able to rotate easily. If a gastric tube was used to help identify the GE junction, it should be removed at this time.

FIG 6 ● Band is buckled after placement around upper stomach.



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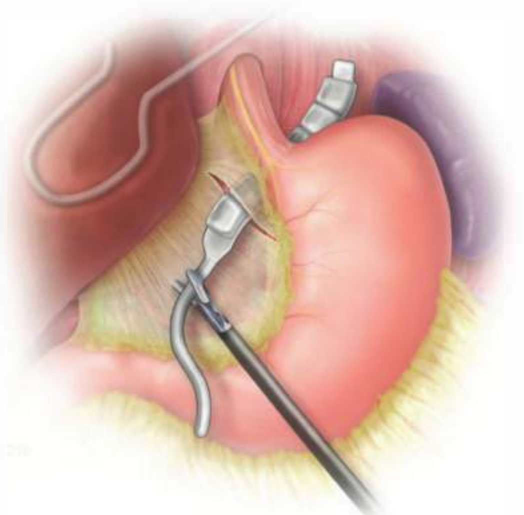

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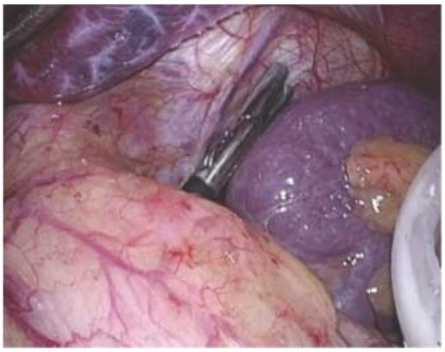


C

FIG 5 ● **A,B.** Grasper placed behind upper stomach at 45-degree angle to grasp tubing and bring unbuckled band behind stomach. **C.** Intraoperative view.

TECHNIQUES

GASTROGASTRIC PLICATION

- A series of gastrogastric sutures are then placed from lateral (left) to medial (right) (**FIG 7**). Nonabsorbable sutures can either be placed in an interrupted or running fashion. The entire lateral and anterior portions of the band should be covered stopping at the buckle. Anywhere from two to four sutures may be needed to complete this step of the procedure.
- Recently, some surgeons have begun to place additional anterior gastric plication sutures below the level of the AGB to possibly (1) improve restriction and weight loss and (2) reduce the incidence of band prolapse.

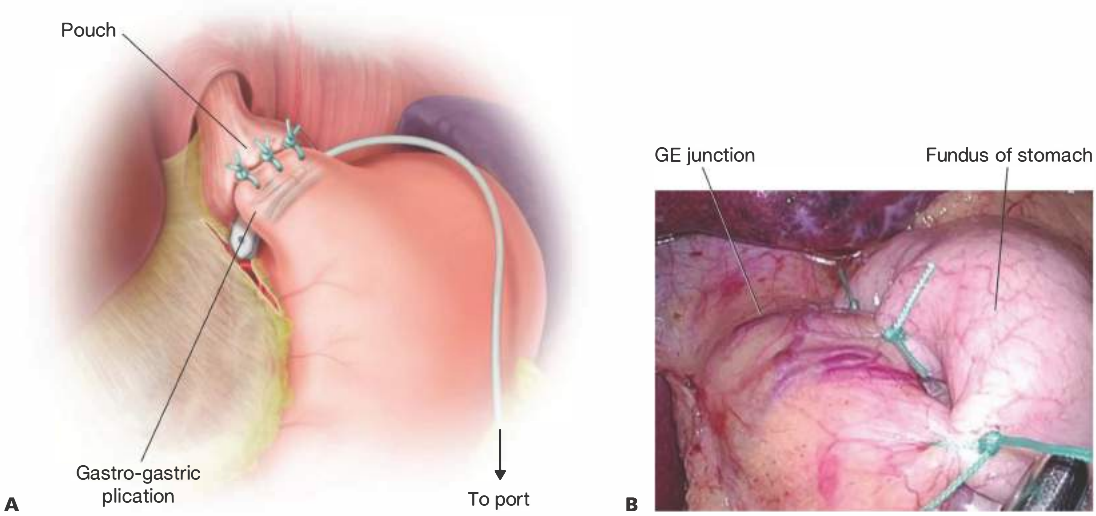


FIG 7 ● **A,B.** Gastrogastric plication sutures. Stomach folded over and laterally and anteriorly. GE, gastroesophageal.

PLACEMENT OF SUBCUTANEOUS ACCESS PORT

- Prior to removal of the trocars, the tubing from the band is exteriorized, trimmed, and connected to the access port. Excessive tubing length should not be left in the patient's abdomen to prevent the possibility of the tubing causing a bowel obstruction. The port is affixed to the abdominal wall on the rectus muscle with care that the port is not placed directly under the costal margin or in a position where it will be aggravated by the patient's clothing. Most surgeons place the port in either the right or left upper quadrant.
- The port can be affixed to the fascia using one of three techniques.
  - The port can be attached to a small disc of mesh and then placed in a small, tight subcutaneous pocket directly on the fascia without any suturing.
  - The port can be attached using interrupted nonabsorbable sutures placed directly into the anterior fascia.
  - A proprietary port applier can be used to affix the port directly to the fascia.
- Care needs to be taken to ensure that the fascia is clear of fat for proper port adherence.
- Scarpa's fascia is closed over the port prior to subcuticular closure of the skin.
- Band adjustment or "prefilling" is generally not required, as the band tends to be tight during the first few postoperative days due to gastric edema.

ALTERNATIVE BAND PLACEMENT TECHNIQUES

- Both single-incision and dual-incision techniques have been described for the placement of AGBs. The authors of this chapter do not perform the procedure using these techniques. However, if such a technique is desired, it requires the ability to
  - Place the band in the same position as in a multiport operation
  - Not jeopardize the exposure of the critical landmarks for the procedure
  - Allow for uncompromised suturing of the gastrogastric plication sutures.

PEARLS AND PITFALLS

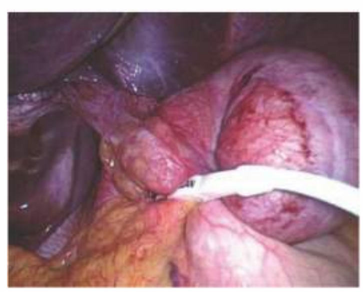
Vitamin supplementation	■ Daily multivitamins, calcium; vitamin B_{12} generally not required
Hiatal hernia repair	■ Always look for and repair at time of surgery.[4] A "dimple" at the hiatus warrants further investigation.
Port mesh fixation	■ Port can be affixed to abdominal wall by sewing a small disc of polypropylene mesh to the port and placing the port on anterior abdominal wall fascia with minimal dissection
Follow-up and adjustments	■ Optimal adjustment critical for success ■ Frequent aftercare visits are needed for best results.
Upper GI contrast swallow study	■ Perform annually and when patient is having difficulty achieving optimal band fill volume
Foods to avoid	■ Dry crumbly foods: chips, crackers, cookies, cakes, pretzels ■ Liquid calories: ice cream, alcoholic drinks, milk, soft drinks

POSTOPERATIVE CARE

- Patients are typically discharged within 24 hours. Patients with low BMI, uncomplicated procedures, and no evidence of obstructive sleep apnea can be safely discharged the day of surgery.
- Venous thromboembolism (VTE) prophylaxis is continued until discharge in all patients and postdischarge in high-risk patients.
- A baseline water-soluble UGI swallow study is selectively obtained on postoperative day 1. This study should demonstrate flow of contrast through the band with minimal restriction. The band itself should lie at approximately 45 degrees to the vertical axis of the body (**FIG 8**). Failure of contrast to pass through the band is usually due to postoperative edema and will resolve within 24 to 72 hours in most cases. Alternatively, a plain upper abdominal x-ray can be obtained in patients already able to tolerate liquids. This baseline image is important as a comparison at a later date if a prolapse is suspected (change in band orientation) (**FIG 9**).
- Sips of water are started on the day of surgery. Sugar-free clear liquids are started on postoperative day 1. Sugar-free full liquid diet is progressed to soft diet over the first 2 weeks after the procedure, and a general bariatric diet is begun 3 to 4 weeks after surgery. Bread, rice, pasta, and fibrous meats are avoided initially.
- Patients are cautioned about the signs and symptoms of dehydration prior to discharge from the hospital. Intravenous (IV) fluid is continued until just prior to discharge to help minimize early dehydration.
- Like other bariatric surgery procedures, good outcomes with adjustable gastric banding require adherence to a regimented diet, daily aerobic exercise, and long-term support and follow-up. However, the AGB also requires regular adjustments for optimal weight loss and comorbidity resolution.
- Patients are seen for a postoperative check 2 weeks after surgery. Wounds are inspected and diet progression is reviewed.
- Patients are evaluated for the following on each visit:
  - Presence of hunger between meals
  - Ability to feel satisfied after eating a small meal
  - Meal size
  - Weight loss since last visit

FIG 8 ● Abdominal radiograph demonstrating normal band orientation.

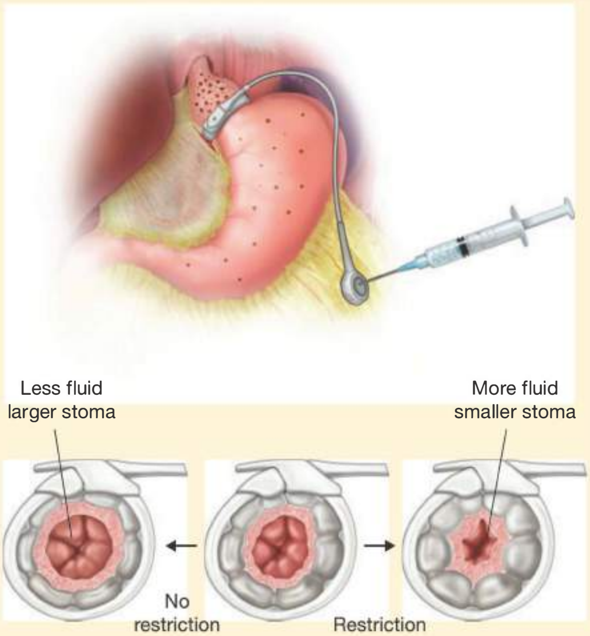
A



B

FIG 9 ● **A,B.** Large prolapse of AGB. Note flattening of band orientation.

Table 3: Band Adjustments



Remove fluid (too tight)	Optimal fluid	Filled (too tight)
Hunger	Small meals	Poor food choices
Large meals	Optimal weight loss	Regurgitation
Poor weight loss	Satiety	Discomfort while eating
	Patient satisfaction	Poor weight loss
		Night cough or GERD

GERD, gastroesophageal reflux disease.

- Patients should lose between 0.5 and 2 lb per week with an optimally adjusted band. Large meals, hunger, and poor weight loss are indications to tighten the band. Small meals, satiety, and optimal weight loss indicate a well-adjusted band. Finally, maladaptive eating behaviors (cravings for dry crumbly foods, sweets, ice cream, and soups), GERD, and nighttime coughing are signs that the band is too tight. See Table 3 for guidelines.

Band Adjustments

- Once determined that an adjustment is needed, the patient is placed in the supine position. Arms crossed behind the head or across the chest can help tense the abdominal musculature to facilitate port access. The port is located, and the area is cleaned with an alcohol swab. The patient is asked to perform an abdominal "crunch" or partial sit-up to elevate the port.
- A noncoring 20-gauge (Huber) needle is used for port access. The needle is placed on a syringe containing sterile saline to prevent air from being introduced into the system.
- The port is stabilized between the thumb and index finger with the nondominant hand (**FIG 10**). Care is taken to not redirect the needle once placed under the skin, as this leads to a bending of the needle. Local anesthetic is generally not necessary.
- Once the port is accessed, a small amount of fluid is drawn back into the syringe to confirm entry into the port. Although some surgeons remove all fluid from the port prior to an adjustment, this step is not routinely necessary, as fluid can simply be either added or removed.
- By quickly removing the needle, leakage from the self-sealing port is prevented.
- Adjustments can be performed under fluoroscopy. Proponents of this technique note that optimal adjustment can be obtained faster and overtightening of the band can be prevented.
- Patients need to be able to swallow water with minimal or no restriction prior to leaving the office after adjustment. A liquid diet for 1 to 3 days after the adjustment minimizes need for early readjustment. Patients should return to the office if progressive dysphagia, pain, cough, or frequent vomiting occurs.
- Each band type and size has its own filling protocol and capacity. It is unusual, however, for patients to reach maximal capacity of the band.
- Patient visits should be scheduled for every 4 to 6 weeks for the first year after surgery, with band adjustments being performed as needed during these visits. Patients are instructed to return to the office immediately if there are any signs or symptoms of a tight band (water brash, dysphagia, vomiting, maladaptive eating behaviors, or dehydration).
- Frequent visits for adjustment are continued long as the patient is losing weight. Once a desired and stable weight is obtained, the frequency of visits can be decreased but should remain at a minimum of one to two visits per year.
- UGI fluoroscopic swallow is performed annually or any time a patient develops any symptoms suggestive of a band prolapse such as progressive dysphagia, frequent vomiting, and/or requirements for frequent removal of fluid with worsening symptoms.

OUTCOMES

- Based on a meta-analysis, laparoscopic gastric banding results in an average percentage of excess weight loss (%EWL) of 47.4% (40.7% to 54.2%) during the first 2 postoperative years.[5]
- A long-term follow-up study has shown that %EWL is preserved at 47.1% 15 years following LAGB, with a revision rate of 50.1% (79% during the perigastric era and 38.4% during the pars flaccida era) and an explant rate of 5.6%.[6]
- In a meta-analysis of 32,908 patients undergoing LAGB, type 2 diabetes mellitus resolved in 56.7% of patients.[7]
- In a prospective randomized study, 60 patients newly diagnosed with type 2 diabetes mellitus, aged between 20 and 60 years and with a BMI between 30 and 40 kg/m^2 were

FIG 10 ● Technique for accessing subcutaneous port. Port is stabilized by nondominant hand.

randomized to either follow a conventional diabetes management program or follow the same program and also undergo LAGB. The conventional program included lifestyle modification and open access to a general physician, dietitian, nurse, and diabetes educator. Remission of type 2 diabetes was achieved by 13% in the conventional-therapy group and by 73% in the surgical group.[8]

- Hypertension, hyperlipidemia, and sleep apnea improve or resolve in 70.8%, 71%, and 68%, respectively.[5]
- There is controversy on the effect of LAGB on GERD. In one study, LAGB led to resolution of GERD in 80% and improvement in 11% of patients at 2 years postoperative.[9] In another study, GERD symptoms decreased postoperatively from 32.9% to 7.7%, but newly developed GERD symptoms were found in 15% of the patients and esophageal dysmotility increased from 3.5% to 12.6%.[10]
- Significant improvement in health-related quality of life (HRQOL) is observed in the first year after LAGB.[11] Food tolerance and gastrointestinal quality of life 2 to 4 years postoperatively appears to be lower with LAGB compared to RYGB or laparoscopic sleeve gastrectomy (LSG).[12]

COMPLICATIONS

- Early device-related complications are rare.
- Port infection in the first few weeks is usually related to the wound itself. However, an unrecognized gastric perforation must be considered in the event the infection does not quickly resolve with antibiotics.
- AGB patients must have long-term surveillance for prolapse (slippage). Prolapse may be a result of the band being too tight, repeated vomiting, or frequent overeating. A patient with a prolapse presents with progressive reflux, dysphagia, and poor weight loss, as well as usually requiring fluid to be removed from the band over time to maintain ability to tolerate solid foods. Confirmation of prolapse is made with a barium swallow. A flattening of the angle of the band toward the horizontal, vertical orientation of the band, or en-face rotation of the band is highly suggestive of AGB prolapse. Early identification of prolapse increases the chances that the band position can be revised.
- Band erosions into the stomach are rare with the pars flaccida (hepatogastric ligament technique). One should suspect erosion anytime there are signs and symptoms of a chronic port infection. Late port infections, in our experience, are usually a sign of a more significant underlying problem with the band.
- Tubing and/or port malfunction are usually a result of incorrect positioning of the port. The nonarmored portion of the tubing can be punctured during band adjustments and is probably the most common cause of a system leak. System leaks of saline and or inability to maintain volume early on after surgery are most likely due to the band being punctured by a needle during initial placement. Rarely, the tubing may become fractured from frequent repetitive motion. Tubing dislodgement has also been described. One should suspect a system leak in a patient who suddenly reports the ability to eat much larger meals due to a lack of restriction.
- Some patients will develop AGB intolerance months to years after placement. Despite a normal positioned band on UGI fluoroscopy, some patients are not able to tolerate even a small amount of restriction from the band. GE reflux and regurgitation can be severe and prevent any meaningful long-term weight loss.

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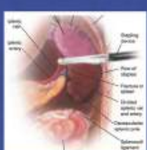
Part **3**

Operative Techniques in Hepato-Pancreato-Biliary Surgery



Chapter 1

Laparoscopic Cholecystectomy

Georgios Rossidis

DEFINITION

- Laparoscopic cholecystectomy describes a procedure involving the removal of the gallbladder using a laparoscope, a fiberoptic instrument inserted into the abdomen.[1]

DIFFERENTIAL DIAGNOSIS

- There are a number of indications for a laparoscopic cholecystectomy. The widespread use of ultrasonography has led to an increasing detection of patients with asymptomatic gallstones and the management of these patients is controversial because only 2% to 3% of these patients become symptomatic per year.
- The indications in asymptomatic patients are the following:
  - Patients who are immunocompromised or awaiting organ allotransplantation or have sickle cell disease
  - Presence of gallbladder polyps that are bigger than 10 mm or are increasing in size rapidly
  - Porcelain gallbladder
  - Gallstones bigger than 3 cm in diameter in areas with high prevalence of gallbladder cancer
- The indications in symptomatic patients are the following:
  - Episodes of biliary colic in patients with identified gallstones
  - Acute cholecystitis
  - Patients with biliary dyskinesia diagnosed with cholecystokinin-HIDA cholescintigraphy
  - Patients with gallstone pancreatitis with no choledocholithiasis based on imaging and laboratory values
  - Patients with choledocholithiasis. In most situations, cholecystectomy follows ERCP for extraction of the common bile duct stones.

PATIENT HISTORY AND PHYSICAL FINDINGS

- A good medical history is necessary to provide information about associated comorbidities that may affect the patient's tolerance to pneumoperitoneum or operative treatment in general.
- Patients with cardiorespiratory disease may not tolerate the impact of CO_2 pneumoperitoneum on cardiac output or CO_2 elimination.
- Coagulopathic disorders or anticoagulants should be identified and managed.
- Medical history can identify the patients who have a higher risk for choledocholithiasis (patients with jaundice, gallstone pancreatitis, or cholangitis).
- Physical examination of the abdomen reveals any surgical scars, hernias, or stomas that may alter the port placement. Previous abdominal surgery does not preclude attempt at laparoscopic cholecystectomy. Adhesive disease is a rare indication for conversion to an open procedure.

IMAGING AND OTHER DIAGNOSTIC STUDIES

- Ultrasonography is now the gold standard for the noninvasive diagnosis of cholelithiasis. This imaging test is highly accurate (>96%), can be performed at the patient's bedside, and does not require the use of ionizing radiation. Gallstones must fulfill three major sonographic criteria. They must (1) show an echogenic focus, (2) cast an acoustic shadow, and (3) seek gravitational dependence (**FIG 1**). Presence of a dilated common bile duct during ultrasonography is suggestive of choledocholithiasis. In the case of acute cholecystitis, ultrasound can demonstrate pericholecystic fluid, gallbladder wall thickening, and even a sonographic Murphy's sign, documenting tenderness specifically over the gallbladder.
- In atypical cases, a hepatobiliary iminodiacetic acid (HIDA) cholescintigraphy scan may be used to demonstrate obstruction of the cystic duct, which definitively diagnoses cholecystitis. Filling of the gallbladder during a HIDA scan essentially eliminates the diagnosis of cholecystitis (**FIG 2**).
- HIDA scan is the diagnostic tool of choice in biliary dyskinesia and is performed with the concurrent administration of cholecystokinin. An ejection fraction of less than 20% is suggestive of the disease.
- If there is suspicion of choledocholithiasis, as in patients with jaundice, pancreatitis, cholangitis, or dilated common bile duct on ultrasonography, the biliary tree can be delineated and inspected for presence of gallstones with the use of magnetic resonance cholangiopancreatography (MRCP) (**FIG 3**). MRCP is highly sensitive (>90%) and almost has a 100% specificity. As a noninvasive test, MRCP provides accurate imaging of the biliary tree, but in the setting of choledocholithiasis, it does not provide a therapeutic solution.
- Endoscopic retrograde cholangiopancreatography (ERCP) can be used as a diagnostic and therapeutic modality (**FIG 4**). In the presence of stones in the common bile duct during ERCP, a sphincterotomy is performed to allow enlargement of the papilla and subsequent extraction of stones with a balloon or basket (**FIGS 5** and **6**). With this approach, more than 80% of all stones can be removed successfully. Larger stones may

FIG 1 ● Ultrasound of the abdomen showing multiple gallstones in the lumen of the gallbladder. There is no gallbladder thickening or pericholecystic fluid, thus acute cholecystitis is ruled out.

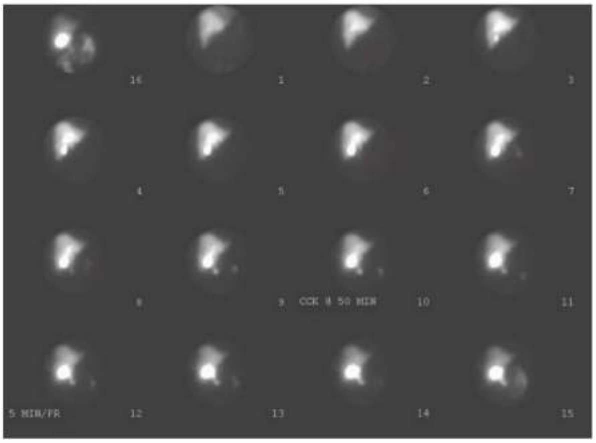


FIG 2 ● HIDA cholescintigraphy scan. Filling of the gallbladder during a HIDA scan, as in this study, essentially eliminates the diagnosis of cholecystitis.

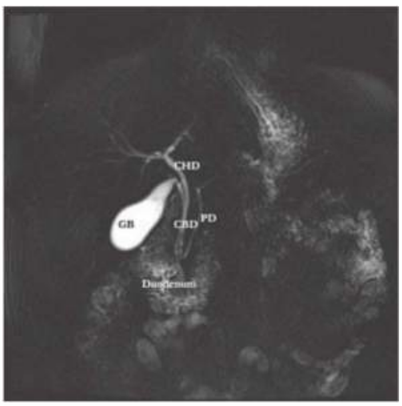


FIG 3 ● Magnetic resonance cholangiopancreatography (MRCP). Note the filling defect in the distal common bile duct suggestive of choledocholithiasis. *CBD*, common bile duct; *CHD*, common hepatic duct; *GB*, gallbladder; *PD*, pancreatic duct.

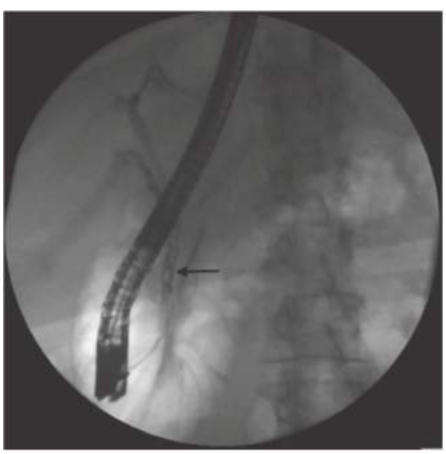


FIG 4 ● Endoscopic retrograde cholangiopancreatography (ERCP). The *solid arrow* shows filling defect in the distal common bile duct, suggestive of choledocholithiasis.

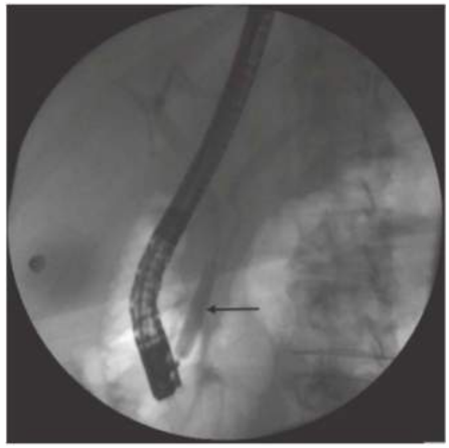


FIG 5 ● ERCP on the same patient with sphincterotomy and balloon sweeping of all common bile duct stones. The *solid arrow* shows the endoscopic balloon.

require additional removal techniques such as mechanical or intraductal lithotripsy. ERCP has a complication rate of around 8%; complications are sedation-related, pancreatitis, bleeding, perforation, and infection.

- Preoperative laboratory studies should include liver function, renal function, electrolyte, and coagulation studies. Abnormal liver function studies may reflect choledocholithiasis or primary hepatic dysfunction.

SURGICAL MANAGEMENT

Preoperative Planning

- In the preoperative area, the patient is asked if any conditions exist that were not present during the last clinic visit and would factor in the operative decision making; for example, a recent myocardial infarction or other cerebrovascular event.
- The patient is asked to void just prior to transfer to the operating room so as to avoid placement of a Foley catheter that is not indicated for an elective laparoscopic cholecystectomy.
- The operative consent, imaging, and laboratory values are reviewed.

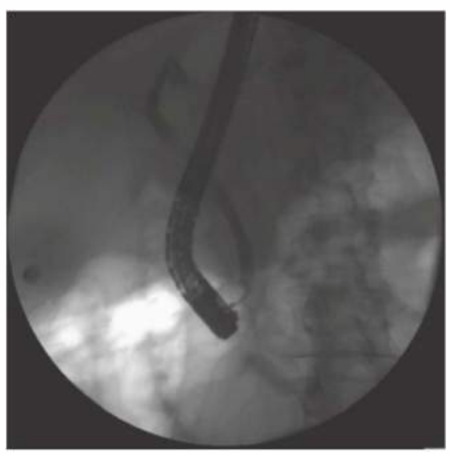


FIG 6 ● Completed ERCP showing a patent common bile duct and absence of filling defects.

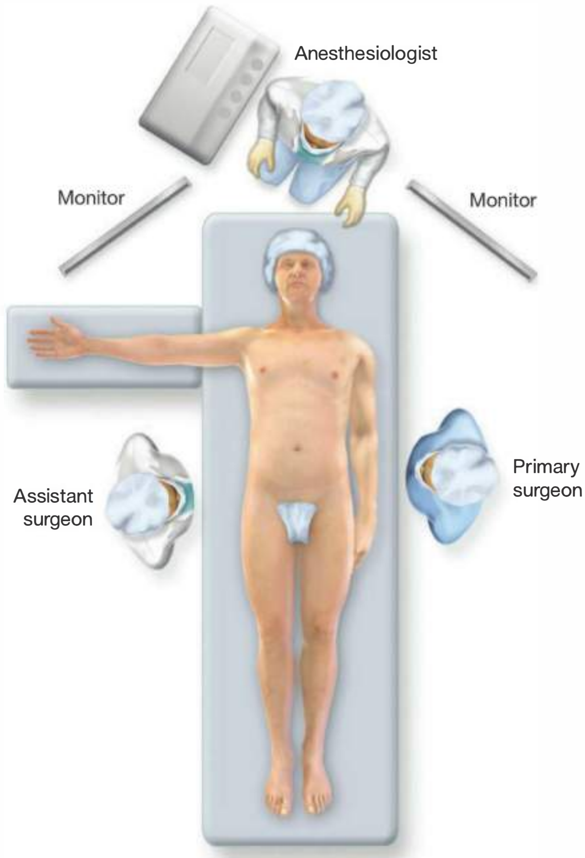


FIG 7 ● The patient is placed in a supine position with the left arm tagged and the right arm extended. The primary surgeon stands to the left of the patient and the assistant to the right of the patient.

Positioning

- The patient is placed in a supine position with the right arm extended and the left arm is secured along the patient's torso (**FIG 7**).
- A footboard is placed at the patient's feet, and the patient is strapped at the thighs and the legs to avoid a fall from the bed during steep reverse Trendelenburg position (**FIG 8**).
- Heel pads, sequential compression devices for deep venous thrombosis prophylaxis, and warming devices are also placed.
- An orogastric tube is inserted to decompress the stomach.
- The primary surgeon stands at the patient's left and the assistant surgeon at the patient's right (**FIG 7**).
- Two monitors are placed at the head of the bed, one on the right and one on the left, facing the surgeon and the assistant.
- The laparoscopic camera, light source, insufflation tubing, suction, and electrocautery are passed to a tower at the feet of the patient.

FIG 8 ● The patient is strapped at the thighs and legs and a footboard is placed to support the patient during reverse Trendelenburg.

ENTRY INTO THE PERITONEAL CAVITY AND ACHIEVING PNEUMOPERITONEUM

- The base of the umbilicus is grasped with two penetrating towel clips and is elevated for easier access. A 5-mm incision is created at the base of the umbilicus with the use of a no. 11 blade. The base of the umbilicus is chosen because it gives a better cosmetic result.
- Through this incision, a Veress needle is introduced into the peritoneal cavity (**FIG 9**). A syringe with saline is attached to the Veress needle. First, aspirate the syringe to rule out placement of the Veress needle in the lumen of intestine or a vessel. Then infuse saline to determine if it will flow through the needle without resistance. This finding signifies that the needle is in the peritoneal cavity and not in the subcutaneous tissues. The insufflation tubing is attached to the Veress needle and pneumoperitoneum is achieved with 15 mmHg of CO_2.
- Next, a 0-degree laparoscope is inserted in a 5-mm OptiView port, and the port is inserted in the peritoneal cavity through the same incision under direct vision (**FIG 10**).
- Alternatively, if the patient has a midline scar and a history of multiple intraabdominal procedures, entry into the peritoneal cavity is achieved through an incision in the left subcostal area just inferior to the rib in the anterior axillary line.

FIG 9 ● Placement of the Veress needle.

FIG 10 ● With the laparoscope inserted in a 5-mm port, the surgeon places the first port under direct vision. Notice that the surgeon watches the monitor as he advances the port.

PLACEMENT OF THE OTHER PORTS

- Once the first port is in place, inspect the intestines immediately beneath the incision to rule out any inadvertent injury. The 0-degree scope is replaced with a 30-degree scope that allows views through different angles.
- The patient is then placed in reverse Trendelenburg position. The gallbladder is typically easy to visualize following this maneuver.
- The next additional port to be placed is a 5-mm port in the patient's right flank. The port is placed in the anterior axillary line around two fingerbreadths below the costal margin. Through this port, the assistant surgeon grasps the fundus of the gallbladder and retracts the gallbladder and the liver in an anterior and cephalad direction toward the diaphragm. This facilitates visualization of the triangle of Calot. If the gallbladder is very distended and inflamed, making it hard to be grasped, the gallbladder may be deflated with an endoscopic needle.
- If the anatomy of the liver precludes visualization of the triangle of Calot, an additional 5-mm port is placed in the left anterior axillary line at the level of the costal margin and a liver retractor inserted.
- With this exposure, precise placement of the working port is determined. This is typically a 12-mm port that is placed in the epigastrium just below the xiphoid process and to the right of the falciform ligament. Ideally, the port is situated above the triangle of Calot just inferior to the liver edge.
- The third port placed is a 5-mm port in the midclavicular line allowing for adequate spacing between the ports (**FIG 11**).

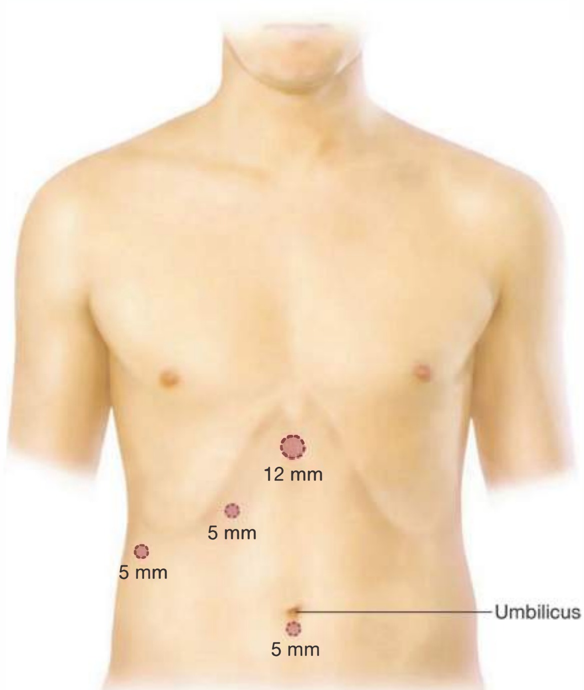


FIG 11 ● Placement of the four ports.

- The assistant surgeon holds the camera and the right flank port retracting the gallbladder, whereas the primary surgeon works through the epigastric and midclavicular ports.

EXPOSURE OF THE TRIANGLE OF CALOT

- With the use of a blunt dissector through the epigastric port, any adhesions between the gallbladder and the omentum or transverse mesocolon are divided, always taking such adhesions along the wall of the gallbladder to minimize bleeding (**FIG 12**).
- A grasping forceps, through the 5-mm midclavicular line port, is used to grasp the gallbladder at the Hartman's pouch and provide lateral traction (**FIG 13**). This maneuver retracts the gallbladder away from vital structures and puts the cystic duct at a 90-degree angle to the common bile duct, minimizing the risk of inadvertent injury to the hepatic or common bile ducts.
- The peritoneum is then bluntly dissected off the gallbladder to expose the infundibulum–cystic duct junction. This is done by stripping the peritoneum at the lateral edge of the gallbladder just below where the infundibulum is grasped (**FIG 14**).
- As the peritoneum is dissected from the gallbladder wall, the lymph node of Calot is also often identified. The lymph node overlies the cystic artery and thus is a useful landmark. Peritoneal attachments around the node of Calot can be taken with hook electrocautery in order to minimize bleeding.

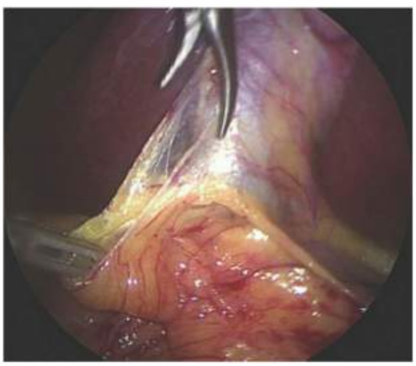


FIG 12 ● Omental adhesions are stripped off from the gallbladder.

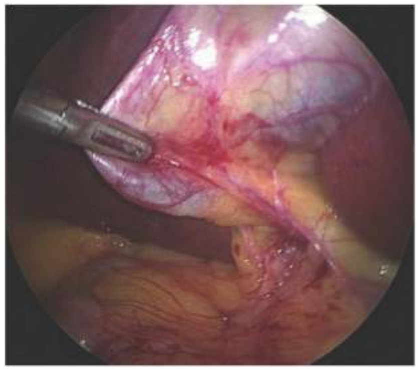


FIG 13 ● The infundibulum is grasped and retracted lateral to the patient's right side. This is a very important maneuver as it places the cystic duct at a 90-degree angle to the common bile duct and minimizes confusion and potential injury to the common bile duct.

- This initial dissection exposes the triangle of Calot, also known as the hepatocystic triangle, bounded by the cystic duct, the common hepatic duct, and the edge of the liver. The content of the triangle is the cystic artery (**FIG 15**).

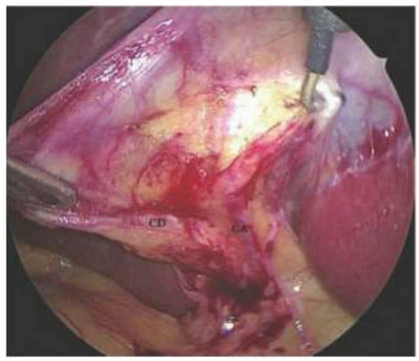


FIG 14 ● The peritoneum is dissected off the gallbladder and the structures are becoming visible, exposing the triangle of Calot. Notice the dissection is carried high along the body of the gallbladder so that injury to the hepatic or common bile duct is avoided. *CA*, cystic artery; *CD*, cystic duct.

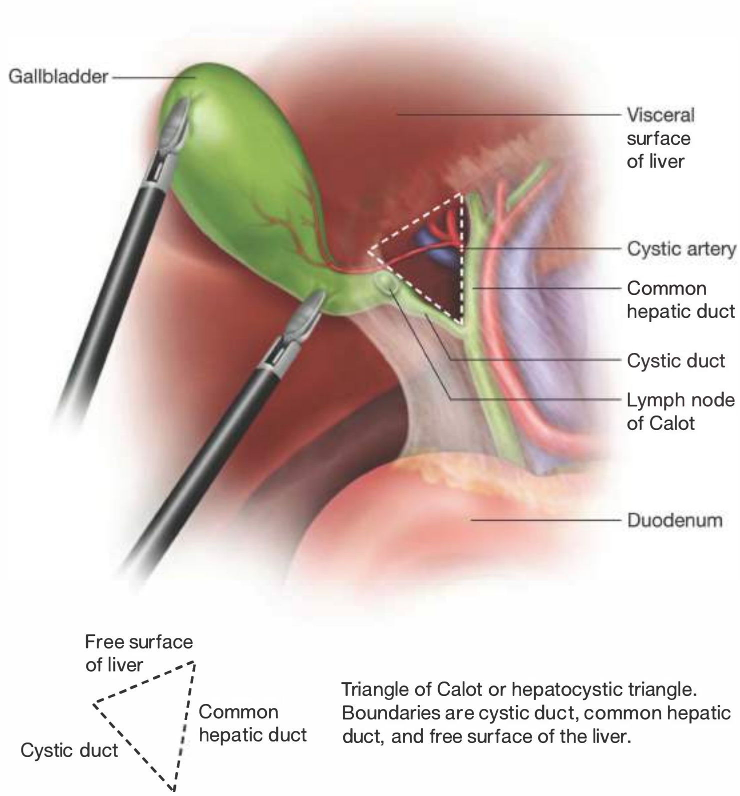


FIG 15 ● Schematic drawing showing the triangle of Calot, its borders and the content of the triangle, and the cystic artery. The *interrupted lines* represent the borders of the triangle. Notice the lymph node of Calot, immediately above the cystic artery. It can act as landmark for identification of the cystic artery.

EXPOSURE OF THE REVERSE TRIANGLE

- The reverse side of the hepatocystic triangle is bordered by the cystic duct, the inferior lateral border of the gallbladder, and the right lobe of the liver.
- In order to expose the reverse triangle, the infundibulum is retracted medially and superiorly and then peritoneal attachments are taken bluntly or with the hook electrocautery (**FIG 16**). This enables one to further identify the cystic duct and cystic artery, and maneuvering the infundibulum from medial to lateral, exposure of both triangles is realized and the ability to circumferentially dissect the cystic duct and cystic artery.
- Importantly, division of the posterior triangle peritoneum early in the dissection can dramatically impact exposure to the anterior triangle by facilitating retraction of the infundibulum away from other portal structures.

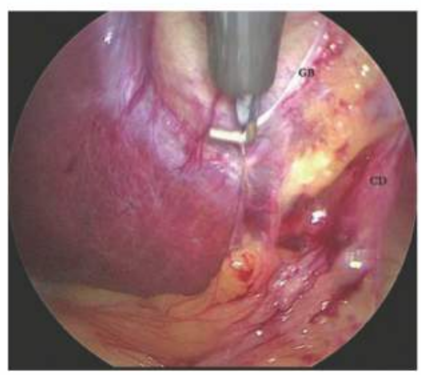


FIG 16 ● Exposure of the reverse triangle. The gallbladder *(GB)* is retracted medially and the reverse triangle can be exposed by dissection of the peritoneum off the structures. *CD*, cystic duct.

THE CRITICAL VIEW

- It is of paramount importance to obtain a critical view of the cystic duct and artery prior to clipping or dividing any structures. This view is obtained when both the cystic duct and cystic artery are circumferentially dissected and windows have been created between the two structures and medial to the cystic artery (**FIG 17**). Ideally, the medial wall of the gallbladder is dissected up to the liver. This visualization minimizes the risk of dividing the hepatic or common bile duct or an aberrant branch of the right hepatic duct. The dissection medial to the cystic artery reduces the risk of injuring a meandering right hepatic artery that is also at risk for inadvertent injury.

- Should this dissection and exposure be limited by inflammation or other factors such as an intrahepatic gallbladder, a hypertrophied left lobe of the liver, or aberrant anatomy, a retrograde dissection of the gallbladder as is classically done during the open procedure can be considered or the decision for conversion to an open procedure should be made.

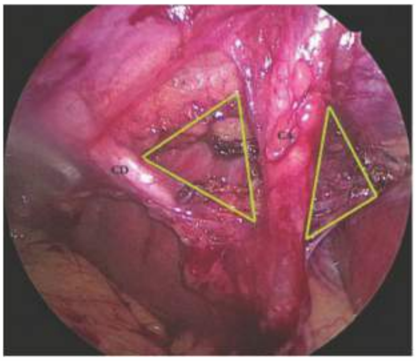


FIG 17 ● The critical view. The two triangles show the windows that need to be formed between the cystic duct and the cystic artery and medial to the cystic artery. The surgeon should be able to see the visceral surface of the liver through these windows. *CA*, cystic artery; *CD*, cystic duct.

DIVISION OF THE CYSTIC DUCT AND CYSTIC ARTERY

- Once the critical view is obtained, the two structures can safely be clipped and divided with laparoscopic shears. A clip applier is introduced through the epigastric port, and the cystic artery and cystic duct are clipped with two to three clips proximally and one clip distally (**FIG 18**). The posterior jaw of the clip applier should be visualized across the structure to assure that the clip will traverse the entire lumen of each structure. Once both structures are divided, the clipped stumps of the two structures are inspected (**FIG 19**). An alternative approach for a large caliber cystic duct or friable tissues is the use of a laparoscopic endoloop or stapling device to control the duct.

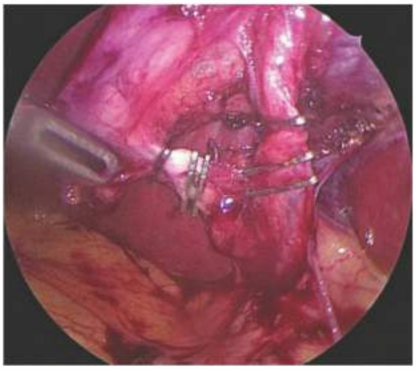


FIG 18 ● Clipping of the cystic duct and cystic artery.

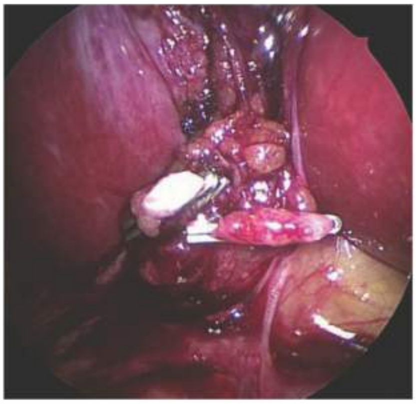


FIG 19 ● Inspecting the clipped stumps of both structures.

DISSECTION OF THE GALLBLADDER OFF THE GALLBLADDER FOSSA

- Next, the gallbladder is dissected from attachments to the undersurface of the liver using hook and/or spatula electrocautery. The infundibulum is grasped and elevated toward the anterior abdominal wall and lateral to create tension and the body of the gallbladder is dissected off the gallbladder fossa (**FIG 20**). In order to dissect the lateral side of the gallbladder, the infundibulum is retracted medially and superiorly and again the hook electrocautery dissects the whole length of the lateral wall of the gallbladder (**FIG 21**). Prior to completely freeing the gallbladder, it can be used as a handle to lift the liver and inspect the operative bed for bleeding. The gallbladder is then completely separated from the liver (**FIG 22**).

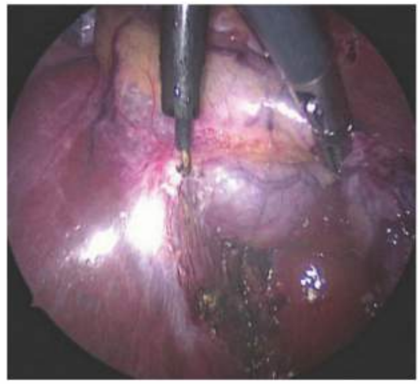


FIG 21 ● Dissection of the lateral wall of the gallbladder off the gallbladder fossa.

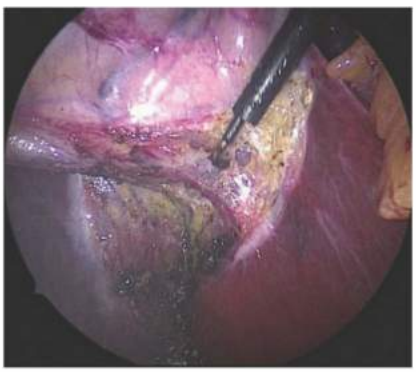


FIG 20 ● Dissection of the gallbladder fossa with electrocautery.

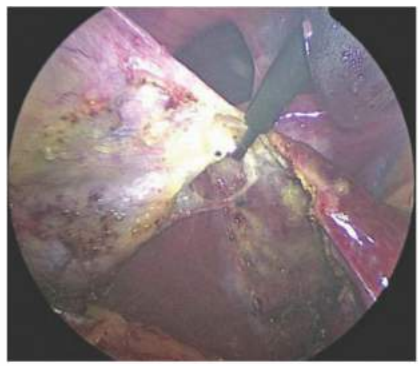


FIG 22 ● The gallbladder is pulled away from the liver, and the tip of the fundus is divided from the liver to complete the gallbladder dissection.

EXTRACTION OF THE GALLBLADDER

- The gallbladder is now completely dissected off the liver. A 10-mm specimen bag is introduced through the epigastric port and opened facing the camera. The gallbladder is placed in the specimen bag (**FIG 23**) and then extracted through the port site. If the gallbladder is too big or contains large stones, the port incision may need to be extended to accommodate the bigger gallbladder.
- The specimen is sent to pathology for histologic examination.

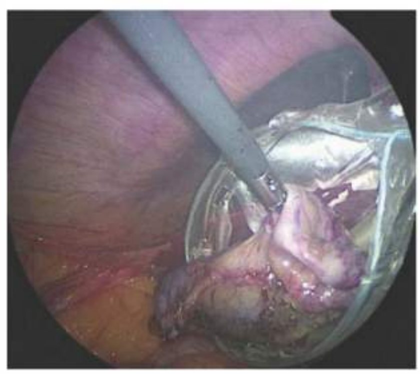


FIG 23 ● The gallbladder is placed in an EndoCatch bag.

CLOSURE

- The epigastric port is closed at the fascial level with the use of a transfascial suture passer and 0 braided absorbable suture (**FIG 24**).
- The other ports are retrieved under direct vision to rule out hemorrhage at the port sites.
- Once hemostasis is confirmed at the port sites, the peritoneum is deflated and the skin incisions are closed with subcuticular 4-0 monofilament absorbable suture.

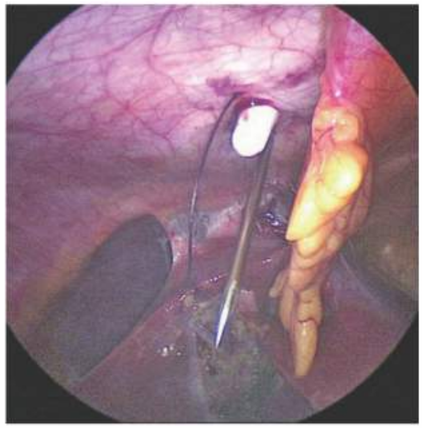


FIG 24 ● The incision is reapproximated with a transfascial suture passer and 0 braided absorbable suture.

PEARLS AND PITFALLS

Placement of 12-mm port	■ Many authors place the 12-mm port in the umbilicus. We advocate placement of the 12-mm port in the epigastrium because the umbilicus is the weakest point of the abdominal wall and the risk of incisional hernia is higher. Furthermore, if a hernia develops at the epigastric port, the risk of bowel incarceration is very low because the port is very high and above the liver, minimizing the risk of strangulation or incarceration.
Intraoperative cholangiogram	■ A surgeon performing laparoscopic surgery should be facile and comfortable performing an intraoperative cholangiogram. We do not advocate routine performance of cholangiograms, but there should be a **very low threshold** for performing a cholangiogram in cases of questionable anatomy or suspicion of injury.
Dissection of triangle of Calot	■ Dissection of the peritoneum to identify the structures should be done *as close* to the gallbladder as possible. This minimizes the risk of injury to the hepatic or common bile duct which lies deeper.
Two-handed skills	■ In the above description, the primary surgeon uses two hands to retract the gallbladder and dissect at the same time. In a teaching institution, or when a laparoscopic novice is performing the cholecystectomy, two-hand laparoscopic cholecystectomy is a very good starting procedure to obtain bimanual dexterity before embarking on more complex laparoscopic cases.
Spilled stones	■ Every effort should be made to avoid perforation of the gallbladder and spillage of gallstones. If this happens, all gallstones should be retrieved to avoid associated complications such as postoperative granulomas or abscesses.

POSTOPERATIVE CARE

- The majority of laparoscopic cholecystectomies are performed as outpatient surgery and thus patients are discharged home on the same day. If the procedure is performed in the setting of resolved pancreatitis or choledocholithiasis on a patient who was already hospitalized, an overnight postoperative stay is the norm. A diet can be initiated immediately.

COMPLICATIONS

- The overall perioperative mortality varies between 0% and 0.3%.[2,3]
- The overall incidence of bile duct injuries requiring corrective surgery varies between 0.1% and 0.3%. Corrective surgery for bile duct injury carries its own risks including perioperative mortality (1% to 4%), secondary biliary cirrhosis (11%), anastomotic stricture (9% to 20%), and cholangitis (5%).[4,5]
- Other complications include the following:
  - Bile leak treated conservatively (0.1% to 0.2%), radiologically (0% to 0.1%) or endoscopically (0.05% to 0.1%), or by operation (0% to 0.05%).
  - Peritonitis requiring reoperation, typically from a missed, inadvertent enterotomy (0.2%)
  - Postoperative bleeding requiring operation (0.1% to 0.5%)
  - Intraabdominal abscesses requiring operation (0.1%)

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Chapter 2

Open Cholecystectomy

Sean P. Montgomery   Preston B. Rich

DEFINITION

- Removal of the gallbladder for benign disease using an open technique when the laparoscopic technique is not prudent.

DIFFERENTIAL DIAGNOSIS

- Acute cholecystitis
- Symptomatic biliary colic
- Acalculous cholecystitis
- Diseases that can present similarly and are not treatable by simple cholecystectomy include peptic ulcer disease, hepatitis, pancreatitis, cholangitis, gallbladder cancer, colitis, irritable bowel syndrome, and atypical appendicitis.

PATIENT HISTORY AND PHYSICAL FINDINGS

- Biliary colic (symptomatic cholelithiasis) is typically a right upper quadrant (RUQ) or epigastric postprandial pain. Symptoms classically start 30 to 90 minutes after eating and association with high-fat meals may be described. Nausea and bloating are common. The pain typically will resolve within 6 hours. Pain lasting more than 6 hours and/or fever is suggestive of acute cholecystitis.
- On physical examination, tenderness will usually be present in the RUQ. The presence of a Murphy's sign (inspiratory arrest with RUQ palpation) is suggestive of acute cholecystitis.

IMAGING AND OTHER DIAGNOSTIC STUDIES

- A fasting RUQ ultrasound is the "gold standard" for the diagnosis of gallstones and is frequently the only imaging necessary to diagnose acute cholecystitis. Gallstones are identified as mobile echogenic foci with posterior shadowing (**FIG 1**). Cholecystitis is suggested by gallbladder wall thickening (>3 mm), pericholecystic fluid, or inspiratory arrest elicited by placement of the ultrasound probe directly over the gallbladder (a sonographic Murphy's sign). The sensitivity and specificity of ultrasound for calculous cholecystitis are around 82%.[1] In critically ill patients with acalculous cholecystitis, the specificity drops significantly.
- The other common imaging study used to diagnose gallbladder pathology is a nuclear medicine test called either hepatobiliary scintigraphy or a hepatobiliary iminodiacetic acid (HIDA) scan (commonly referred to as a HIDA scan.) In this test, a radiolabeled substrate is intravenously administered, taken up by the liver, and excreted into the biliary tree (**FIG 2**). If the substrate fails to fill the gallbladder within 1 hour, the sensitivity is 96% for acute cholecystitis.[1] A HIDA scan will also provide information about obstruction of the common bile duct, as substrate will be seen accumulating in the duodenum if the duct is not obstructed. In the setting of hepatic failure or cholestasis, this study is not useful, as the liver often will not take up enough substrate to allow an adequate study. Gallstones are not revealed with this study, but rather, the presence or absence of cholecystitis is determined by assessing patency of the cystic duct regardless of the etiology. HIDA scintigraphy is generally performed if the clinical findings and ultrasound are inconclusive for calculous cholecystitis or in critically ill patients with suspected acalculous cholecystitis.[2]

SURGICAL MANAGEMENT

Preoperative Planning

- The vast majority of patients will be appropriate candidates for a laparoscopic cholecystectomy. Conversion from laparoscopy due to variable anatomy or severe inflammation is the most common indication for the open procedure. Rare patients in whom a primary open cholecystectomy should be considered are the following:
  - Septic patients on vasoactive agents for hemodynamic support that have failed percutaneous drainage
  - Patients with complicated anterior abdominal walls and/or severe adhesions. Specifically, if there are large pieces

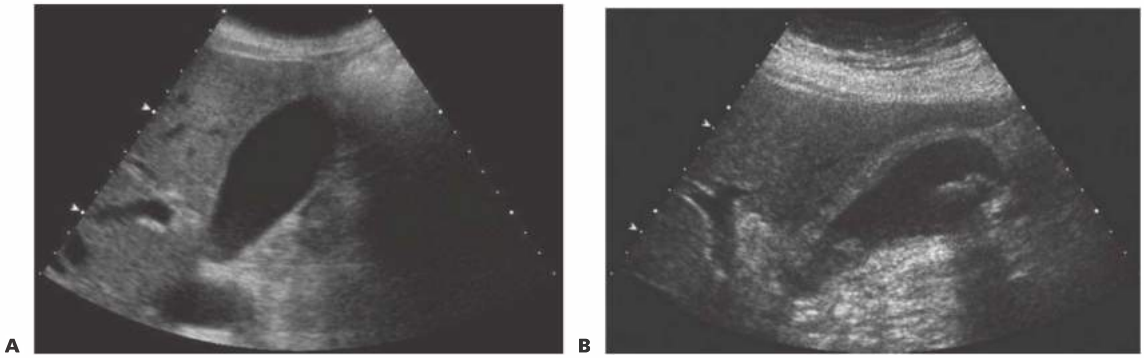
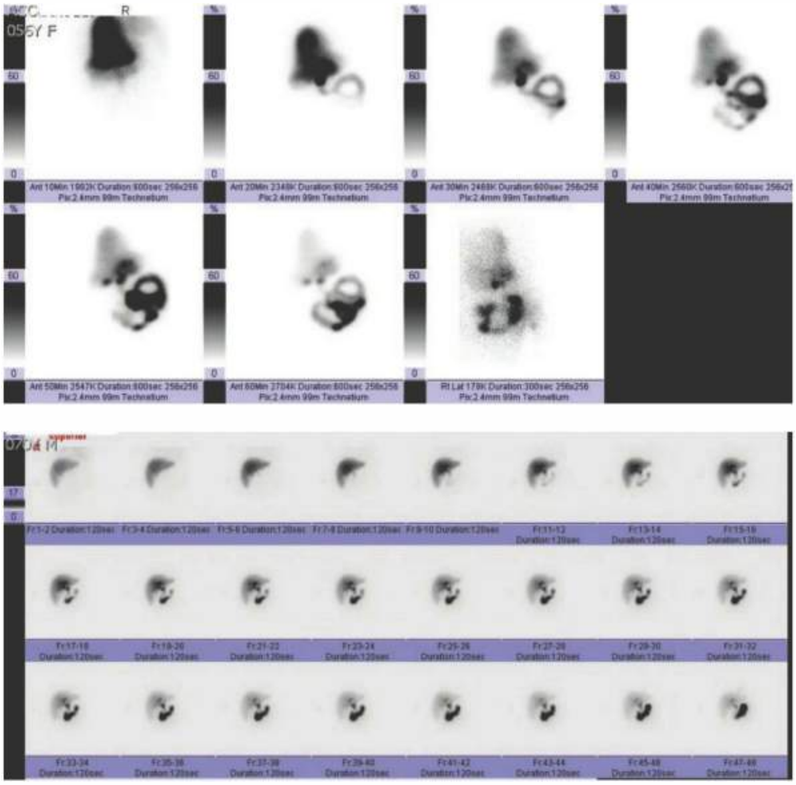


FIG 1 ● Gallbladder ultrasound. Figure **A** demonstrates the normal ultrasound appearance of the gallbladder. In Figure **B**, the presence of gallstones, thickening of the gallbladder wall, and gallbladder wall edema are suggestive of acute cholecystitis.



A

B

FIG 2 ● HIDA scintigraphy. In Figure **A**, tracer promptly fills the gallbladder and duodenum, demonstrating normal gallbladder physiology and a nonobstructed biliary system. In Figure **B**, nonfilling of the gallbladder at 1 hour following substrate injection is consistent with acute cholecystitis.

of prosthetic mesh in the umbilical and epigastric areas and/or prior RUQ surgery, laparoscopic completion of a cholecystectomy can be challenging.

- The need for concomitant open common bile duct exploration

Positioning

- The patient is positioned supine. Arms can be tucked by the side or extended out at right angles to the bed. An oral or nasal tube for gastric decompression is placed.

INCISION

- The gallbladder is most easily accessed through an oblique RUQ incision (**FIG 3**). The incision should be placed two fingerbreadths below the right costal margin to facilitate fascial closure. In patients with significant hepatomegaly, the incision may be moved inferiorly to two fingerbreadths below the palpable liver edge, but this should rarely be necessary. The incision is carried down to the fascia.

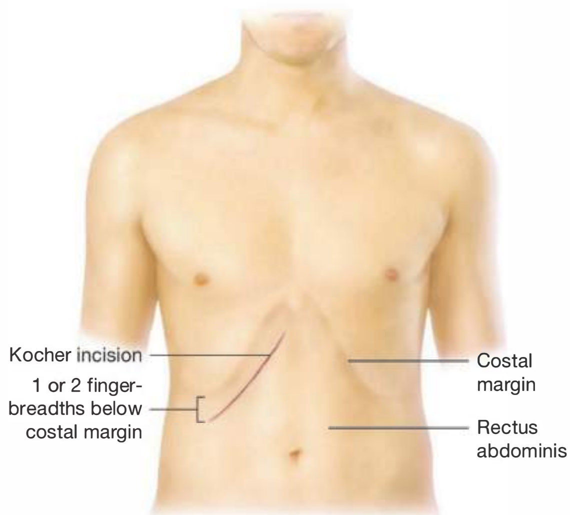


FIG 3 ● Incision. An oblique RUQ incision is created two fingerbreadths below the costal margin (Kocher's incision). The right rectus abdominis muscle is divided before entering the abdominal cavity.

OPENING OF THE ABDOMINAL WALL

- The anterior rectus fascia should be incised with electrocautery. A Kelly or other large clamp is placed under the lateral border of the rectus muscle, retracting it anteriorly, to facilitate division of the muscle with electrocautery. The superior epigastric vessels can be encountered, typically about halfway across the rectus. The vessels can be ligated or cauterized, or they can be reflected medially and preserved with the medial half of the rectus.

PLACEMENT OF RETRACTORS

- This step is the key to a successful operation. Safely keeping the bowel out of the operative field and delivering the gallbladder to the center of the wound will make the remainder of the case straightforward with proper exposure. A Bookwalter fixed retractor or other table-mounted retractor should be used (**FIG 4**). In cases of dense adhesions to the gallbladder, start with body wall retractors placed inferiorly and superiorly. In cases of minimal adhesions or after some initial adhesiolysis, use moist laparotomy pads to push the transverse colon and duodenum inferior and medial, respectively, away from the gallbladder. Malleable or long right-angle retractors for the retractor should be placed inferomedially and inferolaterally to hold these lap pads away from the gallbladder. A deep body wall retractor may be required inferiorly to adequately open the space between the duodenum and gallbladder. Superomedially, a flat deep retractor, such as a Harrington (or *Sweetheart*) or medium right-angle should be placed against the liver to pull it to the superior aspect of the wound. A superolateral body wall retractor can be progressively exchanged for deeper retractors as the gallbladder is progressively dissected from the gallbladder bed to elevate the liver and separate it from the gallbladder. A Kelly or large clamp is then placed on the infundibulum of the gallbladder to facilitate moving it within the space created.

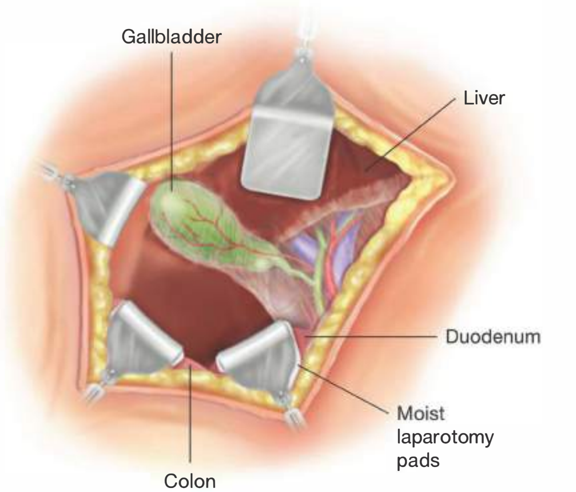


FIG 4 ● Placement of retractors. Correct application of a fixed retracting device (Bookwalter) is the key to a successful and safe open cholecystectomy. Inferiorly, moist laparotomy pads are carefully placed behind deep retractors to exclude the duodenum, colon, and small bowel from the operative field. Superiorly, additional retractors are placed to retain the liver. As the gallbladder is dissected free from its bed, the more lateral superior retractor can be progressively exchanged for deeper retractors placed over the dissected bed to improve visualization.

INCISION OF THE VISCERAL PERITONEUM

- The peritoneum is incised just off the liver edge at the most anterior point of the gallbladder (**FIGS 5** and **6**). A tonsil or other fine-tipped dissector is used to enter the plane between the peritoneum and the gallbladder. Electrocautery is then used to open the peritoneum. This is repeated for the other side of the gallbladder.

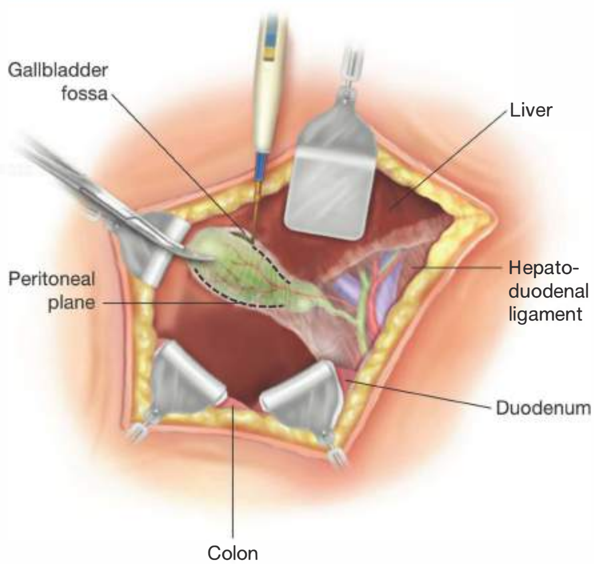


FIG 5 ● Incision of the peritoneum and dissection of the gallbladder from the gallbladder fossa. The infundibulum is grasped with a large clamp (Kelly) to facilitate mobilization. The peritoneum (serosa of the gallbladder) is incised 3 to 5 mm from the interface with the substance of the liver and the areolar tissue between the gallbladder and the liver is divided with electrocautery. The gallbladder is dissected in a top-down fashion toward the porta hepatis.

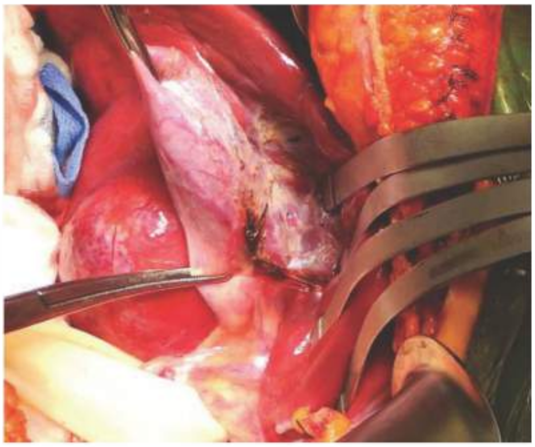


FIG 6 ● Ligation of the cystic duct and cystic artery. After the gallbladder has been dissected free from its bed, a combination of blunt and sharp dissection is used to isolate the cystic duct and cystic artery. Dissection should be directed from the gallbladder toward the portal structures to avoid injury. Both structures are divided separately between ligatures. Care should be taken to not apply electrocautery when in proximity to the colon, duodenum, or portal structures.

RETROGRADE DISSECTION OF THE GALLBLADDER OFF OF THE GALLBLADDER FOSSA

- Electrocautery is then used to dissect the gallbladder free from the liver. This is performed in a top-down fashion, starting anteriorly and continuing until the gallbladder is suspended from its pedicle.

LIGATION OF THE CYSTIC DUCT AND ARTERY

- After the gallbladder has been dissected free from its bed, a combination of sharp and blunt dissection is performed around the pedicle until the artery and duct are dissected free (**FIGS 7–9**). Tracing the cystic duct until its intersection with the common bile duct is not necessary if the duct is confirmed to be headed directly out of the gallbladder. Because the most common indication for an open cholecystectomy is the presence of severe inflammation, unnecessary dissection in the porta hepatis can be unsafe and should be avoided if possible. Simple

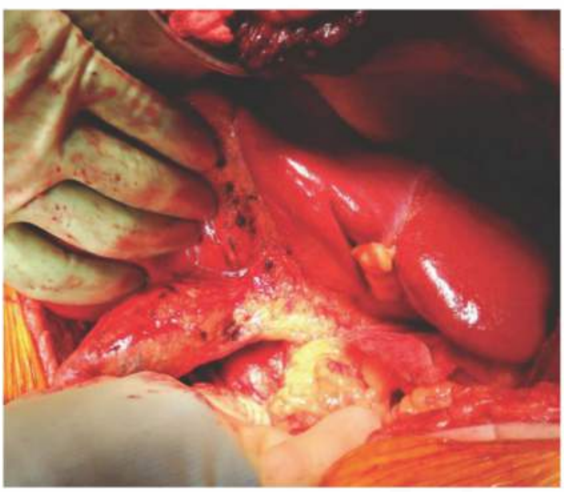
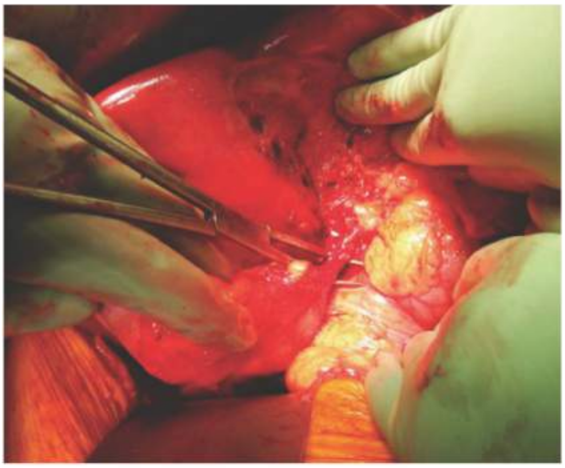


FIG 7 ● Operative photograph of a "top-down" dissection of the gallbladder from the undersurface of the liver. The peritoneum has been incised over the triangle of Calot, exposing adipose tissue around the infundibulum of the gallbladder and the key portal structures.

FIG 8 ● Isolation of the cystic artery. Inferior and lateral retraction facilitates identification of the cystic artery as shown.



ligation of the cystic duct and artery are accomplished with separate ties. The gallbladder is then excised free. If the gallbladder or cystic duct appears necrotic, a drain should be placed to control a bile leak should one occur.

FIG 9 ● Isolation of the cystic duct. Once the cystic artery has been ligated and divided, the cystic duct is circumferentially dissected.

ALTERNATIVE: SUBTOTAL CHOLECYSTECTOMY

- Open cholecystectomy is usually reserved for cases with severe inflammation. In some patients, the inflammation may be so severe that dissection around the neck of the gallbladder to identify the cystic duct becomes unsafe. If the cystic duct cannot be safely identified and dissected free due to adhesions, a subtotal cholecystectomy may be performed. In this case, the gallbladder neck is dissected to the region where inflammation prohibits further dissection. The gallbladder is then transected at that point and the internal opening of the cystic duct is ligated with suture (**FIG 10**). If a significant portion of the gallbladder wall remains, the remainder of the gallbladder fulgurated and then the edges of the wall are sewn closed with a running monofilament suture. In these cases, a drain should be left, as the incidence of bile leak after subtotal cholecystectomy can be in excess of 20%.[3] It is for this reason that a complete cholecystectomy is performed whenever the cystic duct can be safely identified.
- If significant bleeding from the liver is encountered, such as in unsuspected portal hypertension, the back wall of the gallbladder can be left adherent to the liver.[4,5] Fulguration of any viable mucosa is advised.

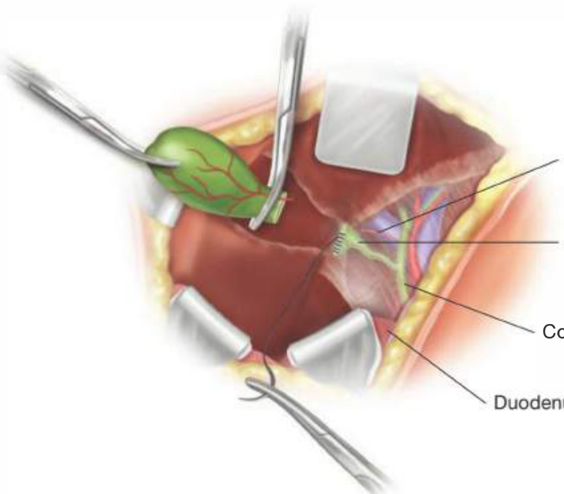


FIG 10 ● Subtotal cholecystectomy. In cases where severe inflammation is encountered, dissection to the cystic duct may be unsafe. In such case, the infundibulum of the gallbladder can be amputated at the junction where dissection must be stopped and the cystic duct opening closed with suture ligature. When a cuff of gallbladder remains, it is fulgurated with electrocautery and closed with a running absorbable monofilament suture.

CLOSURE

- The posterior and anterior fascia should be closed in separate layers. The skin is closed with staples due to the clean-contaminated nature of the procedure.

PEARLS AND PITFALLS

Electrocautery	■ To avoid injury, electrocautery should be avoided when dissecting near the duodenum, colon, biliary structures, or porta hepatis.
Visualization	■ If the colon or duodenum is crowding the operative space, consider a deeper blade for the retractor that is "toed in" slightly on laparotomy pads.
Common bile duct injury	■ If the inflammation is so severe that it is difficult to dissect the cystic duct at the neck of the gallbladder, consider a subtotal cholecystectomy. In this circumstance, leave a drain.
Bleeding	■ During surgery for acute cholecystitis, inflammatory bleeding is often encountered from the gallbladder fossa during top-down dissection. When present, this can usually be best controlled with a laparotomy sponge and pressure applied directly to the raw surface following separation of the gallbladder from its liver bed. Often, a deeper retractor blade can be placed between the gallbladder and its bed to maintain pressure while also improving visualization.

POSTOPERATIVE CARE

- Ileus is unusual after open cholecystectomy, so diet can be rapidly advanced. Narcotic requirements will be higher than for laparoscopic cholecystectomy and a 2- to 3-day hospital stay may be necessary for adequate pain control.[6] If a cystic duct leak occurs, it will often not be clinically apparent for several days after the original operation (an average of 2.3 days).[7] Therefore, if drains were placed due to a high-risk cystic duct stump, they should be left for several days before being removed.

OUTCOMES

- Long-term outcomes after cholecystectomy are excellent. Short-term morbidities include cystic duct leak, the incidence of which averages about 0.4% for elective patients and threefold higher for emergent cholecystectomies. After subtotal cholecystectomy, issues from the remnant gallbladder are rare.[4,5]

COMPLICATIONS

- Cystic duct leak
- Common bile duct injury (<1/1,000).
- Wound infection
- Hemorrhage from the liver

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Chapter 3 Radical Cholecystectomy

Richard J. Bold

DEFINITION

- Radical cholecystectomy is defined as the resection of the gallbladder and gallbladder fossa and is usually combined with a supraduodenal lymphadenectomy for the treatment of gallbladder cancer.[1] The extent of the hepatic resection may include nonanatomic parenchymal resection of the gallbladder fossa to a standard segment IVb/V resection (**FIG 1**), with data suggesting superior survival from segment IVb/V resection over standard cholecystectomy.[2] The goal of the resection is complete resection of all histopathologic disease, which may necessitate resection of the common hepatic duct/common bile duct if clearance of all disease cannot be obtained by division at the cystic duct/common hepatic duct junction.

DIFFERENTIAL DIAGNOSIS

- A variety of other conditions may mimic adenocarcinoma of the gallbladder. These include benign intraluminal polyps (due to the mass appearance on imaging), chronic cholecystitis (due to collapse of the lumen and associated mural thickening due to chronic inflammation), or hepatic masses within the gallbladder fossa (due to presence of a hepatic mass adjacent to the gallbladder).[3]

PATIENT HISTORY AND PHYSICAL FINDINGS

- The majority of early-stage gallbladder cancers are clinically silent and will not be diagnosed preoperatively but instead will be recognized on final pathology following cholecystectomy performed for other conditions, such as symptomatic cholelithiasis or cholecystitis.[4,5]
- Occasionally, polypoid gallbladder cancers will present with right upper quadrant pain similar to cholecystitis, presumably from the intraluminal mass effect or the obstruction of the fundus/cystic duct. In addition, should the tumor extend down the cystic duct to the common hepatic duct, patients may present with painless jaundice.
- Symptoms of abdominal bloating and/or weight loss should be concerning for the presence of malignant ascites due to peritoneal metastasis, a common site of spread. The liver is the most other common site of metastasis.
- The incidence of gallbladder cancer is three times higher in women than in men.[6]
- Hispanics, American Indians, and Mexican Indians have been identified as high-risk groups for gallbladder cancer.[6]
- Large, multiple gallstones have an increased association with gallbladder cancer; gallstones are present in 60% to 80% of patients with gallbladder cancer.[3]
- Obesity is a risk factor for both gallstones and gallbladder cancer; furthermore, obesity increases the risk for the development of nonalcoholic liver disease, particularly nonalcoholic steatohepatitis (NASH), which may impact the suitability for radical cholecystectomy.[7]
- Radical cholecystectomy involves a partial hepatic resection, and therefore, risk factors for cirrhosis (e.g., alcohol abuse, chronic hepatitis virus infection) are important aspects of the patient's history and evaluation for tolerability of hepatic resection.[8]
- Early-stage gallbladder cancer is usually not apparent on physical examination. Physical findings suggesting advanced disease include the presence of ascites (peritoneal metastasis); painless jaundice (either direct extension into the common hepatic duct or bulky portal adenopathy causing external biliary dilation); and a nontender, palpable gallbladder (concerning for extensive mural involvement). In addition, physical findings of end-stage liver disease raise the suspicion of underlying cirrhosis and therefore preclude radical cholecystectomy.

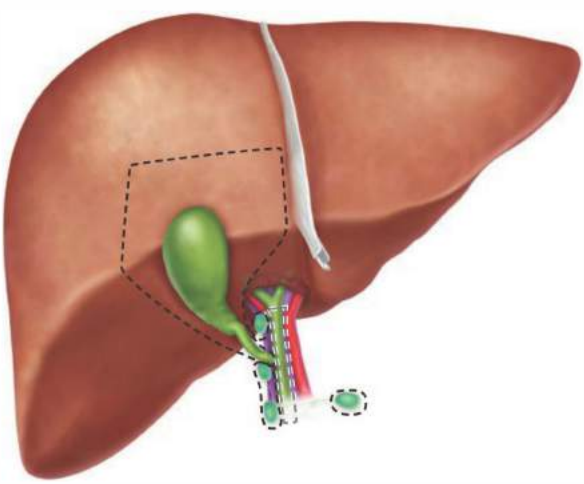

FIG 1 ● Schematic representation of radical cholecystectomy by resection of hepatic segments IV/V *(black dotted lines)* and the gallbladder. Optional resection of the extrahepatic biliary tree is also shown *(gray dotted lines)*.

IMAGING AND OTHER DIAGNOSTIC STUDIES

- Radical cholecystectomy is appropriate only for those patients with T1b, T2, or T3 (primary tumor thickness) or N0 or N1 gallbladder cancer (**FIG 2** and Table 1).[9–14]

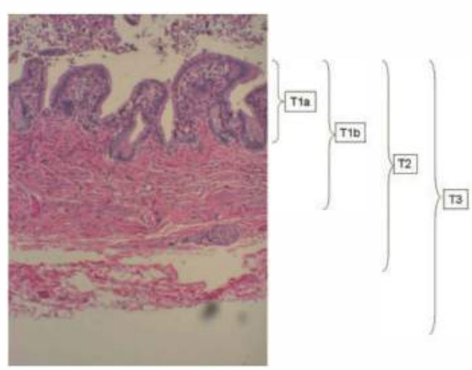

FIG 2 ● Histology of the gallbladder wall with corresponding extent of T1a, T1b, T2, and T3 carcinoma of the gallbladder.

Table 1: American Joint Commission on Cancer Staging System for Gallbladder Cancer

Primary Tumor (T)	Histopathologic Characteristic
TX	Primary tumor cannot be assessed
T0	No evidence of primary tumor
Tis	Carcinoma in situ
T1a	Tumor invades lamina propria
T1b	Tumor invades muscle layer
T2	Tumor invades perimuscular connective tissue; no extension beyond serosa or into liver
T3	Tumor perforates serosa and/or directly invades into the liver and/or one other adjacent organ or structure
T4	Tumor invades main portal vein or hepatic artery or involves multiple extrahepatic structures
Regional Lymph Nodes (N)	
NX	Regional lymph nodes cannot be assessed
N0	No regional lymph node metastasis
N1	Regional lymph node metastasis

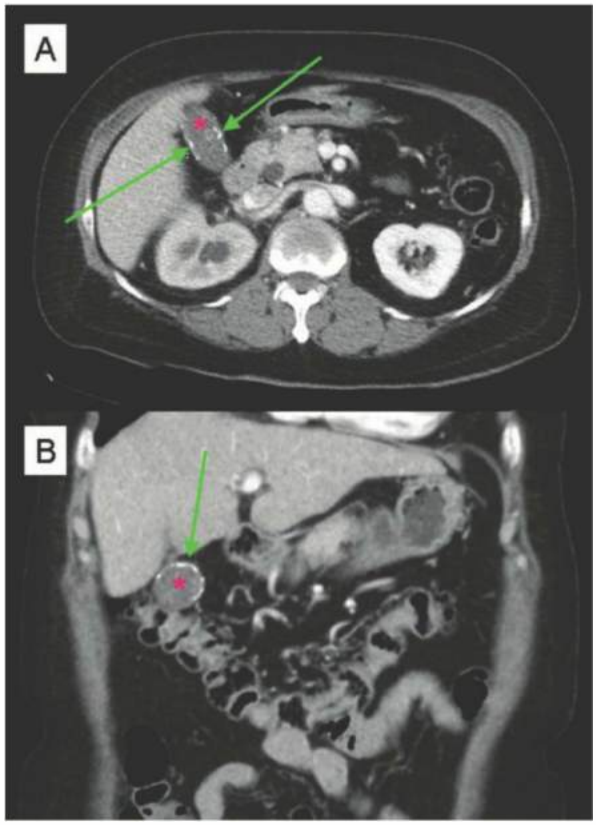

FIG 4 • Axial **(A)** and coronal **(B)** contrast-enhanced CT findings of porcelain gallbladder. The calcification of the gallbladder wall *(green arrows)* is seen as a diffuse process, outlining the lumen of the gallbladder *(red asterisks)*.

- The majority of patients will undergo an initial ultrasound for evaluation of right upper quadrant pain and suspected cholelithiasis. The presence of a gallbladder polyp within the lumen raises the suspicion for gallbladder cancer (**FIG 3**). Given the intraluminal aspect of any polyp, percutaneous biopsy is not usually feasible in the absence of any invasive features beyond the gallbladder wall.[15]
- There is only a weak association between patients with a calcified gallbladder ("porcelain gallbladder") and an underlying gallbladder cancer, such that prophylactic cholecystectomy may no longer be routinely advocated.[16] The calcification of the gallbladder wall may not be readily visible on ultrasound but is clearly seen on contrast-enhanced computed tomography (CT) scans (**FIG 4**). This radiologic finding should prompt concern for gallbladder cancer, even in the absence of any symptoms or associated findings on radiologic imaging.

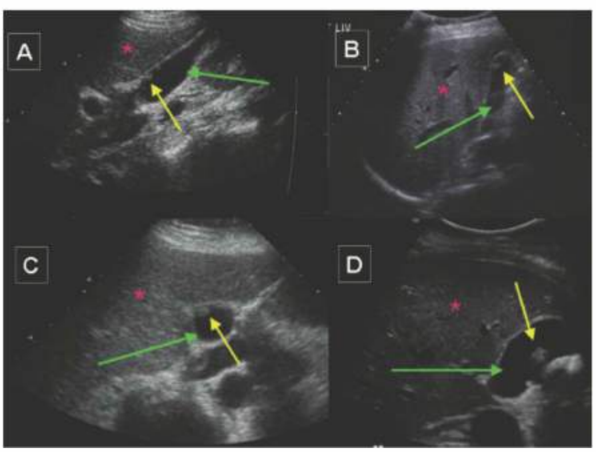

FIG 3 • Longitudinal **(A,B)** and transverse **(C,D)** ultrasonographic imaging of the gallbladder. A polypoid mass *(yellow arrows)* is seen within the gallbladder lumen *(green arrows)*. The relationship of the polypoid mass to the liver *(red asterisks)* can be roughly determined as in **A–C**, likely adjacent to the hepatic fossa, or **D**, likely on the peritoneal/free aspect of the gallbladder.

- If history, physical examination, or ultrasound findings raise concern for gallbladder cancer, contrast-enhanced CT is useful for characterization of the extent of the gallbladder cancer. Radiologic findings of gallbladder cancer on CT include a mass within the gallbladder that typically extends into the lumen or diffuse wall thickening (**FIG 5**).[15]
- Magnetic resonance imaging (MRI) may additionally be useful to characterize any mass seen on either ultrasound or contrast-enhanced CT scan given the ability to differentiate water density (i.e., bile) as well as evaluate any potential involvement of the biliary tree through use of magnetic resonance with cholangiopancreatography (MRCP). Findings on MRI are similar to that of CT scan, including a mass within the gallbladder lumen that is distinct from the density of the hepatic parenchyma and therefore useful for the determination of direct hepatic invasion (**FIG 6**).[17]
- Unfortunately, many gallbladder cancers are not diagnosed preoperatively but identified in the final pathology specimen for early-stage disease after laparoscopic cholecystectomy for cholelithiasis; up to 10% of all laparoscopic cholecystectomies performed for benign conditions such as cholelithiasis will harbor an incidental gallbladder cancer.[18] Additionally, some

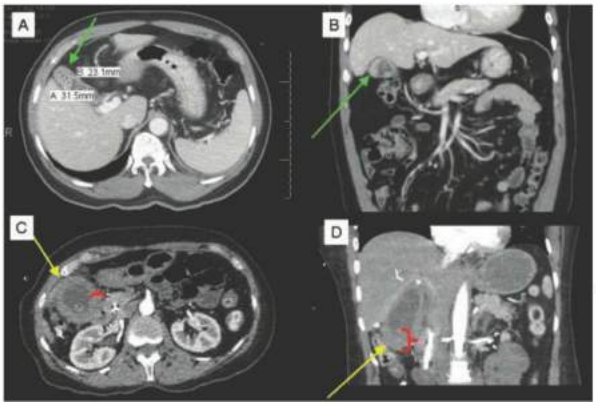

FIG 5 ● Axial **(A,C)** and coronal **(B,D)** contrast-enhanced CT findings of gallbladder cancer. Typical appearance may include that of a mass with intraluminal extension (*green arrows*; panels **A,B**) or diffuse thickening of the gallbladder wall (*yellow arrows noting region of gallbladder, and red brackets noting thickened area*; panels **C,D**) with a measured wall thickness in excess of 2 mm.

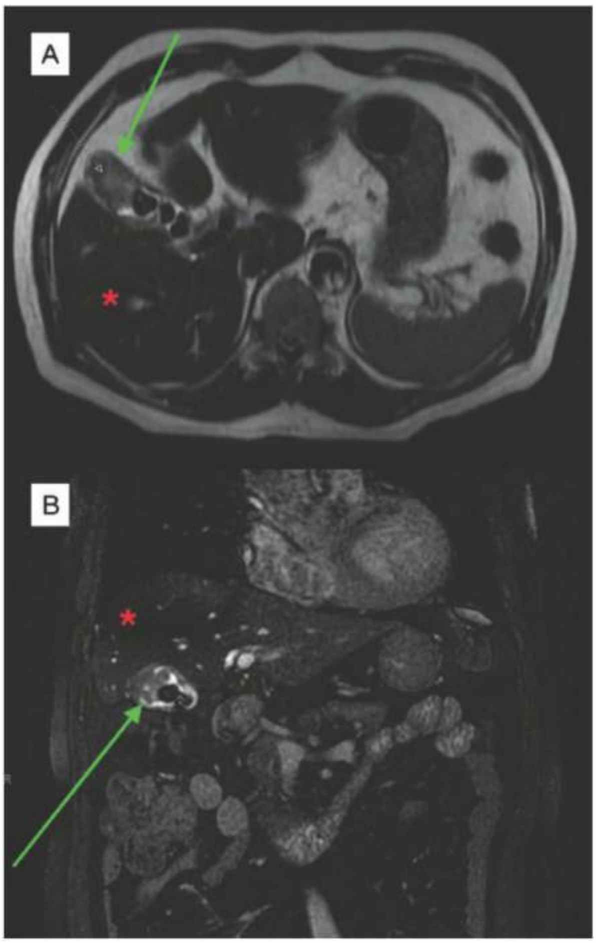

FIG 6 ● Axial **(A)** and coronal **(B)** contrast-enhanced MRI findings of gallbladder cancer. A focal thickening of the gallbladder wall is noted *(green arrows)* adjacent to the normal hepatic parenchyma *(red asterisks)*.

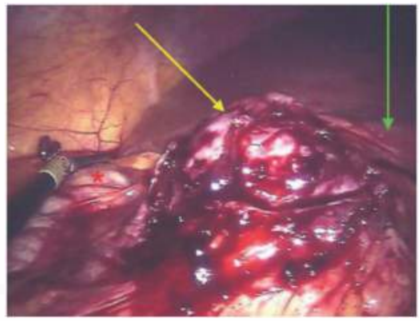

FIG 7 ● Laparoscopic identification of a gallbladder cancer with diffuse, firm, nodular thickening of the gallbladder wall *(yellow arrow)* with direct invasion of the hepatic flexure of the colon *(red asterisk)* as well as the hepatic parenchyma *(green arrow)*.

advanced-stage tumors may be mistaken for chronic cholecystitis preoperatively and only identified in the operating room. These tumors will have preoperative imaging of a contracted gallbladder with thickened walls. Intraoperatively, these tumors are clearly identified as malignant, with laparoscopic findings of nonpliable tissue, extremely thickened gallbladder wall, and often invasion into adjacent structures (e.g., omentum, liver, duodenum, hepatic flexure of the colon) (**FIG 7**).

- The tumor markers carcinoembryonic antigen (CEA) and carbohydrate antigen 19-9 (CA 19-9) may be elevated in patients with gallbladder cancer but are neither sensitive nor specific for diagnostic purposes, or correlation with extent of disease.[19]

SURGICAL MANAGEMENT

Preoperative Planning

- Radical cholecystectomy may involve resection of up to two segments (IVb/V). Therefore, careful preoperative evaluation of hepatic function and the evaluation for the presence of cirrhosis are critical in determining whether the patient will have suitable hepatic reserve following parenchymal removal. Biochemical scoring systems such as Child-Pugh classification or the Model for End-Stage Liver Disease (MELD) can be useful for predicting morbidity and mortality following resection in cirrhotic patients. In addition, functional tests such as indocyanine green clearance can be a useful functional test, which can be used with computer software to preoperatively estimate the amount of resected hepatic tissue.[8,20–22]
- Although infections are uncommon following hepatic resection, prophylactic antibiotics should be administered to cover skin flora. If the patient has had recent biliary instrumentation, including the presence of a decompressive biliary stent, antibiotics should include coverage of intestinal flora.

Positioning

- Radical cholecystectomy is performed through a right subcostal incision. To facilitate exposure of the inferior aspect of the liver, the operative table may be slightly extended or a roll can be placed transversely under the patient's lower thoracic region (**FIG 8A**). These maneuvers elevate the costal margin and increase operative exposure of the liver.

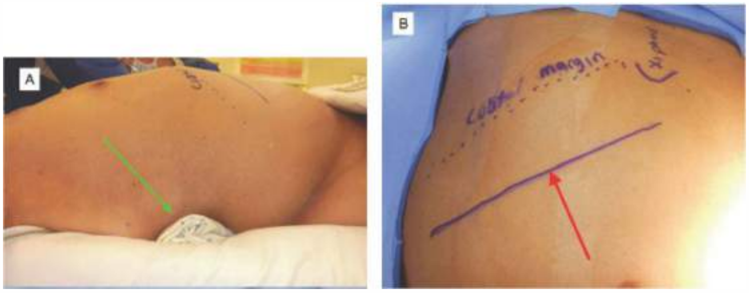

FIG 8 ● Patient position for a radical cholecystectomy with a lateral view **(A)** demonstrating a rolled sheet *(green arrow)* under the back to allow flexion of the patient, which may be combined with flexing of the operative table, and the planned right subcostal (Kocher) incision (*red arrow*, panel **B**) approximately two fingerbreadths below the costal margin.

INCISION AND EXPOSURE

- A right subcostal incision offers excellent exposure of the gallbladder, hepatic fossa, and porta hepatis (**FIG 8B**).
- The falciform ligament is divided to allow exposure and mobilization of the anterior hepatic lobes. A self-retaining retractor is placed, which allows for retraction of the right costal margin and inferior abdominal wall (**FIG 9**).
- Exploration of the abdomen is performed to exclude metastatic disease, which would preclude radical cholecystectomy. This would include hepatic metastasis, peritoneal metastases (including port site disease if the patient had a previous laparoscopic cholecystectomy), or lymph node disease of the common hepatic artery or celiac axis.
- The lesser omentum (also termed the gastrohepatic ligament) is divided to allow exposure of the common hepatic artery as well as the medial aspect of the porta hepatis. The porta hepatis is encircled with an umbilical tape that can be used as a Rommel tourniquet during a Pringle maneuver if vascular inflow occlusion is desired.

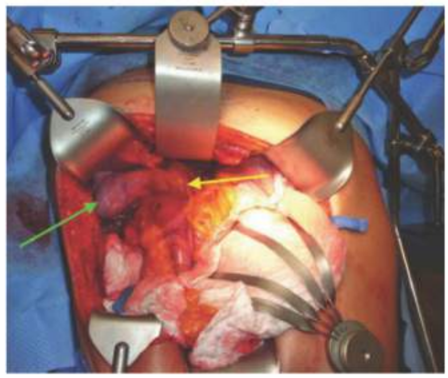

FIG 9 ● Exposure of the gallbladder with placement of a self-retaining retractor to allow complete exposure of the gallbladder *(green arrow)* as well as the porta hepatis *(yellow arrow)*. Costal margins are retracted superiorly as well as the hepatic flexure of the colon inferiorly.

INTRAOPERATIVE ULTRASOUND

- Ultrasound of segments IVb/V of the liver is performed to evaluate any extent of direct invasion of the hepatic fossa by the malignancy. A T-shaped linear array transducer with a broad frequency range (e.g., 4 to 10 MHz) provides excellent resolution, especially when coupled with Doppler scanning mode to facilitate identification of vascular inflow structures for surgical planning (**FIG 10**).

FIG 10 ● Intraoperative ultrasound is performed using a T-shaped linear array transducer *(yellow asterisk)* to allow interrogation of the hepatic parenchyma after the falciform ligament *(green arrow)* has been divided, as well as evaluation of the hepatic vascular inflow, and the possible extent of the cancer from the gallbladder *(yellow arrow)* into the hepatic fossa.

RESECTION OF SEGMENTS IVb/V

- Although nonanatomic resection of the hepatic fossa has been reported and the exact extent of parenchymal resection remains a point of controversy, formal resection of segments IVb (inferior aspect of segment IV) and V has traditionally been considered the appropriate segments of resection for radical cholecystectomy (see Part 3, Chapter 15, Surgical Anatomy, FIG 2).
- The hepatic parenchymal transection can be performed using a variety of techniques including clamp-crushing technique, ultrasonic dissection, thermal-sealing devices (e.g., LigaSure, Harmonic), radiofrequency-sealing devices (TissueLink), or water jet dissection (see Part 3, Chapter 21, Segmental Hepatic Resection).
- Major hepatic vasculature can be ligated with either traditional suture ligation or stapling devices using vascular staple loads (**FIG 11**).
- Should significant bleeding be encountered, the Rommel tourniquet can be used for temporary vascular inflow control (Pringle maneuver) to allow direct suture ligation or hemoclip application to ensure hemostasis.

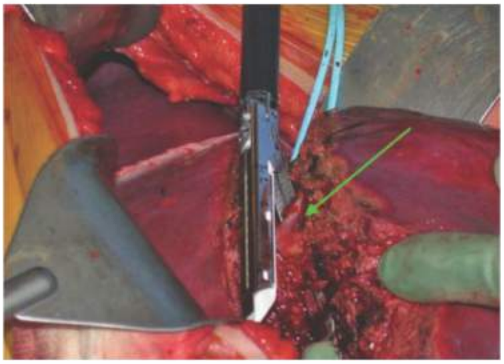

FIG 11 ● Following division of the hepatic parenchyma to segments IVb/V, a vascular stapler can be used to divide the portal venous branch *(green arrow)* to segments IVb/V.

- Following removal of segments IVb/V, the specimen should be oriented for the pathologist with intraoperative gross assessment of the margins if there is concern of significant tumor ingrowth into the hepatic fossa.
- The hepatic parenchymal surface is inspected for hemostasis and any evidence of biliary leak (**FIG 12**). Hemostasis can be obtained with either hemoclips or suture ligations; open biliary radicals should be directly suture ligated. The role of fibrin sealants may be to facilitate achieving hemostasis but has not been shown to reduce the incidence of bile leakage.[23]
- An omental flap should be mobilized from the hepatic flexure of the colon and placed into the parenchymal cavity. This may facilitate closure of small bile leaks. A closed suction drain is then placed into the abdomen over the omental flap ensuring that it provides drainage for the full extent of the hepatic parenchymal raw surface.

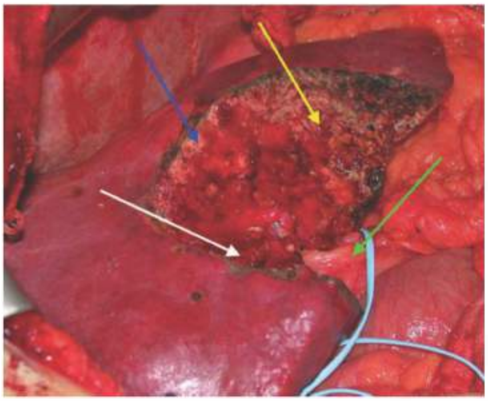

FIG 12 ● Completed radical cholecystectomy with raw surface of the boundary of resection. The margin between segments III and IVb *(yellow arrow)*, segments IVa and IVb *(blue arrow)*, and segments V and VI *(white arrow)* define a resected radical cholecystectomy. The porta hepatis *(green arrow)* can be controlled with a vessel loop (blue vessel loop).

PORTAL LYMPHADENECTOMY AND OPTIONAL RESECTION OF THE EXTRAHEPATIC BILIARY TREE

- If the cystic duct margin status is unable to be assessed or positive, or biliary obstruction is present, excision of the extrahepatic biliary tree is indicated.
- Lymphadenectomy should be performed regardless but may lead to ischemia to the extrahepatic biliary tree, resulting in delayed presentation of biliary stricture. Thus, some surgeons advocate routine excision of the extrahepatic biliary tree as a fundamental component of radical cholecystectomy.
- The peritoneum of the porta hepatis is circumferentially incised just below the liver plate and at the level of the first portion of the duodenum (**FIG 13**).
- The hepatic artery and portal vein are circumferentially dissected of associated lymphatics and splanchnic nerves. Ligation or bipolar electrocautery should be employed as these structures are rich in vascular supply. Care is taken to include the hepatic lymph nodes (**FIG 13**) in this dissection. Note that the majority of the portal lymph nodes are posterior and lateral to the preserved structures.
- If indicated, the common bile duct is divided as it enters the pancreatic parenchyma. The distal lumen should be oversewn with a running, monofilament suture of absorbable material. Assessment of this margin intraoperatively is controversial.
- The proximal hepatic duct is divided just distal to the confluence of the right and left hepatic ducts. An assessment of the proximal margin intraoperatively may be reasonable if an additional margin is feasible.
- Reconstruction of the biliary tree via Roux-en-Y hepaticojejunostomy is reviewed in detail in Part 3, Chapter 14.

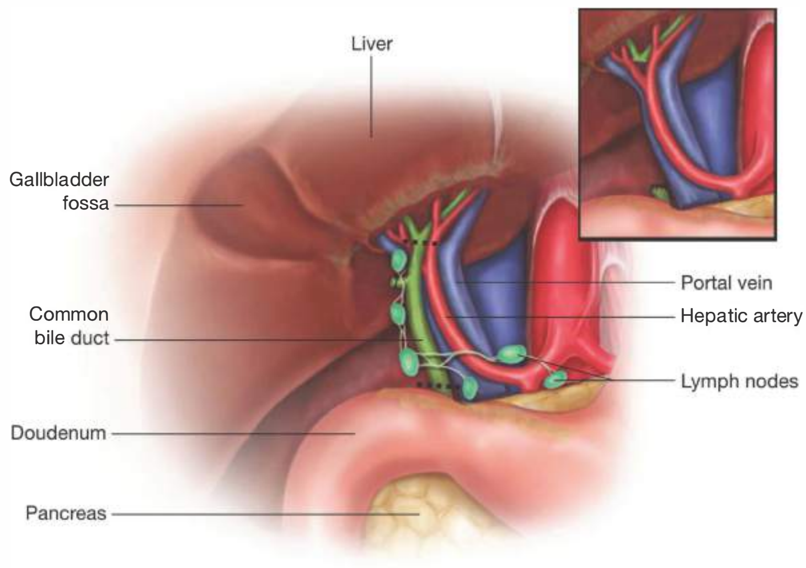

FIG 13 ● Portal lymph node dissection and optional resection of the extrahepatic biliary tree *(dashed lines)*. The hepatic artery and portal vein are dissected free of all surrounding lymphatics and splanchnic nerve tissue. The biliary tree is divided (optional) just distal to the confluence of the left and right hepatic ducts and at the level of insertion into the parenchyma of the pancreas *(inset)*.

PEARLS AND PITFALLS

Indications	■ Preoperative abnormalities on ultrasound should be further evaluated with contrast-enhanced CT scans to rule out advanced/unresectable disease. ■ Liver function should be carefully and thoroughly evaluated to ensure tolerability of hepatic bisegmentectomy. ■ Gallbladder cancers diagnosed on postoperative pathology from laparoscopic cholecystectomy should be reimaged with contrast-enhanced CT scans to rule out advanced disease not identified at laparoscopy.
Placement of incision	■ Right subcostal incisions should be placed approximately 2 cm below the costal margin to ensure sufficient exposure yet allow adequate fascia for closure. ■ If the gallbladder cancer is diagnosed following laparoscopic cholecystectomy, consideration should be given to excising the previous port site incisions.
Parenchymal transection	■ Care should be taken during parenchymal transection (independent of the method used) to seal major biliary radicals to reduce the incidence of a postoperative biliary leak. ■ Marking of the planned lines of parenchymal transection can facilitate complete resection of segments IVb/V, especially posteriorly at the porta hepatis.
Vascular control	■ Preresection intraoperative ultrasound can be useful to identify the major vascular inflow to ensure ligation at the initiation of parenchymal transection. ■ An umbilical tape around the porta hepatis can be a useful adjunct to allow rapid initiation of a Pringle maneuver to allow for hemostasis; care should be taken to minimize the time of vascular inflow clamping.
Closure	■ The closed suction drain should be placed to allow complete drainage of the hepatic operative bed but not placed directly adjacent to the parenchyma but instead over the transposed omental flap.

POSTOPERATIVE CARE

- Adequate pain control is critical to the postoperative recovery of patients undergoing major hepatic resection. Thoracic epidural catheters may be beneficial in environments with sufficient expertise for placement and care.
- Laboratory assessment of coagulation profile should be routinely checked and treated if abnormal to ensure adequate hemostasis.
- Elevated serum bilirubin levels can be a harbinger of bile leak, hepatic insufficiency, or vascular thrombosis. A contrast-enhanced CT scan should be used to differentiate the three etiologies.
- The fluid effluent from the closed suction drain can be evaluated for bilirubin content to evaluate for a bile leak. The drain should be removed as soon as there is no concern for a postoperative bile leak.

OUTCOMES

- Long-term hepatic function should not be adversely affected if the patient had normal preoperative hepatic function.
- Hepatic and peritoneal sites are the most common location for recurrent gallbladder cancer; outcomes are dependent

on the initial TNM stage. Early-stage disease (i.e., stage I) may be associated with 60% to 80% 5-year survival rates, whereas advanced-stage disease (i.e., stage III) is associated with less than 20% 5-year survival.

COMPLICATIONS

- Hemorrhage
- Bile leak
- Abscess formation
- Delayed stricture of the common hepatic duct/common bile duct due to devascularization associated with portal lymphadenectomy

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Chapter 4

Endoscopic Retrograde Cholangiopancreatography

Shailendra S. Chauhan

DEFINITION

- Endoscopic retrograde cholangiopancreatography (ERCP) is an endoscopic technique whereby a specialized side-viewing upper endoscope (duodenoscope) is passed through the mouth to the major papilla in the second portion of the duodenum.
- Using various instruments through the working channel of the duodenoscope, access can be gained into the bile and pancreatic ducts and a variety of complex interventions can be performed. The ducts are usually visualized with x-ray after injection of a contrast medium into the ducts. Alternatively, direct visualization of the ducts is also possible via smaller scopes usually passed through the working channel of the duodenoscope or directly into the ducts without use of the duodenoscope.
- ERCP allows for minimally invasive management of pancreatic and biliary disorders, but it can be a challenging technique to learn and has higher potential for complications than other standard endoscopic procedures.

PATIENT HISTORY AND PHYSICAL FINDINGS

- Prior to ERCP, a thorough patient history and physical exam should be performed to select appropriate laboratory and imaging studies for workup. These preprocedural studies will enable the proper selection of patients to benefit most from ERCP. A careful history of pancreatic and biliary symptoms and previous endoscopic and surgical therapy of the biliary tree or pancreas is essential. In addition, previous intestinal surgery may make ERCP technically difficult or impossible (such as a previous Roux-en-Y gastric bypass). Finally, complicating medical conditions can be elicited, which might impact the safety of anesthesia or increase the risk of complications of ERCP (such as anticoagulation).
- ERCP is indicated for patients with a variety of biliary tract and pancreatic disorders.[1] For patients with such disorders, specific symptoms may include abdominal pain (location, character, frequency, duration, alleviating and exacerbating factors), nausea and vomiting, jaundice, change in color of stools and urine, pruritus, steatorrhea, weight loss, and hyper or hypoglycemia. Physical exam should evaluate for jaundice, detailed abdominal exam, and signs of malnutrition or cachexia, which may suggest underlying chronic disease or malignancy.
- Key aspects of social history include tobacco use and alcohol. In those patients with suspected malignancy, it is important to elicit any family history of similar malignancies.

IMAGING AND OTHER DIAGNOSTIC STUDIES

- Specific laboratory work obtained to decide the need for ERCP usually includes liver enzymes (transaminases, alkaline phosphatase, direct and indirect bilirubin) and pancreatic enzymes (amylase and lipase). In suspected malignancy, certain tumor markers such as carbohydrate antigen 19-9 (CA 19-9), carcinoembryonic antigen (CEA), and α-fetoprotein (AFP) may be obtained as deemed appropriate. Typically, coagulation parameters (platelets, prothrombin time [PT], international normalized ratio [INR], and partial thromboplastin time [PTT]) are not obtained unless the patient is on anticoagulation or history suggests coagulopathy.
- Imaging studies for suspected biliary and pancreatic disease may include transabdominal ultrasound; high-quality, cross-sectional imaging such as abdominal computed tomography (CT) scan; or magnetic resonance imaging (MRI) or magnetic resonance cholangiopancreatography (MRCP). Transabdominal ultrasound is typically not adequate for accurate visualization of the entire pancreas. Endoscopic ultrasound (EUS), however, can provide valuable information about pancreatic ductal and parenchymal anatomy and biliary anatomy for proper selection of patients for ERCP.

SURGICAL MANAGEMENT

- ERCP has evolved from a diagnostic to an almost exclusively therapeutic procedure.[1] Imaging studies that have been described in the previous section (transabdominal ultrasound, CT, MRI/MRCP, intraoperative cholangiography, EUS) should provide diagnostic information for proper selection of patients requiring therapeutic ERCP. In general, a careful assessment of pancreatic ductal and biliary anatomy by one of these techniques is required prior to considering ERCP. ERCP should almost never be used for diagnostic purposes only, as the risk of ERCP outweighs the benefit in this circumstance.
- ERCP is not indicated in the evaluation of abdominal pain of obscure origin in the absence of other objective findings suggesting biliary tract or pancreatic disease.[1]
- ERCP is indicated in patients with various pancreaticobiliary disorders. Specific biliary indications include therapy for choledocholithiasis, management of benign and malignant biliary strictures (including tissue sampling, stricture dilation, stenting), and evaluation and treatment of bile leaks.[1]
- Pancreatic diseases that can be evaluated and treated with ERCP include recurrent acute pancreatitis, management of pain in chronic pancreatitis patients with obstruction of pancreatic duct due to stones and/or strictures, pancreatic duct leaks, drainage of fluid collections that communicate with the pancreatic duct, and pancreatic cancer causing pancreatic duct and/or bile duct obstruction.[1]
- Other specific conditions that can be evaluated and treated with ERCP include ampullary stenosis, sphincter of Oddi dysfunction (SOD), type III biliary cysts (choledochocele), pancreas divisum causing recurrent acute pancreatitis, and treatment of ampullary cancers and adenomas.[1]
- Table 1 outlines indications for therapeutic ERCP.

Table 1: Indications for Therapeutic Endoscopic Retrograde Cholangiopancreatography

Biliary
Choledocholithiasis
– High preoperative probability
– Intraoperatively diagnosed
– Definitive diagnosis prior to surgery
Strictures
– Benign
– Malignant
Postoperative bile leaks
Choledochocele (type III biliary cyst)
Biliary sphincter of Oddi dysfunction
– Type I
– Type II
Pancreatic
Chronic pancreatitis
– Stricture
– Stones
– Both
Pancreatic duct disruption
Transpapillary pseudocyst drainage
Strictures
– Benign
– Malignant
Acute pancreatitis
– Acute biliary pancreatitis
– Recurrent acute pancreatitis
– Pancreas divisum causing recurrent acute pancreatitis
Pancreatic sphincter of Oddi dysfunction
– Type I
– Type II
Other
Ampullary cancer or adenoma

From Pannu DS, Draganov PV. Therapeutic endoscopic retrograde cholangiopancreatography and instrumentation. Gastrointest Endosc Clin N Am. *2012;22(3):401–416.*

Table 2: Risk Factors for Overall Complications of Endoscopic Retrograde Cholangiopancreatography

Definite	Possible	No
Sphincter of Oddi dysfunction	Young age	Comorbid illness
Cirrhosis	Pancreatic contrast injection	Small diameter CBD
Difficult cannulation	Failed biliary drainage	Female sex
Precut sphincterotomy	Trainee involvement	Billroth II anatomy
Lower case volume	Periampullary diverticulum	
Percutaneous biliary access		

CBD, common bile duct.
From Freeman ML. Complications of endoscopic retrograde cholangiopancreatography: avoidance and management. Gastrointest Endosc Clin N Am. *2012;22(3):567–586.*

Preoperative Planning

- ERCP is usually performed as an outpatient procedure, but postprocedural observation may be prolonged due to the potential complexity of the procedure as compared to other standard endoscopic procedures.
- Prior to initiation of the procedure, the endoscopist should be absolutely certain of the indication of the procedure taking into account all of the preprocedural workup. The importance of having a well-defined therapeutic goal for the procedure cannot be overemphasized. ERCP should not be performed for diagnostic purposes only.
- Informed consent should be obtained, explaining all the potential benefits, risks, and alternatives. This should include a discussion of the risk to that individual patient, taking into account the patient and procedural factors which influence the rate of postprocedure complications.
- Table 2 details risk factors for overall complications of ERCP.
- Patients are kept NPO overnight prior to the procedure. Antibiotics with broad-spectrum coverage should be considered periprocedurally in only limited circumstances of biliary ductal obstruction or transpapillary pancreatic pseudocyst drainage.

Positioning

- The patient lies in a left semiprone position on the fluoroscopy table with both arms at their side. The right chest/shoulder is usually propped up slightly so that the head faces the endoscopist (**FIG 1**). A plain radiograph (scout film) is usually taken to ensure the field is clear of any radiopaque material such as monitoring wires and to document the presence/absence of any devices such as drains, stents, feeding tubes, and so forth.
- Sedation can be either conscious sedation (combination of benzodiazepine and opiate) administered under the supervision of the endoscopist or monitored anesthesia care (MAC). Most units now use either MAC or general anesthesia, depending on patient and case specifics.

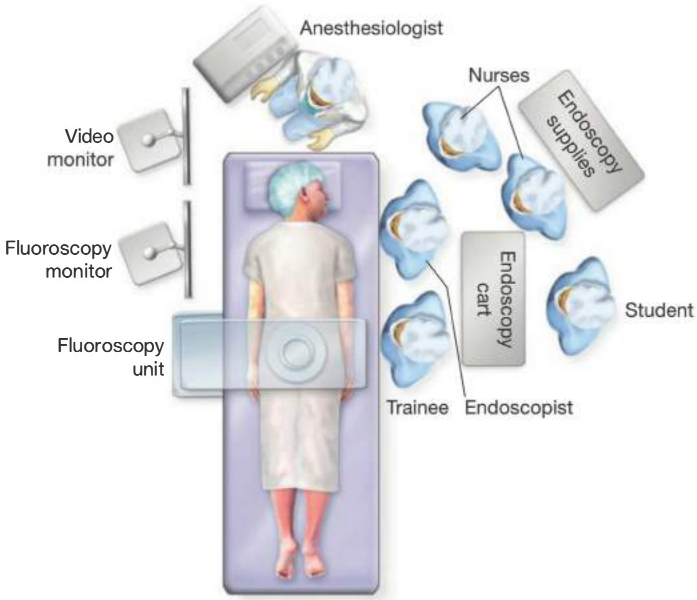

FIG 1 ● Positioning of patient for ERCP.

- Depending on the indications, various maneuvers may be performed during ERCP. However, passage of the scope to the major papilla in the duodenum and selective cannulation of the desired duct is essential to every successful ERCP.

INTUBATION OF ESOPHAGUS AND PASSAGE OF SCOPE TO DUODENUM

- Because the duodenoscope is a side-viewing instrument, passage through the oropharynx and esophagus is more by feel than direct visualization. Before intubation, ensure that instrument is in proper working order. The up-and-down and lateral movement dials should be unlocked and the elevator checked to ensure proper functioning; the elevator should be in a relaxed (down) position during insertion. The light source and attachments to the scope, that is, irrigation, suction, insufflation should be checked. Once the patient is adequately sedated, the back of the scope is lubricated (taking care not to smear over the lens) and the scope is guided over the patient's tongue to the upper esophageal sphincter. With gentle pressure, the scope should pass into the patient's esophagus and down to the stomach. If any abnormal resistance is encountered while intubating the esophagus, the scope should not be forced. It may need to be removed and the anatomy reviewed with a forward-viewing gastroscope.
- Once the scope enters the stomach, slight air insufflation may be required to orient the tip toward the antrum. The scope is then passed along the greater curvature toward the pylorus. Once the exact location of pylorus is determined, the scope tip is angled upward and advanced through the pylorus. Because of the side-viewing nature of the scope, the pylorus will not be seen as the scope passes through it.
- The scope is then passed carefully under direct vision to the level of the second portion of the duodenum. Full forward vision is not possible with this scope, and duodenal perforation is possible if an attempt is made to obtain a full forward view of the lumen. At this point, the scope is usually in a "long position." A shortening maneuver is performed by torqueing the scope shaft clockwise and pulling the scope out of the patient's mouth while the right wheel is locked in a full rightward position. This usually leads to paradoxical forward motion of the scope tip such that the scope ends up in the preferred "short position" (**FIG 2**). From this position, small adjustments can be made with a combination of movement of up-and-down and lateral movement dials as well as the endoscopist changing his/her stance slightly left or right. These motions ultimately bring the major papilla into an adequate en face cannulating position. At this point, depending on endoscopist preference, the scope dials may be locked for a more stable position.

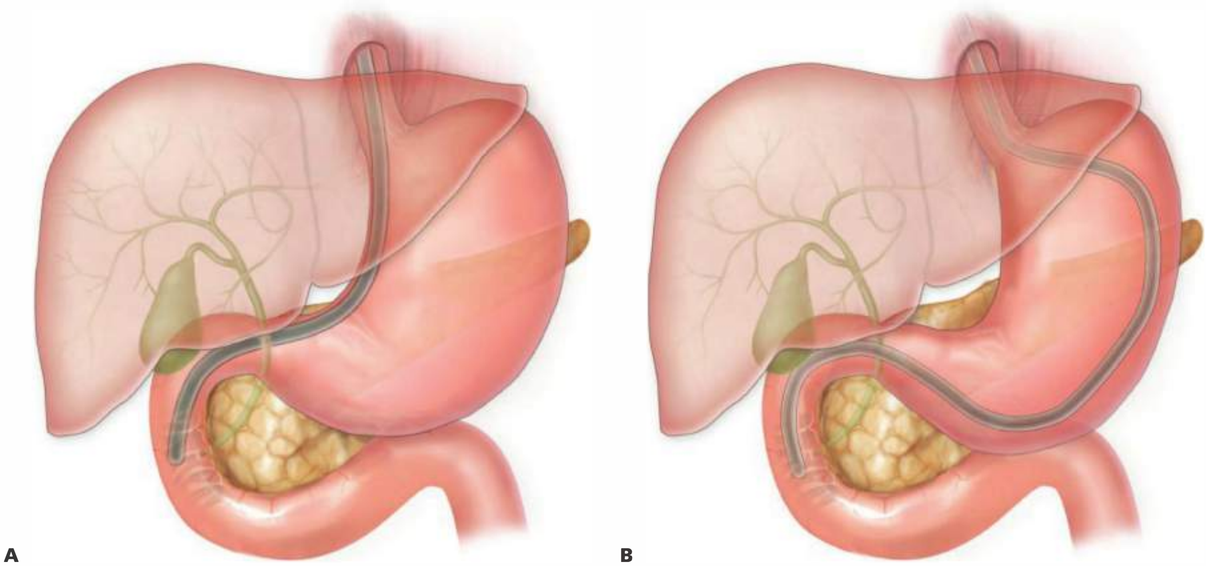

FIG 2 ● Short **(A)** and long **(B)** positions of duodenoscope for major papilla cannulation.

MAJOR PAPILLA CANNULATION

- Selective cannulation of the desired duct is the most important and most difficult skill to master for successful ERCP. Knowledge of normal papillary anatomy is essential, as is adequate training and experience. The most common reason for failure is inability to cannulate the duct of interest. Studies suggest that 180–200 cases in training are necessary before even moderate rates of cannulation are achieved.[2] Furthermore, it has been suggested that it takes about 1000 cannulations to become truly comfortable with the technique and several thousand more to become expert.[3] Various cannulation techniques have been described but all involve the use of catheters and guidewires. Typically, catheters with cutting wires (sphincterotomes) and preloaded guidewires are used for therapeutic ERCP. Another general principle is to avoid too much contrast injection until the endoscopist is reasonably sure that the cannulating device is at least superficially in the desired duct. This serves to avoid too much fluoroscopic exposure, avoid submucosal injection, and reduce the risk of post-ERCP pancreatitis.
- Selective biliary cannulation is initially achieved by superficially probing the major papilla usually at the 10 o'clock to 12 o'clock position, thereby staying superior to the intraductal septum and aiming the catheter upward (FIG 3). Once the catheter tip has advanced slightly into the duct orifice, either the guidewire can be advanced further or contrast can be injected to confirm position. If inadvertent pancreatic duct cannulation is achieved, it is important to avoid or limit any contrast injection (unless pancreatic duct cannulation is desired). Once superficial biliary cannulation is confirmed, the guidewire is advanced further proximally into the duct followed by catheter advancement to achieve deep cannulation.
- Selective pancreatic cannulation is achieved by approaching the papilla generally at its center but aiming at the 2 o'clock position. This usually aligns the catheter tip axis below the septum toward the pancreatic duct orifice (FIG 3). Using a combination of guidewire and catheter advancement, deep cannulation can be achieved. An important aspect is to limit contrast injection to small amounts so as to avoid acinarization of the pancreas, thereby decreasing the potential for post-ERCP pancreatitis.
- In certain instances where selective cannulation of the desired duct may not be easily achieved due to abnormal or pathologic anatomy (such as periampullary diverticulum,

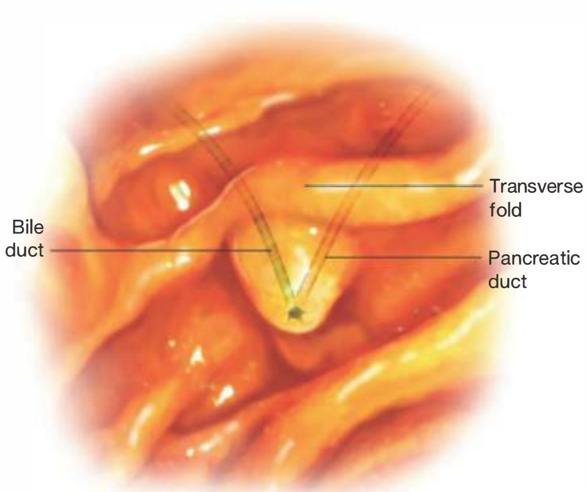

FIG 3 ● Approach to major papilla for selective cannulation of bile and pancreatic ducts.

malignancy, postsurgical anatomy), special techniques and/or devices may need to be used. These may include performance of a "precut" or "access" sphincterotomy, use of rotatable cannulating devices, placement of a pancreatic stent (to facilitate biliary cannulation and reduce risk of postprocedure pancreatitis), and the use of specific guidewires which may differ in caliber or hydrophilic nature. In certain cases of postsurgical anatomy, ERCP may be impossible with duodenoscopes. In these instances, enteroscopes (device or nondevice assisted) may be required, which can make the procedure more technically challenging. Patients who have undergone bariatric surgery in whom the stomach and proximal small bowel is bypassed pose a special challenge. In such patients, the procedure can be attempted with enteroscopes, but laparoscopic-assisted ERCPs (with the assistance of a surgical team) are becoming the preferred approach.

- In patients whom biliary cannulation is initially unsuccessful, the procedure can be reattempted in a day or two if the clinical situation allows. Referral to a center with expertise in ERCP is also reasonable. However, if delay is not feasible, patients generally proceed to percutaneous biliary catheter placement by interventional radiology. Depending on case specifics and endoscopist expertise, EUS-guided biliary access can be performed too.
- Pancreas divisum anatomy poses specific cannulation challenges because the major drainage of the pancreas is via the duct of Santorini via the minor papilla. These cases can be challenging since they may require a "long" scope position, use of smaller caliber catheters and guidewires, and possibly even a pancreatic secretagogue such as secretin, which may allow for the opening of the ductal orifice.

SPHINCTEROTOMY

- Once deep access of the desired duct is obtained, biliary and/or pancreatic sphincterotomy is generally required to perform further therapeutic manipulations. The most common type of device for this maneuver is a traction-type sphincterotomes in which the cutting wire carries the electrosurgical current and bends the tip of the sphincterotome. These are used when deep guidewire access of the desired duct has been attained. Such sphincterotomes may be rotatable (depending on manufacturer) and can be especially helpful in postsurgical anatomy. Additionally, a "needle-knife" sphincterotome may be required in difficult cannulation cases. Occasionally, needle-knife sphincterotomes can be used to perform an over-the-stent sphincterotomy. Electrosurgical current for sphincterotomy generally uses a blend current (mixture of cutting and coagulation) and it is commonplace to use an electrosurgical generator with pulse cutting so as to avoid inadvertent longer than desired or too rapid cuts ("zipper-cuts").
- Biliary sphincterotomy is performed when deep biliary access has been achieved and the guidewire is passed into the proximal biliary tree. Once the scope and sphincterotome are in a stable position, the sphincterotome tip is bowed such that the cutting wire is aiming in the 11 o'clock position. It is important to keep as little of the wire in contact with the tissue so as to get a precise cut and avoid coagulation which causes more of a charring effect. Using the shaft of the scope, the cut is guided toward the 11 o'clock position, taking care to not cut past the transverse fold (**FIG 3**). The size of the sphincterotomy generally depends on the therapeutic maneuver planned. In general, large biliary sphincterotomies are only required for removal of large biliary stones. Furthermore, if an adequate sphincterotomy has been performed but passage of stones is still difficult, balloon dilation of the biliary orifice can be performed (**FIG 4**).
- Pancreatic sphincterotomy is performed with similar technique to biliary sphincterotomy, but the cutting wire is aiming at the 2 o'clock position. In general, pancreatic sphincterotomies should be smaller in length compared to biliary. Some endoscopists prefer to initially place a pancreatic stent as a guide and perform an over-the-stent cut using a needle-knife sphincterotome.

STONE EXTRACTION

- Stones are typically extracted using balloon catheters or baskets. Factors that influence success of stone extraction include their size and shape (especially in relation to duct size) and absolute number. Additionally, pancreatic stones can be much harder to remove compared to biliary due to associated strictures and inflammation from chronic pancreatitis. An adequate sphincterotomy is essential prior to extraction. Occasionally, balloon dilation of the ductal orifice can be performed if the sphincterotomy is deemed to be adequate but further cutting could cause bleeding or perforation (**FIG 4**).
- Typically, balloons are used first line, but if this fails, metal baskets are used to capture stones for removal

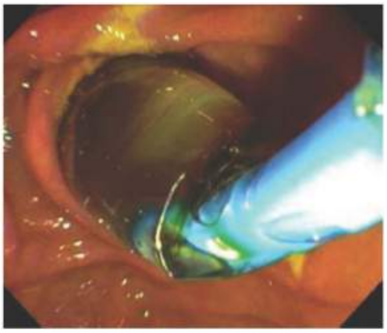

FIG 4 ● Balloon dilation of biliary orifice.

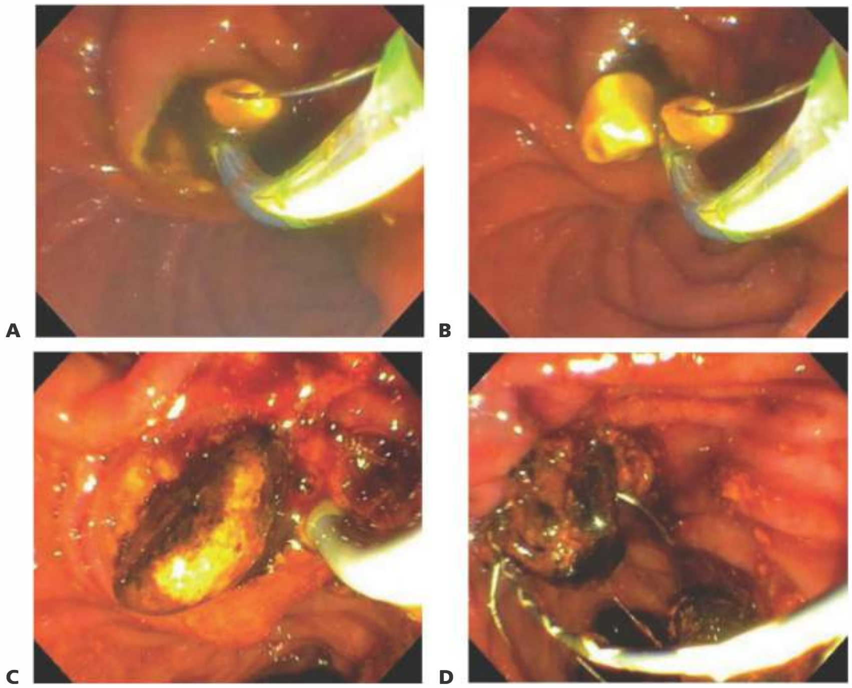

FIG 5 ● Stone extraction from bile duct. In **A** and **B**, small stones may pass spontaneously after adequate biliary sphincterotomy. In **C**, a balloon extraction catheter is deployed proximal to a stone and the stone is being extracted. In **D**, an expanding wire basket has been deployed, enveloping the stone, and then withdrawn back into the duodenum leading to crushing and/or removal of the calculus.

(**FIG 5**). Occasionally, the baskets may become impacted with a stone and difficult to remove due to stone shape and/or ductal anatomy. In this case, mechanical lithotripsy with various accessories can be performed. If complete stone removal is not possible in a single ERCP session, a stent is inserted to ensure ductal drainage prior to next ERCP.

- In cases of failed stone extraction or mechanical lithotripsy, other techniques such as electrohydraulic lithotripsy (EHL), holmium laser lithotripsy, or extracorporeal shock wave lithotripsy (ESWL) may be employed. Surgical removal of biliary stones is rarely required. For failed pancreatic stone extraction, surgery may be indicated to improve patient symptoms from chronic pancreatitis.

STRICTURE DILATION

- Devices for biliary and pancreatic stricture dilation are available. Stricture dilation is indicated for both benign and malignant indications. The general principle is that the dilating device is passed through the working channel of the scope over the preplaced guidewire until it is positioned across the stricture. Dilation is usually performed under fluoroscopic guidance to ensure that the device does not slip proximal or distal to the strictured area.
- Cylindrical-shaped balloon dilation catheters that exert radial force are typically used for dilation of biliary strictures. The balloons can be filled with contrast material and hence are visible on fluoroscopy as the balloon is inflated while ensuring the balloon is centered on the strictured area. The typical balloon diameter sizes for biliary dilation range from 4 to 10 mm. The lengths of the balloons are typically 2 to 4 cm.
- Dilation of pancreatic strictures can be performed using similar balloon dilation catheters as biliary strictures. However, owing to the smaller size of the pancreatic duct, the sizes of the balloons used are smaller. Additionally, smaller graduated bougie type dilators are also available for dilating smaller and tighter pancreatic duct strictures. These dilators provide axial force in addition to radial force and can be quite helpful in patients with chronic pancreatitis and resultant fibrotic strictures.
- Occasionally, larger diameter dilators are required for biliary indications. In cases where the bile duct is dilated proximal to a stricture or dilation of a biliary sphincterotomy orifice is needed for large stone passage, graduated esophageal balloon dilators can be used. In principle, these devices, designed for esophageal strictures, work similarly to dedicated biliary and pancreatic balloon dilators.

STENT INSERTION

- Various biliary and pancreatic stents are available and they differ in terms of material (plastic or metal), diameter, length, and design. Whereas the practice of plastic stent insertion has not changed much over the years, the use of metal stents has expanded greatly (**FIG 6**). Previously, metal mesh stents were used for palliation of malignancy but newer, covered metal stents are available. Such stents are easily removable and hence are being used for benign indications. The general purpose of stents is to serve as a conduit for duct drainage across an obstruction. Stents can be placed temporarily for benign indications or as a bridge to definite therapy. Additionally, they can be permanently placed for palliation in the setting of nonoperable malignancy.
- The general technique for stent insertion is over a guidewire advanced deeply into the desired duct. While keeping guidewire access, the stent is deployed using endoscopic and fluoroscopic guidance through the duodenoscope using a pushing catheter. It is important to keep the scope tip close to the papilla, making sure the stent is aiming in the axis of the desired duct as it is being deployed. If too much of the stent is exposed into the duodenal lumen, it can lead to bowing of the stent and difficulty in passage. This is especially important in trying to pass stents across tight strictures. Whether or not to dilate strictures prior to stent deployment depends on stricture characteristics and endoscopist preference.

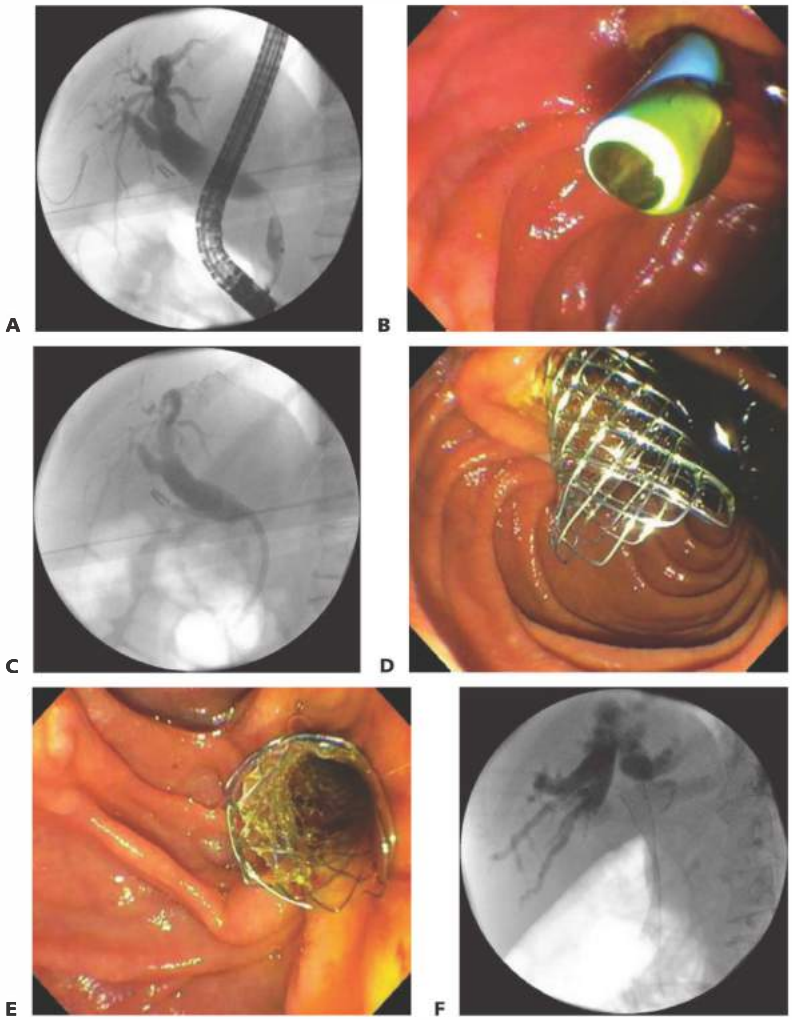

FIG 6 ● Endoscopic and fluoroscopic views of plastic and metal biliary stents. **A.** Fluoroscopic view of a biliary stricture. **B.** Endoscopic image of a deployed plastic biliary stent. **C.** Radiographic appearance of a plastic biliary stent. **D,E.** Endoscopic views of a well-positioned metal biliary stent. **F.** Fluoroscopic appearance of a metal biliary stent.

TISSUE ACQUISITION

- Tissue can be acquired from the biliary or pancreatic ducts for histologic and cytologic examinations. Typically, this tissue is acquired from strictures when the etiology, that is, benign versus malignant, is in question. The usual devices for histology and cytology are cold biopsy forceps and brushes, respectively. These are passed through the working channel of the duodenoscope into the duct and advanced under fluoroscopic guidance to the area in question. Under real-time fluoroscopy, the endoscopist can then take biopsy specimens or brushings, which are then sent to the appropriate laboratory for analysis.
- Occasionally, specimens can be taken under direct visualization of the interior of the duct during choledochoscopy or pancreatoscopy (see next section for details).

CHOLANGIOSCOPY AND PANCREATOSCOPY

- In certain situations, direct visualization of the interior of ducts may be required. The two main indications at the current time are visualization of indeterminate strictures (and tissue acquisition under direct endoscopic guidance) and lithotripsy of large stones. Older systems used a "mother-daughter" system in which a smaller scope was inserted through the duodenoscope directly into the ducts. These "daughter" scopes were prone to damage from the elevator of the duodenoscope. Disposable, multilumen, steerable catheter devices are presently used. These can be inserted through the duodenoscope channel into the pancreatic and biliary ducts. Through these catheters, a reusable optical fiber is passed for visualization and specially designed biopsy forceps can be used for tissue acquisition. Newer systems aimed to provide improved optics and tissue acquisition are being developed.
- Usage of cholangioscopes and pancreatoscopes can be technically challenging because the endoscopist has to maintain simultaneous control of the duodenoscope and the smaller scope. Usually, once guidewire access of the desired duct is achieved, the device with its control dial end is attached to the duodenoscope and the catheter end is advanced through the duodenoscope into the duct. Using both fluoroscopic guidance and endoscopic visualization of the interior of the duct, the endoscopist can evaluate for presence or extent of malignant-appearing lesions, obtain biopsy specimens, examine the duct for any stones, or perform lithotripsy of large stones.
- In specific situations when the duct caliber is very large, it may be possible to insert a forward-viewing gastroscope directly into the biliary or pancreatic ducts (without the use of a duodenoscope). Although such procedures may be technically challenging, the potential advantages include improved visualization, ability to pass standard size biopsy forceps, and capture/removal or mechanical lithotripsy of large stones under direct view. This procedure has been associated with air venous embolism, so the use of carbon dioxide (CO_2) as an insufflating agent is required.

SPECIAL SITUATIONS

- ERCP can be used in special situations such as SOD, performance of ampullectomy, or in the pediatric setting.
- SOD is a somewhat controversial topic but has been implicated as a potential cause of pancreatic or biliary disease. Patients with SOD are especially high risk for post-ERCP pancreatitis, and the procedure should only be undertaken if there is objective evidence to support the diagnosis or an extensive prior workup has been unrevealing. It is generally classified as biliary or pancreatic and further subclassified depending on presence/absence of dilation of the duct and presence of laboratory abnormalities (elevated liver or pancreatic enzymes). Specialized, graduated manometry catheters are passed into the ductal orifices and pressure is measured. A sustained pressure over 40 mmHg is considered abnormal and is an indication for sphincterotomy. Postprocedurally, patients should be well hydrated with intravenous (IV) fluids and a prophylactic, temporary pancreatic stent should always be placed to reduce the risk of post-ERCP pancreatitis. Newer data suggests that the use of postprocedural rectal, nonsteroidal antiinflammatory drugs (NSAIDs) can also reduce the risk of post-ERCP pancreatitis in such high-risk groups.[4]
- ERCP can be used to perform ampullectomy for obstructing adenomas (**FIG 7**). If the lesion is large, EUS should be performed first to ensure endoscopic resectability. Various techniques for ampullectomy have been described; if possible, an attempt should be made to perform an en bloc hot snare resection. A submucosal injection of saline may be performed initially to provide a cautery cushion prior to removal. If the lesion is too large for en bloc resection, piecemeal ampullectomy with cauterization of the edges of the resection base can be performed. Placement of a prophylactic pancreatic stent and biliary sphincterotomy are recommended to reduce the risk of postprocedure pancreatitis and cholangitis, respectively.
- ERCP is less common in the pediatric population but is usually performed for biliary stone extraction. For small children, a specialized pediatric duodenoscope is used. It is limited by the small-sized accessory devices, which can be accommodated through its working channel. For older children and adolescents, generally, the standard duodenoscope with accessories can be used. Other less common indications could include postoperative strictures, traumatic or postoperative bile or pancreatic leaks, or chronic pancreatitis due to a genetic etiology.

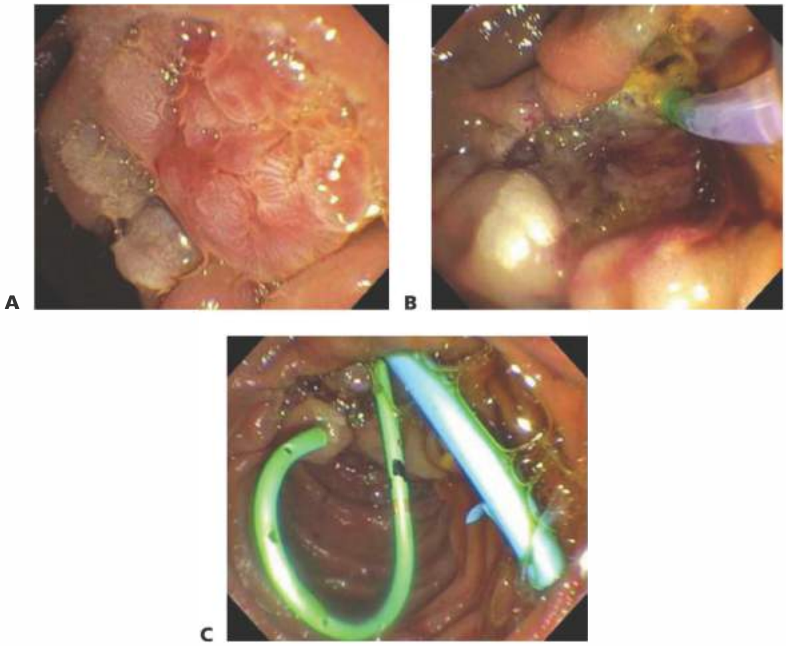

FIG 7 ● Pre- and postampullectomy endoscopic images. **A.** Endoscopic visualization of a sessile, ampullary polyp. **B.** Endoscopic ampullectomy has been performed and catheter access to pancreatic duct is achieved. The biliary orifice is seen above. **C.** Protective stents in both the bile duct **(right)** and pancreatic duct **(left)** are an essential component of endoscopic ampullectomy.

PEARLS AND PITFALLS

Indications	■ ERCP should be performed with a therapeutic intent and not for diagnostic purposes only. ■ The endoscopist should obtain diagnostic information from patient history and physical, imaging, and laboratory parameters to carefully select those patients who will benefit most from therapeutic ERCP.
Intubation of esophagus	■ Due to the side-viewing nature of scope, passage through oropharynx and esophagus is mostly by feel and not direct visualization. ■ If patient's history suggests abnormal or post-surgical anatomy or any difficulty is encountered with the duodenoscope, the anatomy should be evaluated with a forward viewing scope.
Cannulation	■ Selective cannulation of the desired duct is the key to successful ERCP and requires expertise and patience. ■ Successful cannulation is achieved by knowledge of normal papillary anatomy, proper scope position, and aligning the cannulating device to the axis of the duct of choice. ■ The cannulating device should never be forced into the duct.
Post-ERCP complications	■ Patients that are highest risk for post-ERCP complications (especially pancreatitis) are often the ones that do not have a firm indication for the procedure. ■ In those with high risk for pancreatitis, ensure that they receive adequate intra- and postprocedure IV fluids, placement of temporary pancreatic stent, and/or rectal NSAIDs. It may be wise to admit these patients postprocedurally for observation. ■ If complication is suspected or confirmed, admit the patient and treat accordingly. Keep patient and family fully informed of patient progress.

POSTOPERATIVE CARE

- Generally, ERCP can be done as an outpatient procedure; however, patients may need to be observed longer than those undergoing standard endoscopic procedures. High-risk patients (such as those with SOD) or those with difficult cannulation have higher rates of post-ERCP pancreatitis and may be prophylactically admitted to the hospital for observation.
- Once patients recover from the procedure, they can resume their normal activities, medications, and diet. In patients who need to restart anticoagulation, it is generally safe to resume postprocedurally.

OUTCOMES

- ERCP itself has high procedural success rates when performed by skilled endoscopists, but patient outcomes ultimately depend on the indications of the procedure.
- For biliary indications, the procedure has excellent immediate success rates for stone clearance, reestablishing bile flow in benign and malignant strictures, and resolution of bile leaks.
- ERCP in patients with chronic pancreatitis should be in well-selected patients that are maximized on medical therapy. In such patients, it has potential for good short-term results, but due to the nature of the disease, may ultimately need surgical therapy. In patients with pancreatic malignancy causing biliary obstruction, ERCP can reestablish immediate bile flow, but ultimate outcome will depend on the clinical stage of the disease.

COMPLICATIONS

- Table 3

Table 3: Complications of Endoscopic Retrograde Cholangiopancreatography

Post-ERCP pancreatitis (1.5%–20%)
Hemorrhage (0.1%–2.0%)
Perforation (<1%)
Infection (<1%)
Cardiopulmonary (1%)
Miscellaneous
Stent related (migration, occlusion, perforation, acute cholecystitis, biliary or pancreatic duct injury)
Ileus
Hepatic abscess
Pneumothorax/pneumomediastinum
Duodenal hematoma
Portal venous air
Impaction of therapeutic devices (stone retrieval baskets)
Perforation of colonic diverticula

ERCP, endoscopic retrograde cholangiopancreatography.
From ASGE Standards of Practice Committee; Anderson MA, Fisher L, Jain R, et al. Complications of ERCP. Gastrointest Endosc. *2012;75(3):467–473.*

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Chapter 5 Intraoperative Cholangiogram

Chasen A. Croft   Dawood G. Dalaly

DEFINITION

- Intraoperative cholangiography (IOC) is the use of radiography with contrast media injected directly into the biliary tree to determine biliary anatomy, assess the biliary tree for obstructive processes, and to evaluate for potential injury to the biliary tract.

PATIENT HISTORY AND PHYSICAL FINDINGS

- Many surgeons routinely perform cholangiography as a part of every cholecystectomy. Others selectively use cholangiography based on the results of preoperative testing or intraoperative findings. A preoperative common bile duct (CBD) diameter greater than 6 mm, obstructive jaundice (direct bilirubin >4.0 g/dL), pancreatitis, and small stones in the gallbladder have all been forwarded as indications for IOC. Intraoperative indications would include palpating stones in the CBD, unclear biliary anatomy, or to evaluate for inadvertent injury to the biliary tree.[1]

IMAGING AND OTHER DIAGNOSTIC STUDIES

- Prior to proceeding with cholecystectomy with IOC, patients should have an ultrasound evaluation of their biliary tree to assess for cholelithiasis, cholecystitis, and to determine the diameter of the extrahepatic CBD. Note that abdominal ultrasound is not a sensitive indicator of choledocholithiasis as CBD gallstones are often located in the distal CBD within the intrapancreatic portion and are thus obscured by air in the overlying stomach and/or are beyond the depth of penetration of ultrasound.
- In the absence of cholangitis, but presence of ultrasound or laboratory findings suggestive of choledocholithiasis, one forwarded option is to preoperatively evaluate the biliary tree with magnetic resonance cholangiopancreatography (MRCP) to determine the cause of biliary tree obstruction. Should biliary obstruction be present, preoperative endoscopic retrograde cholangiopancreatography (ERCP) is then performed to clear the duct of stones prior to cholecystectomy or identify more ominous etiologies of the biliary obstruction.
- Alternatively, others have advocated directly proceeding to cholecystectomy with IOC in this clinical setting, arguing that current modalities lack accuracy in identifying clinically significant choledocholithiasis and performance of an IOC often clears the duct of small stones. As such, these surgeons argue that the presurgical probability that an ERCP is necessary is low and this approach is more cost-effective by avoiding unnecessary ERCP.

SURGICAL MANAGEMENT

Positioning

- The patient should be placed in the supine position on the operating room table. The left arm is preferentially tucked against the torso to provide room for C-arm fluoroscopy. The table should be positioned with respect to the supporting pedestal so as to allow the fluoroscopy C-arm to slide underneath the operating table unobstructed (**FIG 1**).

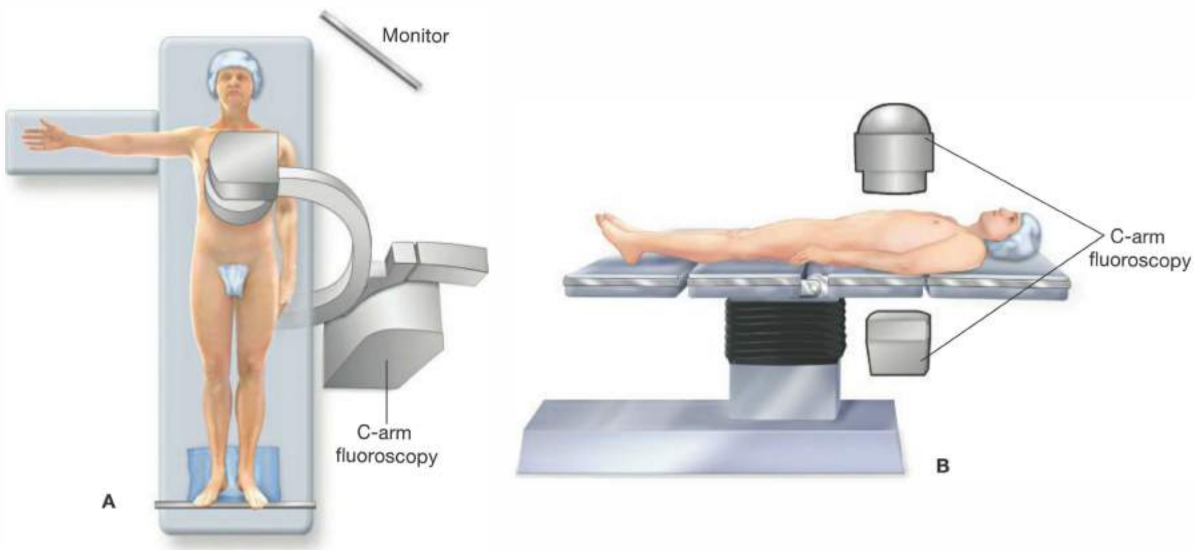


FIG 1 ● **A.** The patient is positioned supine with the left arm tucked. A footboard is placed. The C-arm fluoroscopy unit is positioned to the patient's left, with the monitor readily visible to the operating surgeon who is on the patient's right. **B.** The patient must be positioned with respect to the pedestal of the operating table so that there is adequate room for the C-arm. *(continued)*

C

FIG 1 ● *(continued)* **C.** Photograph demonstrating a clear path beneath the abdomen of the patient for the C-arm.

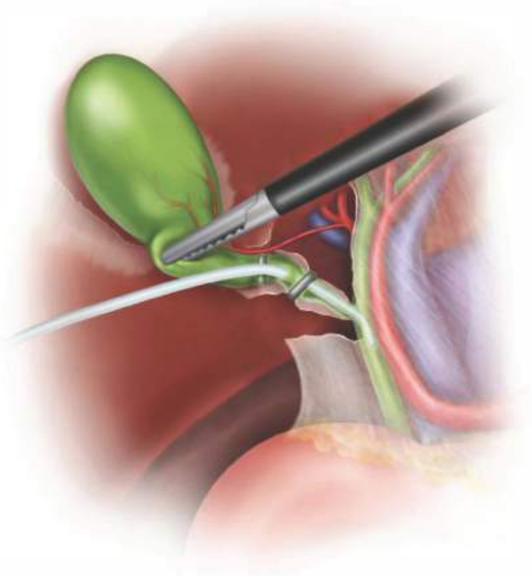
- The C-arm fluoroscopy unit should be positioned to the patient's right with the screen monitor clearly visible to the operating surgeon.
- The bed should have a footboard placed and the patient should be well secured to the operating table, as reverse Trendelenburg position is required during the procedure.

Radiation Safety

- The surgeon must be knowledgeable in the use of fluoroscopy. This should include successful completion of institutional training including certification for use of fluoroscopy in the operating theater.
- All operating room personnel should don appropriate protective garments prior to scrubbing and gowning.

CHOLANGIOCATHETER PLACEMENT

- Cystic duct approach
  - The gallbladder infundibulum should be mobilized and dissection of Calot's triangle should identify the cystic duct and artery entering the infundibulum.
  - Once the cystic duct is circumferentially dissected, a clip should be placed across the cystic duct as proximal as possible to the infundibulum (**FIG 2**).
  - A ductotomy should be made along the cystic duct, leaving adequate length for subsequent double clip ligation. Care must be taken to avoid fully transecting the duct with this maneuver. An intact posterior-cephalad cystic duct wall is essential to maintain exposure and facilitate placement of the cholangiogram catheter (**FIG 3**). Note that it is typical for the ductotomy to enlarge with the necessary lateral retraction to provide exposure or with manipulation with the cholangiogram catheter. Furthermore, the skeletonized cystic duct typically lacks intrinsic strength and can tear easily with aggressive retraction once a ductotomy has been made.
- Two techniques for placement of the cholangiocatheter for laparoscopic IOC have been described:
  - The first technique employs a 5-Fr cholangiocatheter inserted through an introducer sheath (**FIG 4**). This sheath, available as a component



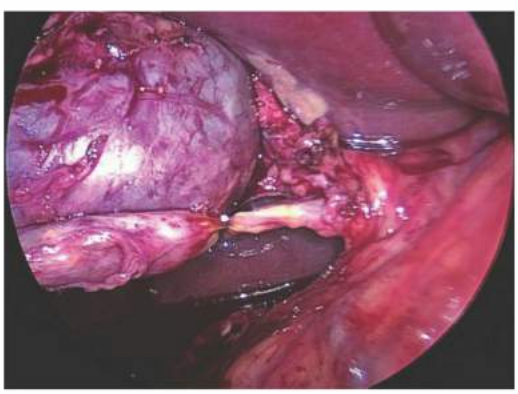
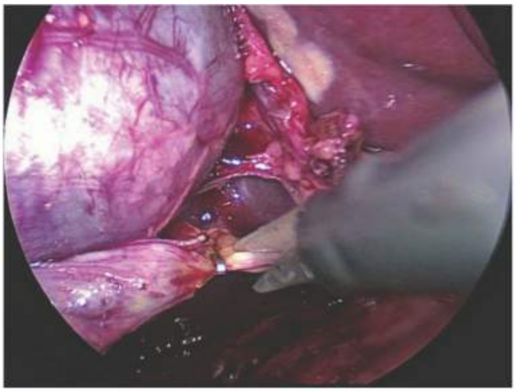


FIG 2 ● After circumferential dissection of the cystic duct, a clip is applied at the junction with the infundibulum.



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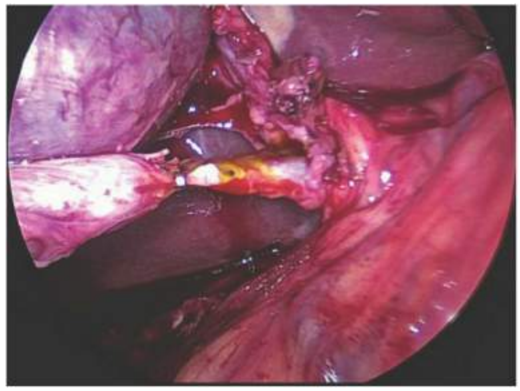


B

FIG 3 ● **A.** A ductotomy is sharply incised. **B.** The ductotomy should just be large enough to admit a small-caliber catheter. Note the majority of the cystic duct remains intact.

of commercially available cholangiogram catheter kits, is inserted through a separate incision along the right subcostal margin. Placement of this incision should be guided by location of the ductotomy. Ideally, the catheter enters the abdomen lateral and caudad to the cystic duct (**FIG 5**).

- The catheter is then gently guided into the cystic duct with atraumatic technique and secured with a partially occluding clip placed just distal to the ductotomy.
- An alternative technique is to use an Olsen-Reddick clamp (**FIG 6**). This device has a channel through the center of the clamp to accommodate a 5-Fr cholangiocatheter. The clamp is advanced though a laterally placed trocar. Once intraabdominal, the jaws of the clamp are opened and the cholangiocatheter is inserted through the center channel until the catheter tip extends beyond the jaws of the clamp. The catheter is then directed into the cystic duct. Once in place, the jaws of the clamp are closed around the cystic duct and cholangiocatheter, preventing leakage of contrast through the ductotomy (see **FIG 2**).
- This method remove the use of clips along the cystic duct during IOC.

- Infundibular approach
  - This approach is less technically demanding than direct cannulation of the cystic duct. It is also of value should identification of the cystic duct be difficult secondary to inflammation or scarring of the porta hepatis; however, in this clinical setting, the cystic duct may be occluded, precluding the approach.

FIG 4 ● The cholangiogram catheter is inserted into the cystic duct. The catheter depicted has an expandable cuff that can be appreciated within the cystic duct.

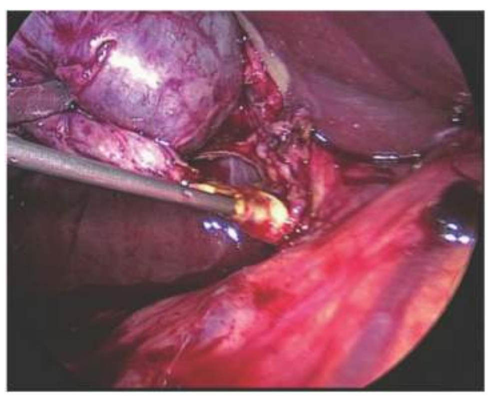


FIG 5 ● Cannulation of the cystic duct using a flexible 5-Fr cholangiogram catheter. A clip is placed across the cystic duct just proximal to infundibulum of the gallbladder and a second, nonoccluding clip is placed across the cystic duct and catheter to prevent retrograde leakage of contrast material.

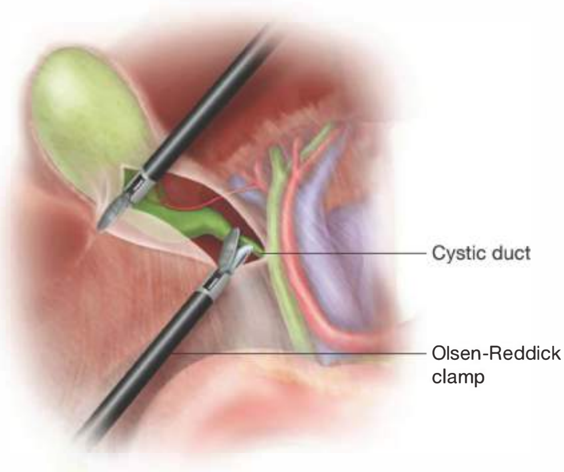


FIG 6 ● An Olsen-Reddick clamp can be used to stabilize and expose the cystic duct. The clamp has a channel for passage of the cholangiogram catheter.

- The peritoneum should be incised and the infundibulum dissected free from the hepatic bed. Once the infundibulum is mobilized, a Kumar clamp should be inserted through a laterally placed subcostal trocar. This clamp has long, atraumatic jaws, which completely occlude the infundibulum, and a side channel for the introduction of a needle-tipped cholangiocatheter. The clamp is applied along the lower body of the gallbladder, just above Hartmann's pouch (**FIG 7**).
- Advance the Kumar catheter through the side channel and visualize the needle as Hartmann's pouch is punctured.
- Once the catheter is placed, aspiration of bile contents ensures adequate biliary access.

- Fundus approach
  - If neither cystic duct nor infundibular approaches are feasible, a cholangiocatheter can be inserted directly through the fundus of the gallbladder. This technique is similar to that of the cystic duct approach. During IOC, a larger volume of contrast must be used as the entire gallbladder must fill prior to visualizing the cystic duct.

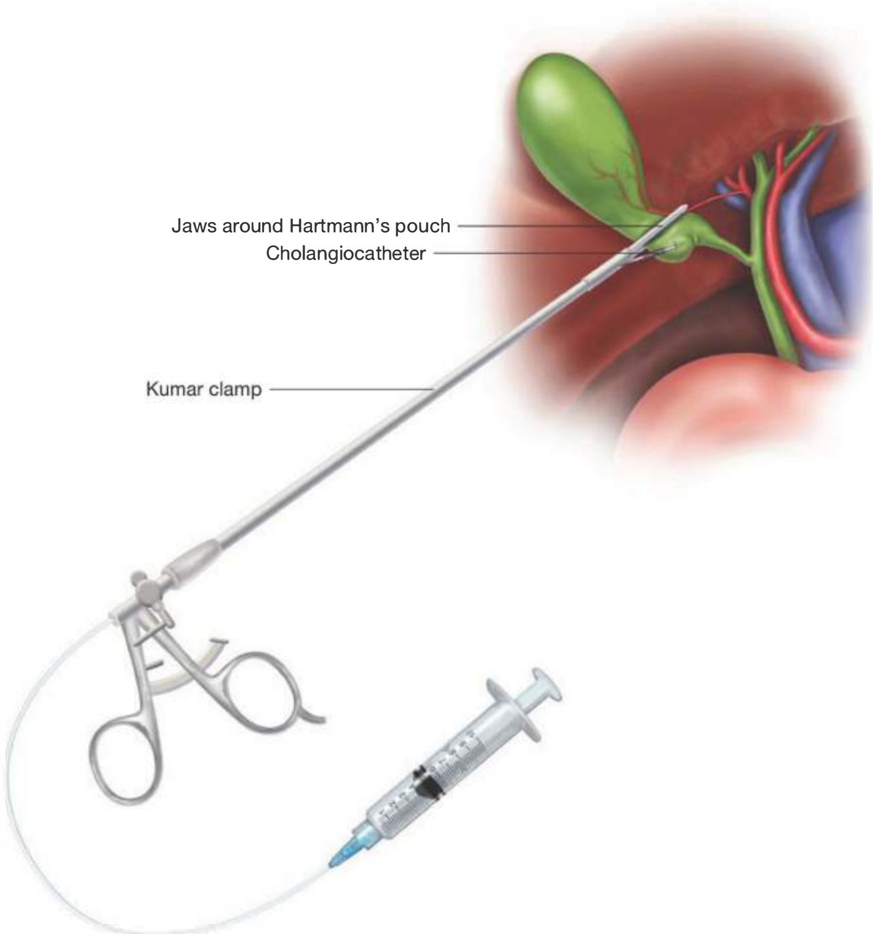


FIG 7 ● A Kumar clamp is used when performing an IOC by injecting the infundibulum of the gallbladder. This is the least technically demanding approach to IOC but not an option in the setting of acute cholecystitis.

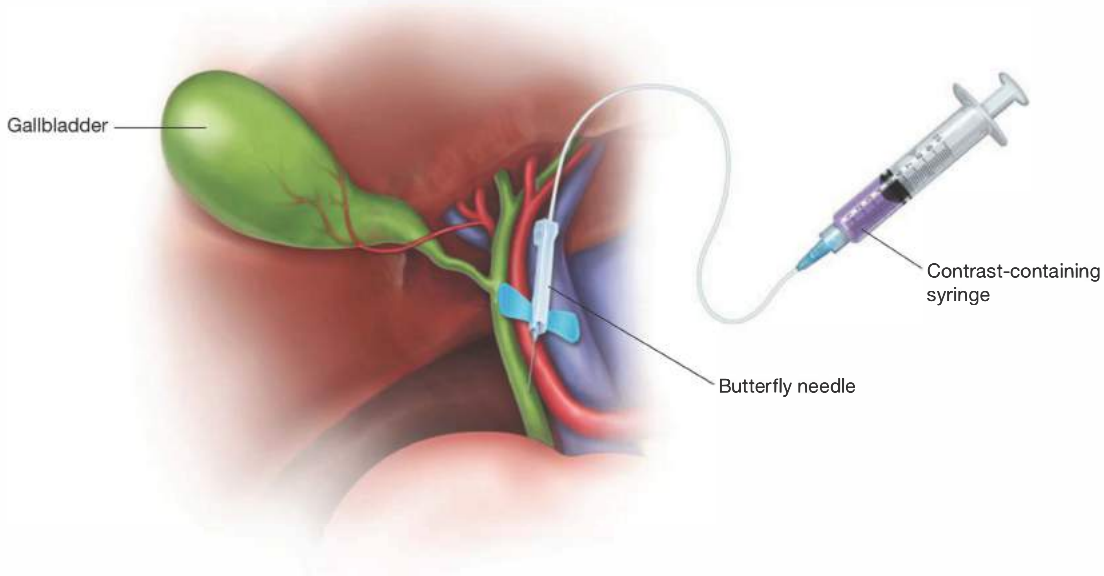


FIG 8 ● A 25-gauge butterfly needle can be directly inserted into the CBD. When performed laparoscopically, one of the flanges of the needle can be removed to facilitate passage through the trocar.

- Needle cholangiogram approach
  - In the clinical situation of acute cholecystitis where inflammation is extensive and the primary indication for cholangiography is defining the anatomy of the biliary tree, the CBD can be directly cannulated with a small-gauge butterfly needle (**FIG 8**). Once complete, the puncture site should be closed with an interrupted 4-0 absorbable monofilament suture.
- Open technique
  - During open hepatobiliary surgery, IOC may be performed by inserting a cholangiocatheter in a similar fashion using any of the aforementioned laparoscopic techniques.

CHOLANGIOGRAM

- Prior to insertion, the cholangiogram catheter should be flushed with saline to avoid injection of air bubbles that can easily be misinterpreted as CBD stones.
- Once the cholangiogram catheter has been successfully placed, the catheter should be gently flushed with saline to ensure no leakage of contrast will occur during cholangiography.
- The fluoroscopy C-arm should be moved into position, taking care to maintain sterility (**FIG 9**).
- The accessory laparoscopic instruments and camera should be removed.

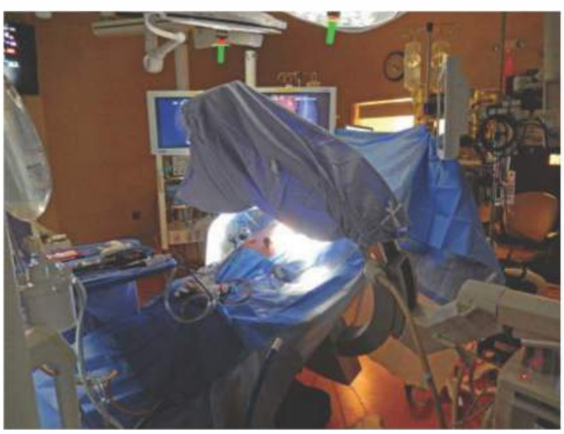
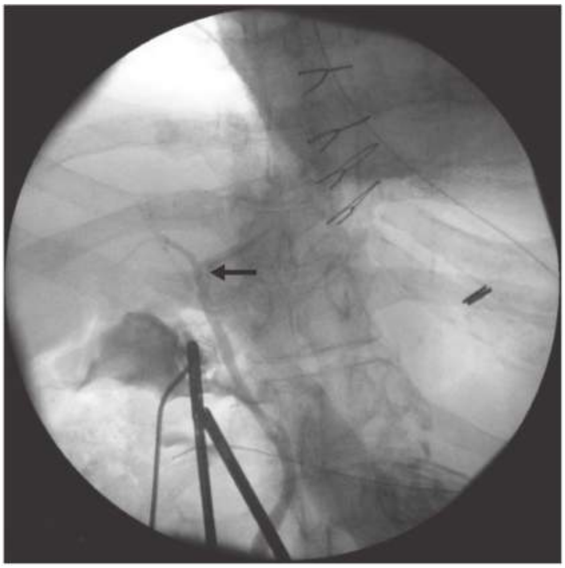


FIG 9 ● Operative photograph of appropriate C-arm positioning.



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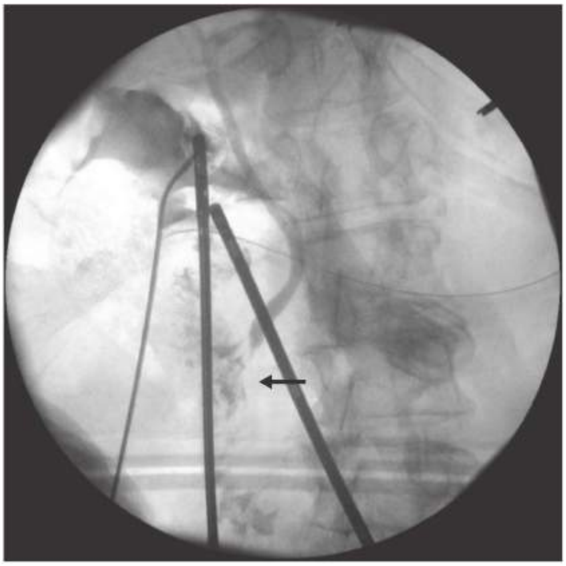

B

FIG 10 ● Normal cholangiogram. Note visualization of the entire biliary tree including the intrahepatic ducts *(arrow)* **(A)**. Passage of contrast into the duodenum without filling defects is also demonstrated *(arrow)* **(B)**.

- A test cholangiogram should be performed to verify adequate positioning of the fluoroscopic C-arm.
- After position is verified, the IOC is performed. Ten to 25 mL of low osmolar, radiopaque contrast is usually required for visualization of the entire biliary tree. The authors typically dilute the water-soluble contrast 1:1 in normal saline. An IOC is not adequate until the cystic duct, CBD, left and right hepatic ducts, and passage of contrast into the duodenum are all visualized. This may be facilitated by altering patient positioning, using Trendelenburg, reverse Trendelenburg, and lateral rotation of the patient (see **FIG 6**).
- Examples of distal obstruction remove from malignancy, inflammation, or calculi are shown in **FIGS 10** to **12**.

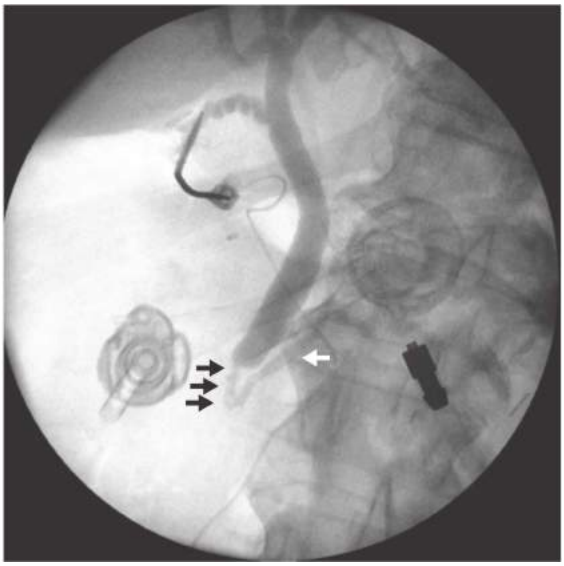

FIG 11 ● Visualization of a CBD stone by IOC. A filling defect is noted in the distal CBD; there is lack of flow of contrast material into the duodenum despite adequate pressure *(black arrows)*. Incidental filling of the pancreatic duct can also be appreciated in this example *(white arrow)*.

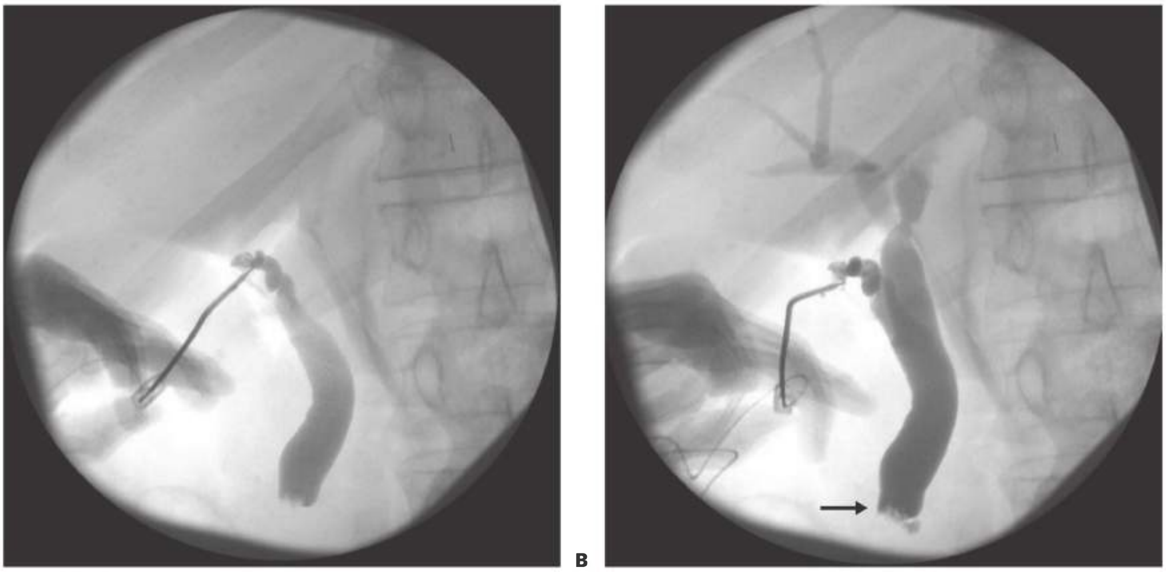

FIG 12 ● **A.** Biliary obstruction due to malignancy. **B.** Note the irregular border of the malignant "shelf" *(arrow)*.

PEARLS AND PITFALLS

Patient selection	■ Routine versus selective application of IOC is a subject of controversy.
Surgical management	■ Positioning of the patient with respect to the pedestal of the operating table is essential for access of the C-arm fluoroscopy unit. ■ The semicircular valves of the cystic duct can impede the advancement of the cholangiogram catheter. Care must be taken to not cause a laceration while advancing the catheter into the duct.
Operative decision making	■ Intraoperative cholangiogram during cholecystectomy should be used whenever anatomy is confusing. ■ If the cystic duct cannot be adequately mobilized, either the infundibular or fundus approaches are acceptable alternatives for placement of the cholangiocatheter.
Cholangiogram interpretation	■ Flush the catheter prior to insertion to avoid the introduction of air into the CBD. The bubbles that form cannot be easily differentiated from stones. ■ If the entire biliary tree cannot initially be visualized during IOC, the patient should be repositioned to ensure flow of contrast is not being inhibited by hydrostatic pressure. If, after repositioning, the biliary tree cannot be seen in its entirety, one should suspect an obstructive process or inadvertent ductal injury. ■ If distal obstruction is identified, ligate the cystic duct rather than clip it to reduce the risk of postoperative bile leak. Leave a drain.

POSTOPERATIVE CARE

- Postoperative care does not differ from that described for cholecystectomy.

OUTCOMES

- The selective application of IOC versus routine IOC remains a subject of controversy; differences in outcomes between the two approaches have not been well demonstrated.[2,3]
- IOC with CBD exploration versus postoperative endoscopic retrograde cholangiography has been shown to be more cost-effective than routine preoperative assessment of CBD stones.[4]

COMPLICATIONS

- Laceration of the cystic duct or CBD
- Bile leak
- Radiation injury to the skin

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Chapter 6

Percutaneous Transhepatic Biliary Imaging and Intervention

Brian S. Geller

DEFINITION

- Cholangiography is the term used to describe the evaluation of the biliary system by fluoroscopy after injection of radiopaque material (contrast). The introduction of contrast can be performed either in a retrograde (via endoscope) or an antegrade manner.
- The antegrade introduction of contrast requires percutaneous transhepatic access into the biliary system. A percutaneous transhepatic cholangiogram (PTC) is commonly performed when a magnetic resonance cholangiopancreatography (MRCP) and endoscopic retrograde cholangiopancreatography (ERCP) were inconclusive or unable to be performed.
- When an obstruction of the biliary system cannot be managed by endoscopic means, a drainage catheter can be placed. This procedure is known as percutaneous transhepatic drainage (PTHD).
- Numerous biliary pathologies are routinely managed by the percutaneous route: stone/debris removal, stricture dilation, long-term catheter drainage, and metallic stent placement.

PATIENT HISTORY AND PHYSICAL FINDINGS

- A PTC is an invasive procedure and as such, non- or less invasive imaging of the biliary system should be attempted; these include MRCP and ERCP. If these options fail to make the diagnosis or cannot be performed due to the patient's anatomy, then a PTC should be performed.
- Indications for cholangiography include biliary stenosis or obstruction, or bile leak. The underlying pathology includes stones, malignancy, infection, inflammation, fibrosis/scarring, and iatrogenic complications.
- Patients with biliary obstruction or moderate- to high-grade stenosis usually present jaundice with elevations of the alkaline phosphatase (ALP) and total bilirubin (TB). ALP is a more sensitive identifier of biliary pathology and typically precedes elevation of the TB. If the bile has become infected, the patient can also present with fever, leukocytosis, and sepsis. Bile leaks present with abdominal pain (secondary to a chemical peritonitis), fever, leukocytosis, nausea/vomiting, and jaundice.

IMAGING AND OTHER DIAGNOSTIC STUDIES

- Ultrasound (US) or computed tomography (CT) can be used to diagnose biliary dilation. Note: Posttransplant livers do not normally have dilated ducts when obstructed.
- First-line imaging of the biliary system is routinely a US. This modality is readily available, inexpensive, and uses no radiation. US is optimal for detection of biliary dilation, gallbladder pathology, and ascites. It also serves a role in the identification and characterization of hepatic masses and Doppler mode provides information regarding potential vascular pathology (**FIG 1**).
- When a broader view of the abdomen is needed, a CT scan can be performed. Intravenous (IV) contrast is routinely administered, and due to the nature of the exam, the patient will be exposed to radiation (equivalent of ~100 chest x-rays) (**FIGS 2** and **3**).
- MRCP can also be performed to evaluate the biliary system and surrounding liver parenchyma. Note that the nature of the magnetic resonance (MR) protocol that is required to optimally visualize, the biliary system, does not optimally assess surrounding structures, thus limiting the evaluation of nonbiliary pathology (**FIG 4**).

FIG 1 ● Axial US image of the liver demonstrating marked intrahepatic biliary ductal dilation.

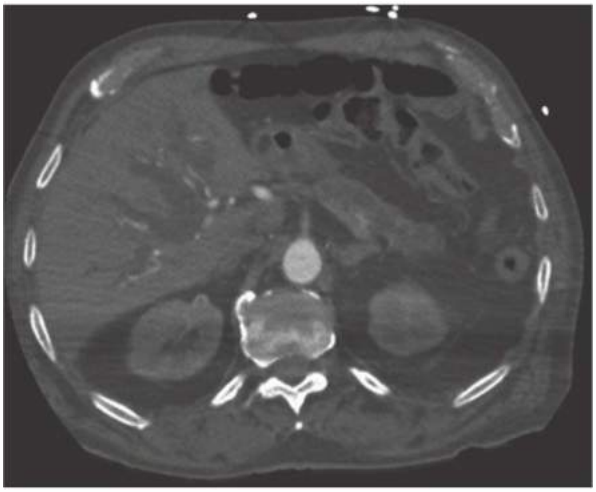

FIG 2 ● Axial CT image with marked intrahepatic biliary ductal dilation and pancreatic ductal dilation.

FIG 3 ● Axial CT image with biloma and free fluid. The patient was following right hepatectomy.

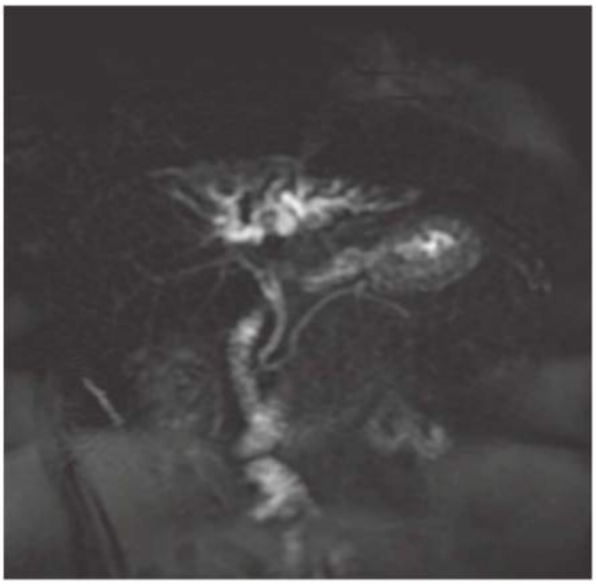

FIG 4 ● Coronal image from MRCP demonstrating dilation of the right anterior and left hepatic ducts. The right posterior, common hepatic, and pancreatic ducts are of normal caliber.

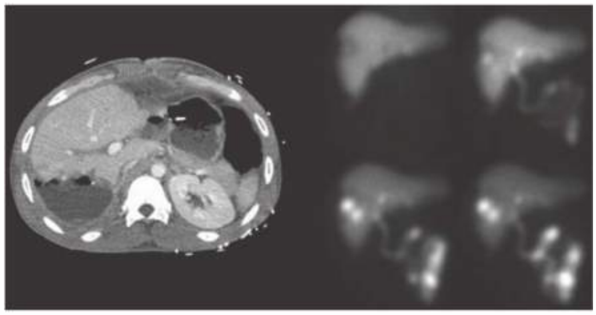

FIG 5 ● Images from a HIDA scan (four images on right) of a trauma patient with a liver laceration. There is tracer accumulation in the region of the right hepatic lobe, which corresponds to an increasing fluid collection on CT.

- When evaluating for a bile leak, cholescintigraphy (also known as a hepatobiliary iminodiacetic acid [HIDA] or diisopropyl iminodiacetic acid [DISIDA] scan) can be performed. The radiopharmaceutical is taken up by the liver and excreted into the bile. When the tracer is seen accumulating outside of the liver, or in intrahepatic cavities, the diagnosis of leak can be confirmed (**FIG 5**).

SURGICAL MANAGEMENT

Preprocedure Planning

- All related imaging to the patient's condition should be reviewed. A PTC/PTHD can be performed either under conscious sedation or with general anesthesia (preferred). Thus, the patient ideally will be *nil per os* for at least 6 hours prior to the procedure.
- For any procedure that manipulates the biliary system, there is an increased risk of septicemia and endotoxemia. The patient should receive antibiotics within 1 hour of start time. The mix of gastrointestinal flora should guide antibiotic choice (gram negatives and anaerobes). At our institution, piperacillin/tazobactam 3.375 g is routinely used. In patients who are penicillin allergic, ciprofloxacin 400 mg and metronidazole 500 mg are given.
- Unless the left-sided ducts are unilaterally dilated, a right-sided approach is routinely used, as this will drain a larger portion of the liver and will decrease radiation exposure to the interventionalist.

Positioning

- Biliary procedures are performed with the patient in the supine position, arms at the side.

PERCUTANEOUS TRANSHEPATIC CHOLANGIOGRAPHY

Immediate Preprocedure

- The patient's abdomen should be cleaned and prepped from the nipple line to the left midaxillary line to 5 cm below the umbilicus and beyond the right posterior axillary line.
- When right-sided access is warranted, a hemostat should be placed at the right midaxillary line at the selected access site during deep inspiration (**FIG 6**). This is used to verify that the entrance site is below the greatest diaphragmatic excursion. Access above this mark should *not* be attempted as it exposes the patient to the risk of violating the pleura, resulting in pneumothorax or biliary–pleural fistula.
- Local anesthetic should be used and a small incision (2 to 3 mm) made to facilitate needle passage.

FIG 6 ● Placement of hemostat to mark the entrance site.

FIG 7 ● Fan pattern of needle passes (*solid line*, initial pass; *dashed line*, subsequent passes). *Yellow* indicates midaxillary line.

Duct Cannulation

- Duct cannulation can be performed with a 15-cm, 21- or 22-gauge Chiba needle. These needles are relatively small (thereby reducing bleeding risk) and can accept a 0.018-in wire.
- When left-sided access is required, US is routinely used to localize a relatively superficial duct. The duct is then cannulated under direct US guidance.
- Due to the overlying ribs, right-sided access is usually accomplished with a "blind" technique, which can either be subclassified into an antegrade or retrograde approach.
- When using the retrograde approach, the Chiba needle is advanced from the liver margin to the midaxillary line. The stylet is removed, and under fluoroscopy, a small amount of dilute contrast is injected as the needle is pulled back.
- When using the antegrade approach, the stylet is removed from the Chiba needle, and under fluoroscopic guidance, the needle is advanced while injecting dilute contrast until reaching the midclavicular line.
- Regardless of approach, multiple passes through the liver at different obliquities (cranial–caudal *and* anterior–posterior) are often required before a duct is cannulated (**FIG 7**). The technical challenge and number of passes required for successful cannulation is directly related to the extent of intrahepatic biliary dilation. This is particularly problematic in the setting of bile duct injury with a biliary tree that is fully decompressed into the peritoneal space.
- Peripheral cannulation is the goal. Cannulation of centrally located duct increases the risk of arteriobiliary or venobiliary fistula and hemorrhage.

Cholangiogram

- It is very easy for a well-placed needle to dislodge while the patient is breathing. To prevent this from occurring, a 0.018-in wire is placed through the Chiba needle and coiled within the biliary system. The needle is exchanged for the inner portion of an AccuStick catheter. A Tuohy-Borst sidearm introducer is then placed over the wire and attached to the catheter, allowing for contrast injection without loss of wire access.
- While injecting dilute contrast, either an angiographic run or static images are obtained in multiple obliquities (**FIG 8**).
- Once adequate images are obtained, the catheter and wire are removed.

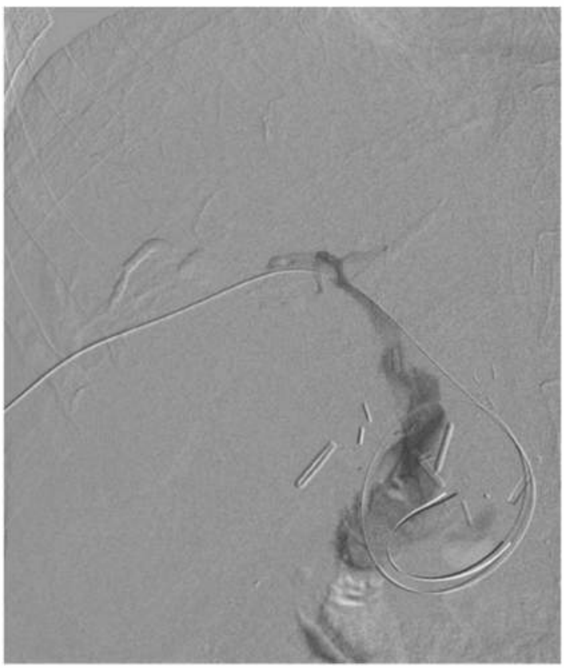

FIG 8 ● PTC in a patient following liver transplant with history of hepaticojejunostomy stricture. Cholangiogram demonstrates no evidence of stricture. Intrahepatic ducts were normal on other images (not shown).

PERCUTANEOUS TRANSHEPATIC DRAIN

- If durable access to the biliary tree is indicated, once a 0.018-in wire is coiled within the biliary system, a fully assembled AccuStick is advanced and the inner metallic cannula and 4-Fr catheter are removed. A hydrophilic wire and hockey-stick catheter are then used to cannulate the small bowel.

FIG 9 ● Internal/external biliary drainage catheters in both the right anterior and posterior ducts.

- The hydrophilic wire is removed and exchanged for a stiff wire through the hockey-stick catheter. The tract is dilated to accommodate a biliary drainage catheter, which is positioned so the proximal side holes are draining the intrahepatic ducts and the distal pigtail is in the bowel (**FIG 9**).
- The catheter should then be sutured to the skin and placed to external drainage for 24 to 48 hours, after which it can be capped.
- If the area of stenosis cannot be crossed, an external drain can be placed with the pigtail coiled within the intrahepatic biliary ducts (**FIG 10**). This catheter must be kept to gravity bag drainage.

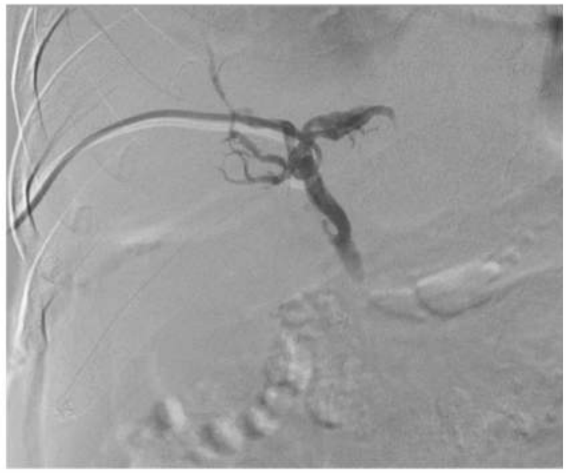

FIG 10 ● Digital subtraction angiography (DSA) image of an 8-Fr external drainage catheter within the main hepatic duct.

BALLOON DILATION

Dilations

- Postsurgical or focal inflammatory scarring can routinely be treated with serial balloon dilation.
- With a stiff wire in place, serial dilations, starting with balloons 1 to 2 mm smaller than the area of stenosis and then 2 to 3 mm larger than normal ducts, are performed. The length of the balloon can be either 2 or 4 cm in length, depending on the area of stenosis.
- When a regular balloon is not adequate, a scoring balloon or a cutting balloon can be used in certain circumstances, which are dependent on the anatomic relationship of the stricture to the hepatic vasculature (**FIG 11**).
- After dilation, the same size or larger internal/external biliary drain is replaced.
- Dilations are performed every 2 to 3 weeks, for a total of three dilations.

Challenge

- When the patient returns 2 to 3 weeks after the third dilation, a TB is drawn preoperatively.
- If the cholangiogram shows that the area of stenosis is patent, an external drainage catheter is placed with the pigtail peripheral to the area in question and capped (**FIG 10**).

Success or Failure

- The patient returns in 1 to 2 weeks after challenge. A TB is drawn preoperatively.
- A cholangiogram is performed through the existing catheter. If the area in question remains patent and the bilirubin is normal, the catheter is removed.
- If either the cholangiogram is abnormal or the bilirubin is elevated, the external drainage catheter is replaced with an internal/external catheter (**FIG 12**).
- Until definitive surgical management, the patient will require routine (every 3 months) changes of this catheter.
- Alternatively, if anatomically feasible, an endoscopically retrievable stent can be placed until definitive surgical management (see following discussion of "Stent Placement").

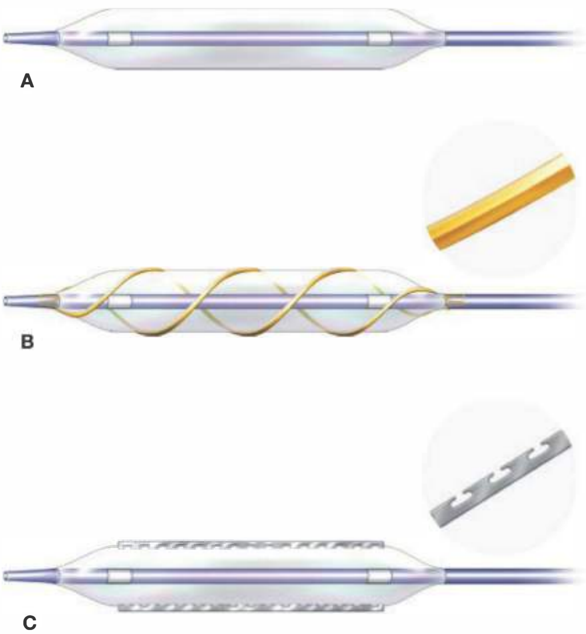

FIG 11 ● **A.** Standard noncompliant balloon. **B.** A modified balloon allows for the scoring of the ductal walls, which has shown to increase the chances of successful dilation. **C.** A cutting balloon for extremely difficult stenoses. Due to the risk of perforation, great care should be taken when using this balloon.

FIG 12 ● Arrow indicates residual high-grade anastomotic stricture after challenge. Patient required replacement of the internal/external drainage catheter.

STENT PLACEMENT

Evaluation

- Only until recently, metallic stents were permanent and reserved for those patients with a life expectancy of less than 6 months, as there is a 50% occlusion rate at this interval.[1] With introduction of the covered metal stents that can be endoscopically exchanged, patients with longer life expectancies can benefit from indwelling metallic stents (FIG 13). However, in patients whose biliary systems are not endoscopically accessible, these stents cannot be changed.
- Once a PTHD has been performed and the biliary system has had time to drain (24 to 72 hours), a formal cholangiogram is performed.
- There must be an adequate landing zone (proximally and distally) for a metal stent to be used. Additionally, each area of stenosis will usually require a stent. In most situations, a single central area of stenosis of either the right, left, and/or main hepatic ducts are amendable

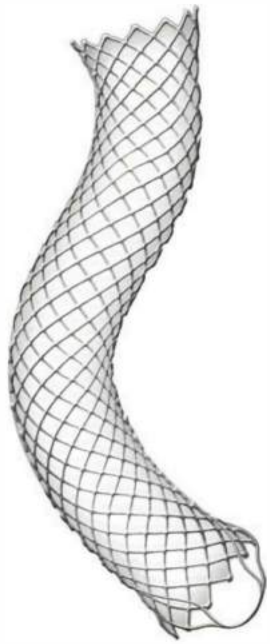

FIG 13 ● A covered, self-expanding metal biliary stent.

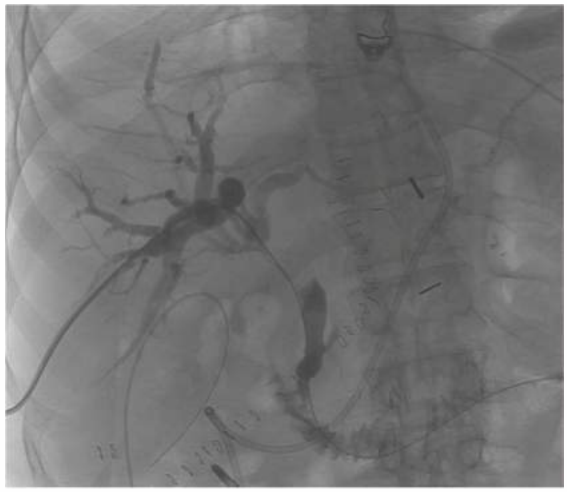

FIG 14 ● Cholangiogram demonstrating multiple central intrahepatic biliary strictures as well as a long-segment stricture of the peripheral common bile duct consistent with a Klatskin tumor. Due to the number of strictures, this patient was not a stent candidate.

to stent placement. Patients with Klatskin tumors, who present with multiple areas of stenosis, are typically not candidates (**FIG 14**).

Placement

- Over a stiff wire, a properly sized stent is advanced and deployed (**FIG 15**).
- If the stenosis involves the distal common bile duct, a short segment of stent (1 to 2 mm) should extend into the small bowel. When there is an associated duodenal stricture that also requires stenting, a longer segment of the biliary stent should extend into the bowel, alongside the duodenal stent.
- A small catheter should remain across the stent for 24 to 72 hours.

Follow-up

- The patient should return for a cholangiogram in 24 to 72 hours to determine if the stent remains patent. If the stent is patent, the catheter can be removed.
- If the stent is occluded, an internal/external catheter should be placed. The patient should return for routine catheter changes every 3 months.

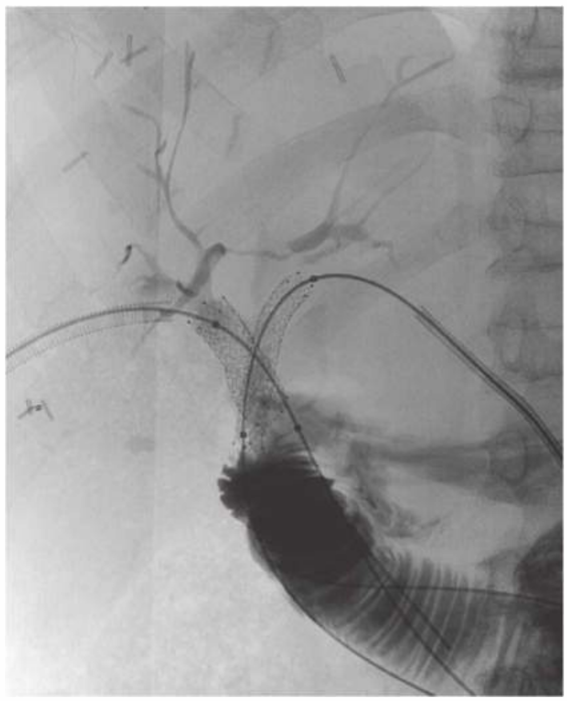

FIG 15 ● With sheaths and wires through both the right and left biliary ducts, self-expanding stents were deployed. In each stent is an angioplasty balloon, which will be inflated simultaneously to prevent one from crushing the other.

MISCELLANEOUS BILIARY INTERVENTIONS

Brushings/Biopsy

- Once a PTHD has been performed, the area of stenosis crossed and the biliary system has had time to drain, and any associated blood that is invariably present after the initial access procedure had cleared, biopsies can be performed. Both brushings and a forceps biopsy are routinely performed to increase in the likelihood of diagnosis (**FIG 16**).
- To obtain brushings, a sheath must be placed across the stenosis, through which the brush system is advanced. The sheath is pulled back to expose the brush system. The brush is advanced out of its catheter multiple times to collect the cells. The brush is removed and placed in cytology solution.
- When performing a forceps biopsy, the sheath is placed just proximal to the lesion and two to three samples are obtained and placed in formalin.

Stone and Debris

- After adequate drainage, a sheath is placed through which a noncompliant angioplasty balloon is advanced to dilate any common bile duct stricture, if present.
- Using a compliant balloon, debris and small stones are swept into the common duct and then pushed into the bowel.
- When the stone is too large to be pushed into the bowel, a stone-crushing basket can be used to break the stone into smaller pieces.

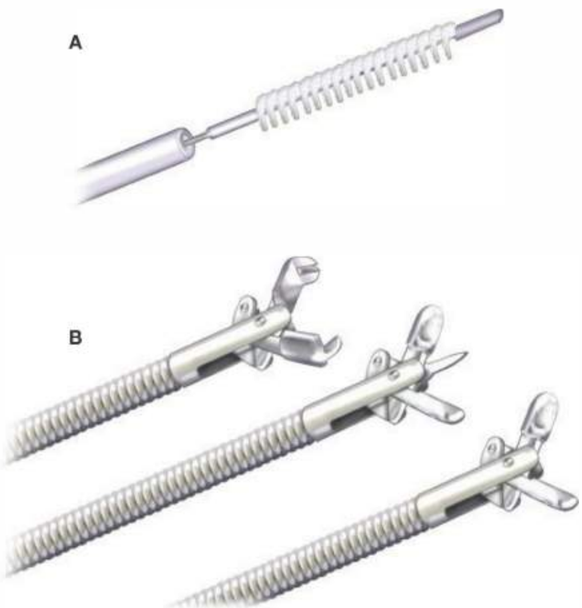

FIG 16 ● **A.** Biliary brush. **B.** Biliary introducer forceps.

PEARLS AND PITFALLS

Patient history and physical findings	■ Biliary dilation does not normally occur in posttransplant livers.
Operative technique	■ Defining maximum inspiration is important to prevent pleural transgression. ■ To prevent septicemia and endotoxemia, dilated biliary systems should be drained for 24 to 72 hours after catheter placement. Further intervention should be delayed. ■ Crossing the midclavicular line during duct cannulation increases the risk of a left-sided cannulation as well as traversing central vessels in the porta hepatis. ■ Minimizing the ductal entry angle allows for a proper force vector when dilating the tract and advancing the catheter. ■ Each puncture of the liver capsule increases the risk of bleeding. When redirecting the needle, care should be made not to remove it completely from the liver.
Postoperative care	■ Upper endoscopy should not be performed for up to 6 weeks after PTHD to prevent lethal air embolus from possible biliary to hepatic vein fistula.

POSTOPERATIVE CARE

- Drainage catheters should be flushed twice a day with 10 mL of sterile 0.9% saline.
- Patients with internal/external biliary catheters that are capped should be instructed to uncap the catheter and place it to gravity bag drainage if they experience abdominal pain, fevers, leakage, or pruritus. They should be evaluated in the next 24 to 48 hours.
- During the process of a "challenge," it is not uncommon for there to be some leakage around the biliary catheter; this should resolve in a few days. If it does not resolve, it may indicate a challenge failure.
- When a patient is draining externally, the possibility of dehydration and electrolyte loss must be taken into consideration. Patients should replace the amount of bile loss with an oral fluid that contains electrolyte replacement.

OUTCOMES

- For a PTC, the success rate is linked to whether the ducts are dilated. For a dilated system, the success rate nears 100%, however, in a non-obstructed system the success rate is considerably lower (65%).[2]
- The success rate for all biliary interventions is dependent on the technical success of cannulating the biliary tree. The success rate for a dilated system is significantly higher than for a nondilated system (including transplants), 99% and 74%, respectively.[2,3]
- Once cannulated, internalization of the catheter is successful in 78% of native livers but only 59% in transplanted livers.[4]
- Technical and clinical success rates for balloon dilation of benign strictures are 93% to 100% and 75% to 94%, respectively.[5] However, there is a wide variation based on the location of stenosis.[6]
- Average patency of metallic stents for malignant strictures is about 6 months.[1]

COMPLICATIONS

- The risk of all complications is <3%[7] and include:
  - Hemorrhage
  - Bile leak
  - Bile peritonitis
  - Sepsis
  - Pancreatitis
  - Pleural transgression
  - Contrast reaction
  - Death

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Chapter 7

Surgically Assisted Endoscopic Retrograde Cholangiopancreatoscopy

Kfir Ben-David Steven J. Hughes

DEFINITION

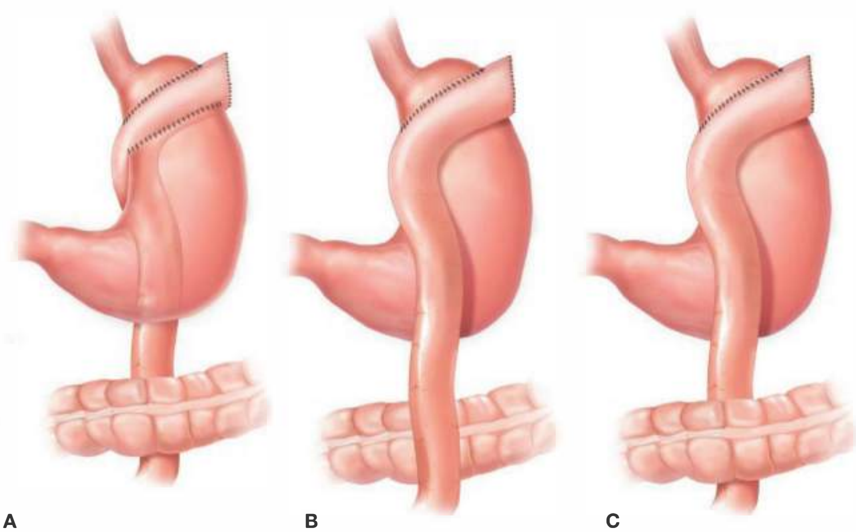
- Surgical assistance to successfully perform endoscopic retrograde cholangiopancreatoscopy (ERCP) is necessary when intestinal continuity has been surgically modified such that the ampulla of Vater cannot be accessed via the mouth.
- Previous gastric bypass with a long Roux-en-Y limb is the surgical procedure that leads to the need for surgically assisted ERCP.
- The presence of a gastric remnant is essential to the performance of surgically assisted endoscopic retrograde cholangiopancreatoscopy (SA-ERCP).
- Rarely, a clinical scenario may arise where surgical access to a gastric remnant may be indicated to facilitate endoscopic ultrasound (EUS).
- As magnetic resonance cholangiopancreatography (MRCP) provides a noninvasive means to assess the pancreaticobiliary duct systems in most patients, ERCP is generally not indicated merely as a diagnostic modality—therapeutic intent is the indication for ERCP; this concept must be emphasized when considering SA-ERCP.

DIFFERENTIAL DIAGNOSIS

- Choledocholithiasis
- Sphincter of Oddi dysfunction
- Ampulla of Vater pathology
- Intraductal papillary mucinous neoplasm (IPMN)
- Chronic pancreatitis
- Disrupted pancreatic duct syndrome

PATIENT HISTORY AND PHYSICAL FINDINGS

- Historically, the most common indication for SA-ERCP was for the diagnosis and treatment of sphincter of Oddi dysfunction (SOD)—a condition thought to be elicited by gastric bypass surgery. However, results from a recent study have led to serious concerns about the value of therapeutic intervention for symptoms attributed to SOD.[1]
- A history of prior cholecystectomy must be obtained. If the gallbladder is in situ, a cholecystectomy is likely warranted as part of the SA-ERCP.
- The gastric bypass operative note must be reviewed. The location of the Roux limb with respect to the gastric remnant and transverse colon must be known preoperatively and this information factored into the counseling the patient as to the risks of the procedure—an antegastric and/or an antecolic Roux limb will increase the technical complexity and thus risk (**FIG 1**).
- Specifically review any potential allergy to iodinated contrast agents. Medical preparation to mitigate an allergic reaction may be indicated.



A B C

FIG 1 • Anatomic relationships of the Roux limb following gastric bypass **(A)** retrocolic, retrogastric; **(B)** antecolic, antegastric; and **(C)** retrocolic, antegastric.

SURGICAL MANAGEMENT

Preoperative Planning

- The potential need for serial ERCP procedures should be determined. A gastrostomy tube (G-tube) can be placed at the index procedure to facilitate subsequent endoscopic interventions. Potentially affected patients should be prepared for this possibility.
- These operations require significant coordination between multidisciplinary teams. The authors highly recommend that these procedures be scheduled as the first case of the day.
- The procedure needs to be scheduled in a room that can accommodate two teams, a C-arm fluoroscopy unit, and a mobile endoscopy cart.

Positioning

- The operative table should be configured so that C-arm fluoroscopy can be readily performed of the upper abdomen (**FIG 2**).
- After induction of general anesthesia, a urinary bladder catheter is placed. An orogastric tube is rarely necessary.
- The patient is positioned supine, ideally with both arms tucked to facilitate access for both C-arm fluoroscopy and the endoscopy team. A footboard is placed. A fixed liver retractor can be positioned on either side of the patient if needed.
- Venous thromboembolism prophylaxis (both mechanical and pharmacologic) should be used. Antibiotics are administered within the guidelines of Surgical Care Improvement Program (SCIP) criteria for a clean-contaminated procedure.

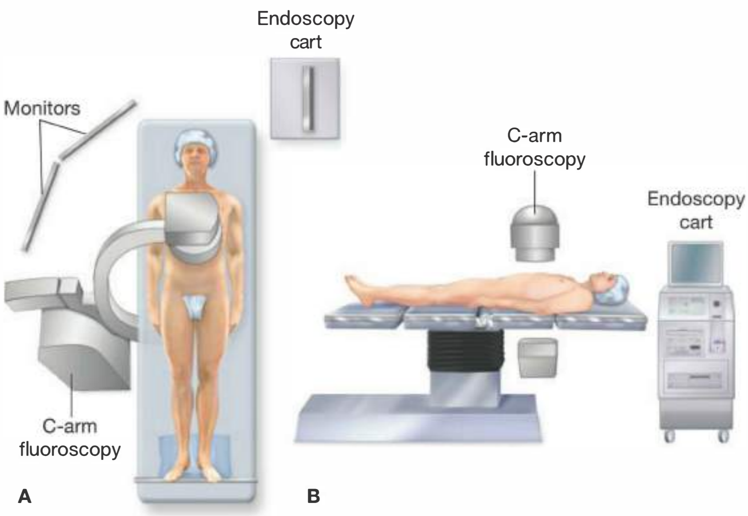


FIG 2 • The C-arm fluoroscopy unit is positioned on the patient's right, and the mobile duodenoscopy equipment on the patient's left.

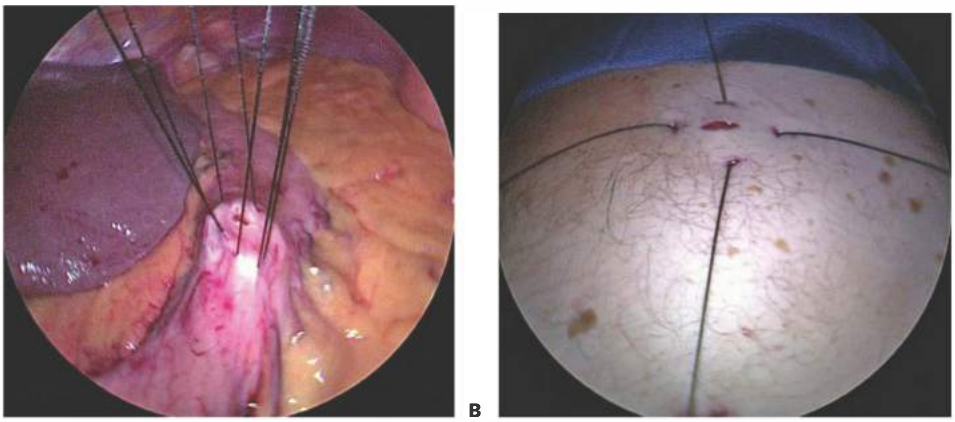
TROCAR PLACEMENT

- Trocar placement is depicted in **FIG 3**. Four trocars will be required for placement of stay sutures in the stomach, and one of these can be subsequently used for clamping of the small bowel. A subxiphoid, transgastric trocar is also necessary.
- Initial trocar placement is performed in the left midclavicular line at the level of the umbilicus following insufflation of the abdomen with a Veress needle. The authors prefer the use of an optical separator and a 30-degree scope.
- Subsequent trocars are placed under direct vision.

FIG 3 • Trocar placement for SA-ERCP. Pneumoperitoneum is established via a left midabdominal incision (alternatively, a periumbilical approach). The far right abdominal 5-mm trocar is used for grasping and the bowel clamp. The right, midclavicular line port (12 mm) is used for suture and stapler placement. The left abdominal 5- to 12-mm trocar is used for the camera and left port (5 mm) is used for grasping. The subxiphoid trocar *(X)* is placed transgastrically to provide access for the duodenoscope. It must be at least 15 mm in diameter.

GASTRIC PEXY

- The patient is placed in reverse Trendelenburg position and the location of the transgastric trocar placement determined and marked. Ideally, the trocar will enter the anterior gastric wall at the junction of the body and the antrum of the stomach at the midpoint between the mesentery of the greater and lesser curves.
- Determine the relationship of an antegastric Roux limb and the associated mesentery to the ideal target for the transgastric trocar. Dissection of the Roux limb or mesentery should be taken with great caution; injury to or vascular compromise of the Roux limb can be catastrophic. It is better to accept a more lateral target, including one that may require taking down some of the greater curve mesentery, than to engage in a significant dissection of the Roux limb from the stomach.
- Four stab wounds are placed around the planned site of the transgastric trocar.
- Starting with the cranial suture, four stay sutures are deeply placed in the gastric wall and snared using a Carter-Thomason device deployed through the appropriate stab wound. If a G-tube is planned, the Carter-Thomason should not be passed through the same tract so that the stay suture can ultimately be used to secure the gastric wall to the anterior abdominal wall (Stamm technique). Tag each suture without applying tension. The tension that will be subsequently applied to these sutures is significant and the risk of these sutures lacerating the stomach under this tension must not be underestimated. These sutures should be positioned in the stomach to create a 3 cm × 3 cm target for the transgastric trocar (**FIG 4**).



A B

FIG 4 ● **A.** Stay sutures are passed in all four quadrants to secure the stomach during placement of the transgastric trocar, facilitate closure of the gastrostomy, or serve as securing points for a Stamm gastrostomy. **B.** Close up of the subxiphoid, transgastric trocar site, and the associated stab wounds used for passage of the stay sutures.

PLACEMENT OF THE TRANSGASTRIC TROCAR

- Advance a 15-mm trocar through the abdominal wall (**FIG 5**). This larger trocar is absolutely necessary to accommodate the side-viewing duodenoscope. While applying gentle traction to the stay sutures, use an electrocautery device passed through the 15-mm trocar to create a small, anterior gastrotomy in the center of the target. This maneuver will facilitate falling away of the posterior gastric wall, thus mitigating the risk of inadvertent trocar injury to the posterior wall of the stomach.
- Advance the 15-mm trocar into the gastric lumen. This can be performed under direct vision through the trocar; alternatively, this maneuver can be visually supervised from the umbilical trocar. Intussuscept the trocar deeply into the stomach, directing it toward the pylorus while applying tension to the stay sutures. Confirm intraluminal location by passing the laparoscope into the lumen of the stomach via the trocar. Tag the stay sutures.

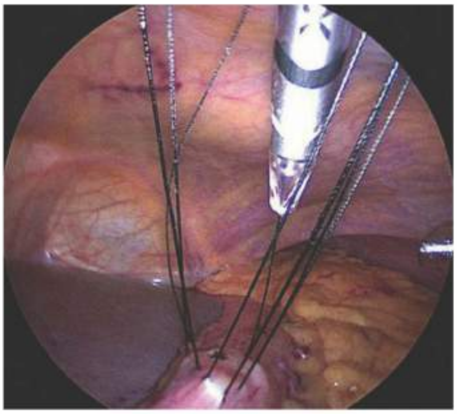


FIG 5 ● The transgastric trocar is first advanced across the abdominal wall. Electrocautery through this trocar establishes an anterior gastrostomy, centered in a 3 cm × 3 cm target zone, prior to advancing the trocar across the anterior gastric wall. This facilitates hemostasis and allows the posterior gastric wall to fall away, thus reducing the risk of posterior gastric wall injury as the trocar is advanced through the anterior wall.

ATRAUMATICALLY CLAMP THE PANCREATICOBILIARY LIMB

- Elevate the omentum and transverse colon to expose the ligament of Treitz. The reconstruction anatomy can dramatically impact the ease of this step.
- Identify the pancreaticobiliary limb and place an atraumatic bowel clamp through a right abdominal trocar to occlude the lumen and prevent gaseous distention of the small bowel (FIG 6).
- The authors routinely use a table-mounted fixed retractor that can stabilize this bowel clamp during the endoscopy phase of the procedure.
- Once this clamp is placed, transfer CO_2 insufflation to the transgastric trocar and confirm an airtight seal by the bowel clamp. This insufflation strategy can be maintained through the ERCP; it assists the endoscopist.

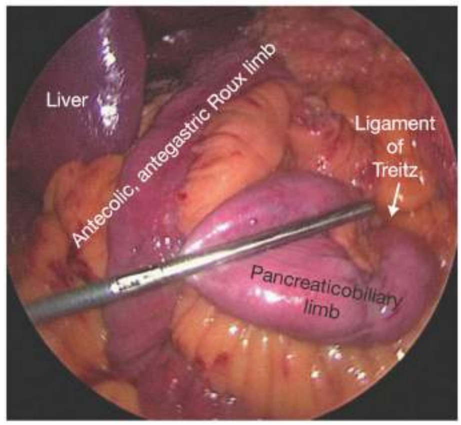


FIG 6 ● The pancreaticobiliary limb is atraumatically clamped to prevent distention of the small bowel from insufflation required during the ERCP.

DRAPE THE OPERATIVE FIELD AND PERFORM ENDOSCOPIC RETROGRADE CHOLANGIOPANCREATOSCOPY

- We prefer to cut a small hole in the center of a large laparotomy sheet and drape this over the entire patient so that only the 15-mm trocar is visible.
- ERCP then proceeds. We advise that the surgical team remain in the room during this portion of the procedure.
- At completion of the ERCP, desufflate the stomach via the transgastric trocar and move the insufflation to one of the remaining abdominal trocars. The duodenoscope and the 15-mm trocar (no longer sterile) are removed before the second surgical drape is removed.

GASTROSTOMY CLOSURE OR TUBE PLACEMENT

- The two lateral stay sutures are cut and removed, leaving the cephalad and caudad stay sutures in place to facilitate Endo GIA stapler closure of the gastrostomy.
- Alternatively, all stay sutures are left in place and used to secure the stomach to the anterior gastric wall.
- If indicated, a large-caliber G-tube with an inflatable balloon is advanced through the abdominal wall and into the lumen of the stomach (FIG 7). The balloon is inflated and the stay sutures secured under direct vision if possible. Occasionally, the pneumoperitoneum will lead to excessive tension of these sutures and securing them should be deferred until pneumoperitoneum is released.
- Consider placing a purse-string around the gastrostomy using monofilament suture. This will allow the caliber of the gastrostomy to equal that of the G-tube.

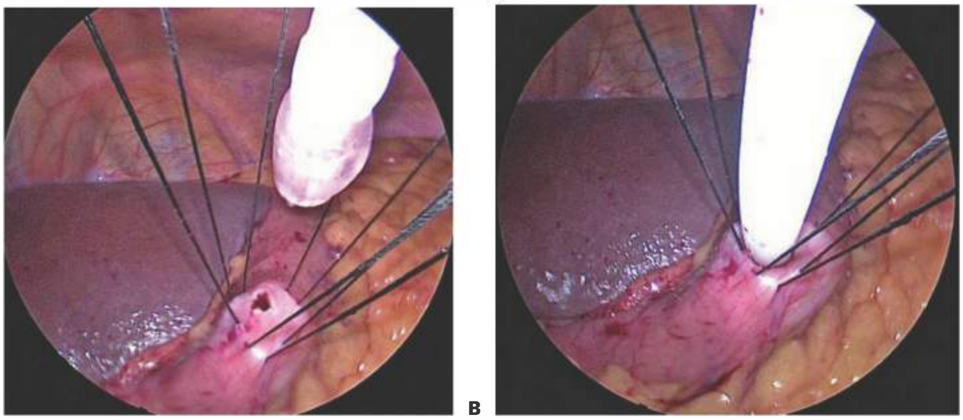


FIG 7 • A,B. Operative photographs of the laparoscopic placement of a G-tube. Inflate the balloon, release the pneumoperitoneum, and then tie the stay sutures.

PEARLS AND PITFALLS

Patient history and physical findings	■ You must know the reconstructive anatomy prior to surgery. An antegastric (and then potentially antecolic) Roux limb impacts the complexity and thus risk of the procedure. ■ Therapeutic management of SOD is now very controversial. Have clear therapeutic goals for the procedure before embarking on SA-ERCP.
Surgical management	■ Take large, deep bites of the stomach with the stay sutures. The stomach is prone to laceration by the sutures given the significant tension that is typically applied during this procedure. ■ A duodenoscope will not pass through a 12-mm trocar. Use a 15-mm trocar. ■ If you do not effectively occlude the pancreaticobiliary limb with a bowel clamp, you will not be able to see anything once the ERCP is completed. The bowel will be distended with gas.
Postoperative care	■ If multiple ERCP sessions are planned, leave a large-caliber, balloon-tipped, G-tube.

POSTOPERATIVE CARE

- Patients should be monitored overnight for evidence of complications.
- A liquid diet can usually be initiated the evening of surgery.
- If a G-tube has been placed, it should be left to gravity drainage overnight and can be clamped the morning of the first postoperative day prior to discharge.

COMPLICATIONS

- Devascularization or laceration to the Roux limb
- Posterior gastric wall injury
- Pancreatitis
- Other complications of ERCP (i.e., retroduodenal perforation)

OUTCOMES

- SA-ERCP should be successfully completed in a very high percentage of cases.[2] The supine position can be challenging for even experienced endoscopists.
- Outcomes should be equivalent to those reported for ERCP without the need for surgical access to a gastric remnant.

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Chapter 8

Roux-en-Y Choledochojejunostomy

Shawnn Nichols Mark Bloomston

DEFINITION

- Choledochojejunostomy involves the anastomosis of the common bile duct (CBD) to the jejunum, thereby reestablishing continuity of biliary flow (**FIG 1**). It may be used for repair of biliary strictures, after traumatic or iatrogenic CBD injury, or following for surgical resection for benign or malignant disease of the distal CBD. It may also be incorporated in resection of duodenal, ampullary, or pancreatic tumors, such as in pancreaticoduodenectomy.
- Our discussion here is limited solely to choledochojejunostomy.

DIFFERENTIAL DIAGNOSIS

- Choledochal cyst excision (type I, II, or III)
- Repair of CBD strictures
- Repair after traumatic or iatrogenic injury of the CBD
- Diversion of biliary flow in the presence of distal obstruction or pending obstruction for palliation
- Orthotopic liver transplantation
- Reestablishing biliary continuity after resection of benign or malignant disease, including biliary, ampullary, duodenal, or pancreatic head neoplasms

PATIENT HISTORY AND PHYSICAL FINDINGS

- A thorough medical history and physical exam is important in determining the possible etiology causing the need for reestablishing biliary continuity. The overall health of the patient must be considered in determining whether the patient is a surgical candidate. Past surgical history is essential to identifying those patients at risk of iatrogenic strictures.
- Symptoms of easy bruising, pruritus, acholic stools, nausea, vomiting, right upper quadrant pain, fevers, chills, mental status changes, and weight loss are important indicators of hepatic dysfunction and biliary obstruction.
- Physical exam findings of abdominal mass, abdominal pain, abdominal surgical scars, jaundice, and scleral icterus should be sought. Additionally, indicators of cholangitis should be identified and rapidly treated: Charcot's triad (right upper quadrant abdominal pain, jaundice, and fever) or Reynolds' pentad (Charcot's triad findings plus mental confusion and septic shock) indicate the need for preoperative biliary drainage.

IMAGING AND OTHER DIAGNOSTIC STUDIES

- Hilar anatomy must be evaluated prior to surgery, identifying any aberrant biliary or arterial anatomy and elucidating the possible etiology, site of injury, extent of obstruction, and planned surgical approach needed.
- Contrast-enhanced computed tomography (CT) or magnetic resonance imaging (MRI) should be used to properly identify the anatomy and assess for potential vascular involvement in neoplastic processes or injury in iatrogenic biliary injuries. Magnetic resonance cholangiopancreatography (MRCP) is particularly useful to elucidate the biliary and pancreatic ductal anatomy and adjacent structures (**FIG 2**). Imaging is useful and often helpful in predicting the etiology of benign or malignant neoplasms. Image-guided percutaneous

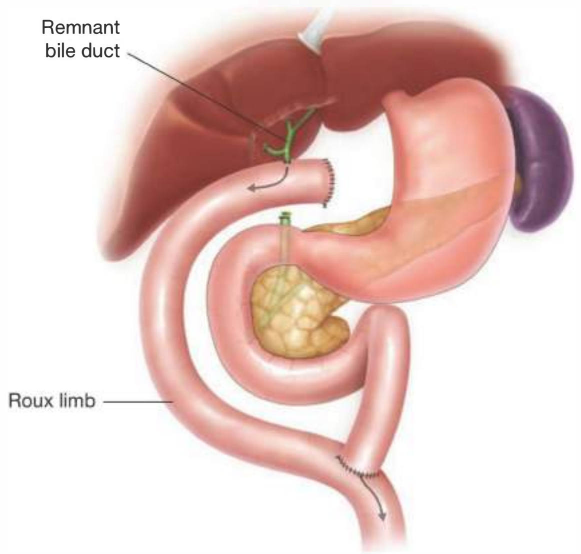

FIG 1 ● Illustration of a Roux-en-Y choledochojejunostomy.

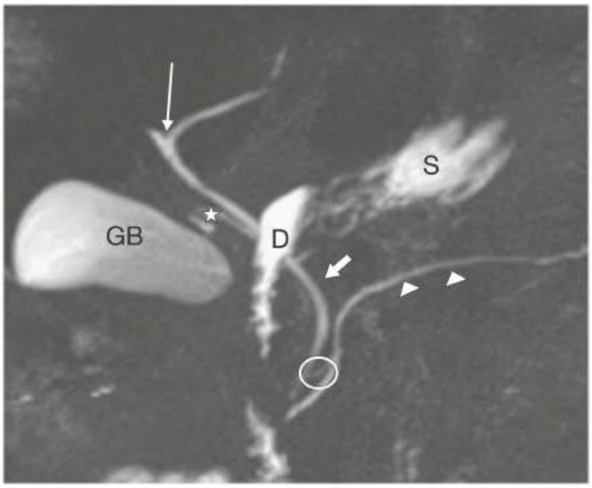

FIG 2 ● MRCP image depicting normal biliary anatomy. *S*, stomach; *D*, duodenum; *GB*, gallbladder; *arrowheads*, pancreatic duct; *thin arrow*, confluence of the right and left hepatic ducts; *thick arrow*, CBD; *star*, cystic duct; *white circle*, accessory pancreatic duct.

FIG 3 ● ERCP image reveals dilated intrahepatic and extrahepatic ducts, with the CBD dilated at 17 mm and narrowing of the distal portion at the ampulla in an ampullary cancer.

approaches with ultrasound or CT guidance may enable tissue biopsy of suspicious lesions.

- Evaluation with endoscopic ultrasound (EUS) or with endoscopic retrograde cholangiopancreatography (ERCP) offers another method to assess the anatomy and for tissue biopsy (**FIG 3**).
- In cases of cholangitis or biliary obstruction, biliary decompression by ERCP or percutaneous transhepatic cholangiography (PTC) may be warranted prior to surgical repair. It should be noted that biliary stenting in the face of asymptomatic mild to moderate hyperbilirubinemia, prior to elective surgery, may increase the postoperative risk of infection.[1]
- A previously obtained intraoperative cholangiogram (IOC) may be available and prove beneficial. Many cases of iatrogenic injuries occurring during laparoscopic cholecystectomy (LC) are identified by this technique (**FIG 4**).

SURGICAL MANAGEMENT

- Indications include:
  - Bypass of distal or ampullary strictures.
  - Reconstruction after traumatic or iatrogenic injuries.
  - Reconstruction following Choledochal cyst excision (type I, II, or III).
  - Benign or malignant disease: biliary, ampullary, duodenal, or pancreatic head neoplasms. It can be included for palliative diversion or following resection.
  - Reconstruction during Orthotopic Liver transplantation.

Preoperative Planning

- Standard optimization of comorbidities should be managed as permitted; for example, diabetes, hypertension, and cardiopulmonary status.

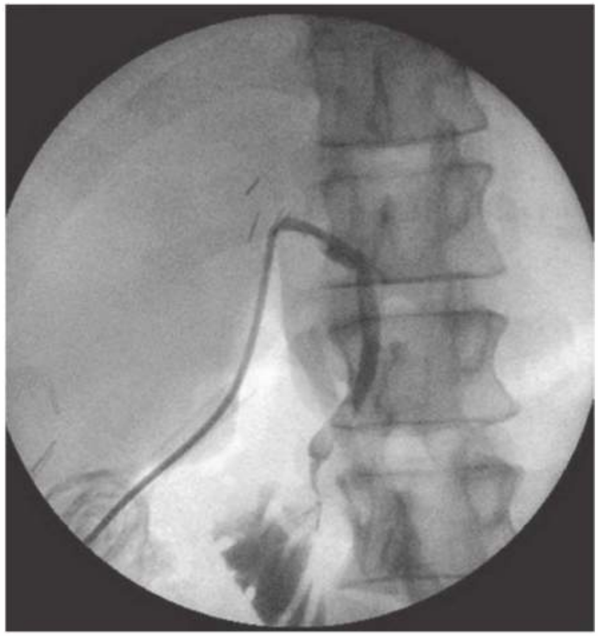

FIG 4 ● IOC image with identification of an iatrogenic duct injury occurring during an attempted LC for acute cholecystitis. Surgical clips are noted. Contrast is seen with antegrade flow into the duodenum, but no retrograde flow is appreciated, indicating iatrogenic occlusion of the proximal bile duct.

- Coagulation disorders, if present, should be corrected with vitamin K as required.
- In the appropriately selected jaundiced patient, preoperative stenting via ERCP and/or PTC may be necessary.
- Cholangitis, if present, should be treated with appropriate drainage and antibiotics. Common biliary pathogens include *Escherichia coli*, *Klebsiella* spp, *Enterococcus* spp, streptococci, *Enterobacter* spp, and *Pseudomonas aeruginosa*.
- In the absence of cholangitis, preoperative antibiotics should be given, and expanded in the presence of biliary stenting due to the increased risk of biliary contamination, even in asymptomatic patients.
- In malnourished patients, nutritional support may be considered preoperatively and continued into the postoperative period to minimize postoperative complications. Adequate nutrient absorption may be hindered preoperatively due to biliary blockage or diversion.
- In the face of malignant disease, preoperative workup should also be tailored to the assessment of the type and extent of disease present. Surgical resectability is of primary concern in malignant processes; however, choledochojejunostomy may be undertaken as a palliative biliary diversion in unresectable malignancies.

Positioning

- Patient is placed in supine position with both arms at 90 degrees, ensuring pressure points are protected and padded (**FIG 5**).
- We use a bilateral post, framed retractor system (**FIG 6**) to maximize exposure via a bilateral subcostal incision.

FIG 5 ● Proper patient positioning with arms at 90 degrees and placement of an airflow warming device over the patient's upper body to prevent hypothermia. *Solid line* denotes the costal margin. *Dotted line* depicts planned placement of bilateral subcostal incision.

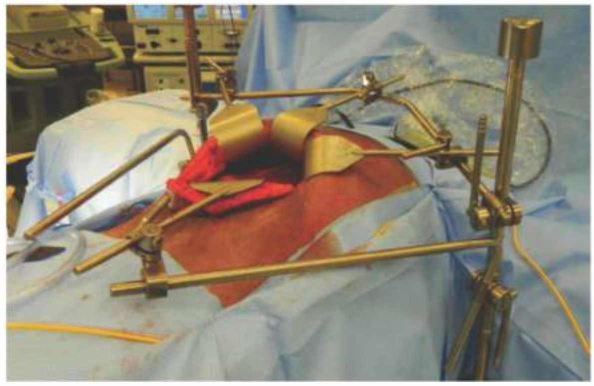

FIG 6 ● Bilateral subcostal incision with a bilateral post retractor system in place to maximize exposure.

PLACEMENT OF INCISION AND OPERATIVE EXPOSURE

- A bilateral subcostal incision provides optimal exposure. Once the peritoneum is entered, adhesions are cleared if present, and the falciform ligament is divided between ties or with an energy device. This further exposes the operative field and permits retractor placement (**FIG 6**).
- The abdomen is explored and all peritoneal surfaces are palpated if malignancy is suspected. The root of the mesentery is palpated early to assess for foreshortening due to tumor infiltration, inflammation, or previous surgery, which may impact the ability to develop a Roux limb for reconstruction.
- Exposure of the porta hepatis is begun by mobilizing the hepatic flexure of the colon, as necessary.
- Kocherization of the duodenum provides optimal exposure of the distal CBD.
- The gallbladder, if present, is removed in a top-down fashion. If the porta hepatis is involved in acute and/or chronic inflammation, the cystic duct should be traced to locate the common hepatic duct (CHD) and the CBD.
- Meticulous dissection of the porta hepatis is necessary to identify essential structures to prevent inadvertent injury. Care should be taken to search for and prevent injury to aberrant or replaced anatomic variations. A replaced right hepatic artery arising from the superior mesenteric artery will lie to the right and deep to the CBD and can be injured during CBD transection if not anticipated. The right hepatic artery commonly courses behind the CHD but on occasion the artery may lie anterior to the CHD. Biliary anatomic variations should also be expected (see Part 3, Chapter 15, FIG 17). The absence of aberrant anatomy on preoperative imaging should not usurp careful dissection with anticipation of variance.
- Dissection and exposure of the CBD may be difficult in the face of inflammatory changes resulting from prior surgeries, radiation exposure, and/or preoperative placement of a biliary stent. At times, intraoperative ultrasound may be helpful in proper identification of the structures within the porta hepatis. Another method to identify the CBD when dissection is difficult is to use a small-gauge needle and aspirate looking for bile.
- With proper identification and dissection of the CBD, the site of transection is selected proximal to the location of injury or obstruction. It should be noted that the arterial supply to the bile duct runs along the lateral and medial aspects of the CBD and CHD, and care should be taken to avoid extensive dissection or mobilization that may compromise this blood supply. When transection of the bile duct with end-to-side reconstruction is planned, the predominant blood supply will come from the right hepatic artery near the liver hilum. Thus, a higher point of transection is desired to optimize blood supply to the anastomosis. The margin of resection should be pathologically assessed intraoperatively in the face of malignancy.
- With the transection site selected, the CBD can be divided sharply or with electrocautery in cut mode to minimize thermal damage. If a stent has been placed preoperatively, it is removed at this point. Cultures of the bile fluid may be warranted. The proximal duct should be probed to ensure patency and confirm ductal anatomy—The probe should be guided up both the left and right hepatic ducts. Cholangioscopy can be undertaken if there is concern for proximal obstruction or hepatolithiasis. To control bile spillage and facilitate hemostasis, the proximal stump is temporarily closed with a vascular bulldog clamp.

CREATION OF THE ROUX LIMB

- Although choledochoduodenostomy or choledochojejunostomy using a loop of jejunum are reconstructive options that may be appropriate in the clinical setting of a short life expectancy or a particularly hostile abdomen due to adhesions, a defunctionalized segment of jejunum using a Roux-en-Y technique is preferred due to superior outcomes. Beginning at the ligament of Treitz, the jejunum is examined to the first point at which a loop can easily be brought up to the divided CBD without tension based on the length of the mesentery and at a point where the vascular arcade can be preserved to both limbs as determined by transillumination of the mesentery. A gastrointestinal anastomosis (GIA) stapler is used to divide the jejunum at this point. The mesentery is then divided down to its base using ligatures for hemostasis. Care must be taken to maintain proximal and distal orientation of the divided jejunum. A defect is created in the transverse mesocolon, to the right of the middle colic vessels, and the Roux limb is brought up in a retrocolic orientation to serve as the defunctionalized biliary-enteric limb and placed without tension near the divided CBD.

CHOLEDOCHOJEJUNOSTOMY ANASTOMOSIS

- The choledochojejunostomy is created in a single-layer, interrupted fashion using no. 4-0 or no. 5-0 polydioxanone monofilament absorbable suture. If nonabsorbable suture is used, all knots must rest outside of the anastomosis to prevent stone formation.
- Stenting across the anastomosis is not routinely undertaken, even in the case of a normal-sized duct.
- An end-to-side anastomosis provides for ease of exposure during the reconstruction. Electrocautery is used to create an enterotomy on the antimesenteric side of the Roux limb approximately 3 to 4 cm from the stapled end. The enterotomy is sized smaller than the transected CBD width, in anticipation of "enterotomy stretch" that occurs with suturing.
- The CBD is reopened, bile flow is again confirmed, and the duct cleared as necessary. The duct is trimmed as needed with Potts scissors, allowing for maximal diameter; sharp, crisp edges; and identification of good vascularity.

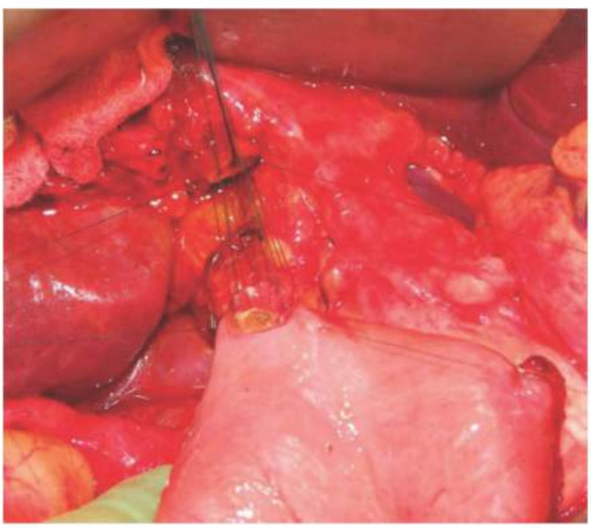

FIG 7 ● Creation of the choledochojejunostomy anastomosis. Corner sutures placed to permit lateral traction and orientation of the posterior and anterior rows. Posterior row of monofilament sutures are placed in such a way that the knots will lay within the lumen.

- The jejunum is placed near the CBD stump, positioned so as to limit redundancy and kinking of the jejunum. Lateral traction sutures are placed full thickness out-to-in on the jejunum and in-to-out on the bile duct, left untied, and placed on hemostats under gentle lateral traction.
- The posterior row sutures are placed approximately every 2 to 3 mm apart, taking full-thickness bites of the duct and jejunum, working from one lateral corner to the other. Be certain that the jejunal mucosa is incorporated into the stitch. Sutures are placed in-to-out on the jejunum and out-to-in on the duct, such that when tied the knot will be within the lumen (**FIG 7**). Gentle upward traction on the anterior wall of the bile duct provides nice exposure of the lumen to ensure proper suture placement through the posterior wall. The sutures are tagged and left untied to allow the Roux limb to be manipulated freely to maximize exposure.
- Great care is taken to maintain orientation of the suture so that it does not become twisted. Suture order must be preserved to prevent overlaping, and thus narrowing of the anastomosis when the posterior row is complete and the knots tied. Small hemostats should be used to tag each suture and place them in the proper orientation and order on a sponge forceps, thus making this task less cumbersome and more efficient (**FIG 8**).

FIG 8 ● Sutures placed during creation of the posterior and anterior rows are left untied, tagged with hemostats, and their orientation and order maintained by arranging them on a sponge forceps clamped to a laparotomy sponge. This is placed above the retractor system on the drapes and optimizes efficiency when tying the sutures.

- Once all of the posterior row sutures are placed, we begin tying each suture in order from one corner to the other, carefully laying the knots to ensure optimal intervals along the way. If an interval is determined to be too large (>3 to 4 mm), an additional suture is placed, tied, and then the remainder of the row sutures are tied (**FIG 9**). The corner sutures are left untied to allow mobility and maximum exposure of the entire back row while placing the anterior row of sutures. Suture tails are then cut short and the anterior row is addressed.
- The anterior row sutures are placed in an out-to-in fashion on the jejunum and an in-to-out fashion on the duct so that the knots will be on the outside when tied (**FIG 10**). Again, intervals are assessed and additional sutures placed as needed.
- Once complete, the anastomosis is inspected for evidence of a bile leak (**FIG 11**). Absence of tension on the anastomosis is confirmed. The surgical field is dried, ensuring good hemostasis and a clean, white surgical sponge is carefully packed around the anastomosis, and attention is turned to creating the jejunojejunal anastomosis.

FIG 10 ● The anterior row of sutures have been placed. Visual inspection confirms proper interval placement of the sutures. The sutures are ready to be tied to complete the choledochojejunostomy anastomosis.

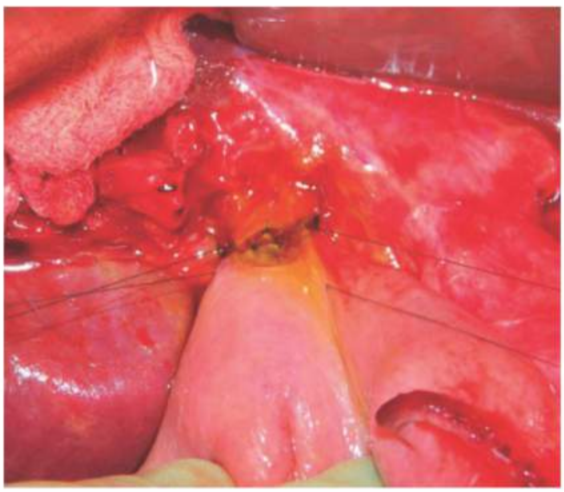

FIG 9 ● The choledochojejunostomy posterior row sutures have been tied and the row inspected. The previously placed lateral traction sutures are left untied in preparation for placement of the anterior row sutures. Gentle downward traction on the Roux limb enhances exposure as shown in the picture.

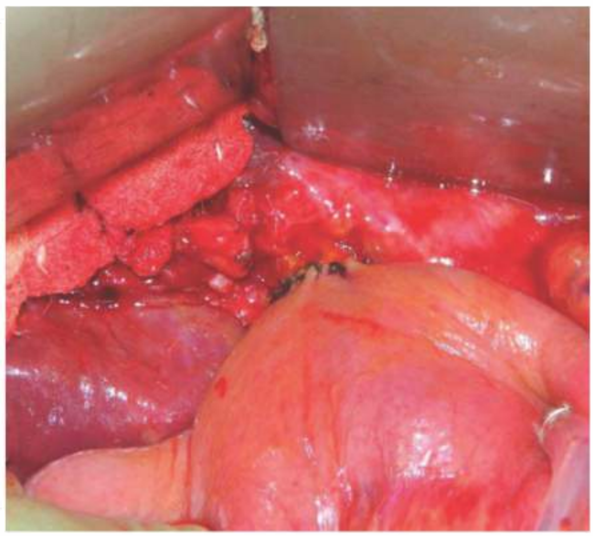

FIG 11 ● The anterior row sutures have been tied, and the choledochojejunostomy anastomosis is carefully inspected for any bile leak. A small, clean, white gauze (not pictured) is placed posterior to the anastomosis to aid in evaluation of a biliary leak.

JEJUNOJEJUNAL ANASTOMOSIS

- Intestinal continuity is reestablished by a Roux-en-Y anastomosis. The proximal biliopancreatic limb is anastomosed to the biliary-enteric Roux limb approximately 45 to 65 cm downstream from the choledochojejunostomy anastomosis to minimize enteric reflux. We prefer to create a side-to-side, functional end-to-end anastomosis using a linear stapling device, then closing the common enterotomy with a single row of interrupted no. 3-0 silk sutures using a modified Gambee technique.
- The small bowel mesenteric defect is closed at the Roux-en-Y anastomosis.
- If a retrocolic position for the biliary-enteric limb was used, any redundancy laying in the subhepatic bed is reduced without placing tension on the anastomosis. The mesocolic defect is closed, incorporating a seromuscular bite of the passing jejunum, with no. 3-0 silk sutures to prevent the possibility of limb migration and/or internal herniation. Every attempt should be made to ensure that this closure does not impinge upon the bowel.

PREPARING FOR CLOSURE

- Returning to the choledochojejunostomy, the previously placed sponge is carefully removed and inspected for any bile staining. If present, further inspection of the anastomosis is warranted and additional sutures are placed as needed.

CLOSURE

- We routinely place a single fluted surgical drain on closed suction posterior to the choledochojejunostomy anastomosis and down into Morrison's pouch, then out through a separate stab incision on the right side of the abdomen. The drain is appropriately secured with suture at the skin.
- The abdominal fascia is closed in two layers (posterior fascia and anterior fascia) with no. 1 absorbable synthetic monofilament.
- The skin is reapproximated with buried, deep dermal, interrupted, no. 3-0 absorbable braided sutures. The skin is closed with surgical glue.

PEARLS AND PITFALLS

Indications	■ A thorough history and physical (H & P) exam with good preoperative imaging is important in anticipating the extent of the procedure.
Dissection	■ Anticipate aberrant and accessory anatomy within the porta hepatis.
Excision	■ Send CBD margins for frozen section analysis when considering malignant disease.
Choledochojejunostomy	■ Meticulous suture technique is critical. There should be no concerns with the posterior row prior to proceeding with the anterior row. ■ Avoid the urge to place too many sutures. ■ Proper suture orientation is important as any crossing of suture knots will lead to ischemia of the interposed tissue. ■ Ensure there is no tension on the anastomosis.

POSTOPERATIVE CARE

- We typically remove the nasogastric tube (NGT) early (i.e., 1 to 2 days postoperative), unless ileus is anticipated (e.g., emergency surgery, active cholangitis, extensive enterolysis), and start a clear liquid diet.
- The patient is encouraged to begin ambulating on postoperative day (POD) 1. Appropriate postoperative thromboembolism prophylaxis is started on POD 1.
- Drain output is assessed and followed for the presence of bile. If present, the drain will be kept until bile output has cleared, as it almost always will do so on its own. If drain output is serous, then the drains can be pulled with little concern for volume of output. Drains are pulled after the patient is tolerating a diet and usually prior to discharge.
- Postoperative laboratory studies are followed on a daily basis to include a complete blood count, serum chemistry, and liver function tests.

OUTCOMES

- Long-term survival rates after choledochojejunostomy are dependent on the underlying indication for the procedure.

COMPLICATIONS

- Complications occur in up to 40% of cases[2] and include the following:
  - Wound infection
  - Biloma—can usually be managed with percutaneous drainage
  - Anastomotic leak (biliary and/or enteric)—may require operative drainage but often can be managed with the surgically placed drain or by radiologically placed percutaneous drains
  - Cholangitis—generally indicates reflux from ileus; it can be managed with NGT decompression and antibiotics; PTC may be used to decompress Roux limb specifically if NGT ineffective.
- Biliary stricture (can occur up to 10 or more years after surgery)—heralded by rising alkaline phosphatase; often can be treated with PTC and balloon dilation but may require surgical revision of the anastomosis

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Chapter 9 Minimally Invasive Choledochojejunostomy

Janak Parikh C. Max Schmidt Eugene P. Ceppa

DEFINITION

- Hepaticojejunostomy is the operative formation of an anastomosis between the biliary tree and a Roux limb of the jejunum to manage biliary obstruction secondary to benign or malignant strictures, or to reconstruct continuity following resection of the extrahepatic biliary tree or pancreaticoduodenectomy.

DIFFERENTIAL DIAGNOSIS

- Benign
  - Traumatic or iatrogenic bile duct injury
  - Chronic pancreatitis
  - Choledochal cyst
  - Mirizzi's syndrome
- Malignant
  - Extrahepatic cholangiocarcinoma (palliative or after resection)
  - Periampullary tumors (palliative or after resection)
  - Portal lymphadenopathy (palliative)

PATIENT HISTORY AND PHYSICAL FINDINGS

- History—The following features may be obtained:
  - Weight loss (malignancy vs. malabsorption)
  - Fevers/chills (cholangitis)
  - Yellow eyes/skin (obstructive jaundice)
  - Tea-colored urine (obstructive jaundice)
  - Acholic stools (obstructive jaundice)
  - Right upper quadrant pain (distended gallbladder, may suggest a process distal to the cystic duct confluence)
- Physical examination
  - Temporal wasting (cachexia)
  - Scleral icterus
  - Jaundiced skin
  - Right upper quadrant tenderness
  - Courvoisier's sign—painless, palpable gallbladder with jaundice

IMAGING AND OTHER DIAGNOSTIC STUDIES

- Ultrasonography—preferred initial evaluations as it is readily available and inexpensive. Findings may include the following:
  - Gallbladder
    - Stones
    - Cholecystitis
  - Biliary tree
    - Extrahepatic duct dilatation
    - Intrahepatic duct dilatation
- Cross-sectional imaging
  - Computed tomography abdomen/pelvis (CT A/P) with intravenous (IV) contrast—Triple-phase CT A/P is warranted in most cases of obstructive jaundice as part of determining the probable etiology and defining surgical anatomy. This includes the following:
    - Determine location of hepatic arteries and potential anomalous anatomy
    - Compression, invasion, or thrombosis of portal, splenic, and/or superior mesenteric veins
  - Magnetic resonance imaging/magnetic resonance cholangiopancreatography (MRI/MRCP) with IV contrast is preferred by some institutions. It is superior to ultrasound (US) and CT in identifying the location of biliary strictures.
- Cholangiography
  - Endoscopic retrograde cholangiopancreatography (ERCP) is the "gold standard" when biopsy or other therapeutic intent is warranted.
    - Provides superior diagnostic information by identifying level of obstruction/anatomy
    - Allows for sampling of tissues at the level of obstruction via brushings for cytology
    - Is therapeutic by placement of biliary endoprosthesis to decompress biliary tree
  - Percutaneous transhepatic cholangiography (PTC) is reserved for therapeutic intervention when ERCP is technically not feasible, that is, following gastric bypass or in the clinical setting of concomitant gastric outlet obstruction.
    - Second option—Palliation is less effective as the patient will have pain from the PTC site and will need to perform daily care to the catheter.

SURGICAL MANAGEMENT

Preoperative Planning

- Underlying cardiopulmonary disease must be evaluated when considering the laparoscopic approach; affected patients may not tolerate reduced venous return or clear increased concentrations of carbon dioxide resultant from the pneumoperitoneum.
- An extensive past abdominal surgical history or previous peritonitis may impact the ability to perform the hepaticojejunostomy laparoscopically due to extensive adhesions. Prior abdominal surgery may also impact the approach of initial peritoneal access and subsequent port placement (i.e., avoiding abdominal wall defects), or mandate modification of the formation or routing of the reconstructive Roux limb.
- Morbid obesity can preclude adequate laparoscopic visualization, but these patients have the greatest potential benefit of a minimally invasive approach due to the reduced wound morbidity. Obesity mandates several considerations:
  - Distinct, longer instrumentation may be required to reach the right upper quadrant and level mechanics, thus may impact fine motor movements limitations with suturing and intracorporeal knot tying.
  - Mobilization of the hepatic flexure and a Kocher maneuver are made more difficult when the transverse mesocolon

and omentum contain more fat and organs are larger in size overall.

- Large, friable livers as a result of fatty liver disease and are prone to lacerations (hemorrhage within the operative field significantly impairs image brightness).

Positioning

- The patient is positioned supine with both arms abducted on arm board extensions of the operating table.
- A nasogastric tube and Foley catheter are placed.
- Use a footboard.

LAPAROSCOPIC CHOLEDOCHOJEJUNOSTOMY

- Port placement and role of each in the procedure is depicted in **FIG 1**.
- To first create the Roux limb, elevate and retract the omentum and transverse colon to the upper abdomen. The ligament of Treitz is identified at the base of the transverse mesocolon. Reverse Trendelenburg positioning may facilitate visualization by dropping the small bowel into the lower abdomen.
- A point for division of the proximal jejunum is identified distal enough from the ligament of Treitz to facilitate the jejunojejunostomy and such that the mesentery will have adequate length to reach the right upper quadrant without tension on the blood supply. At this location, the small bowel is divided using a laparoscopic stapler with a 2.5-mm staple load after a window is created between the vasa rectae of the small bowel.
- Use bipolar energy device or a vascular staple load to divide the mesentery toward the base. Use care not to encroach on the arterial arcade on either side of the divided bowel. This maneuver will give additional length of the mesentery necessary to reach the bile duct without putting the anastomosis under undue tension. The bowel proximal to the staple line is the alimentary limb; an additional 40 to 60 cm of small bowel distal to the staple line is measured and referred to as the Roux limb.
- A side-to-side jejunojejunostomy is fashioned. Two 3-0 stay sutures are placed 6 to 10 cm apart. Small, adjacent enterotomies are created in each limb of the jejunum with the cautery. An articulating 60-mm long, 2.5-mm staple load is introduced into the bowel via the enterotomies. Care must be taken to ensure that the mesentery is outside the staple load. The anastomosis between the alimentary and Roux limbs is created with the stapler. The common enterostomy is oversewed with a 3-0 absorbable running suture. Alternatively, this common defect can be closed with an additional firing of the stapler. The jejunojejunostomy mesenteric defect is closed with a running 2-0 nonabsorbable suture to prevent future internal hernias. Avoid full-thickness bites across the bowel mesenteric edge that was previously sealed with an energy device; this can lead to unnecessary hemorrhage, ischemia, or hematoma near your anastomosis resulting in bleeding, perforation, or obstruction postoperatively. Solely suture the peritoneum superficially together.

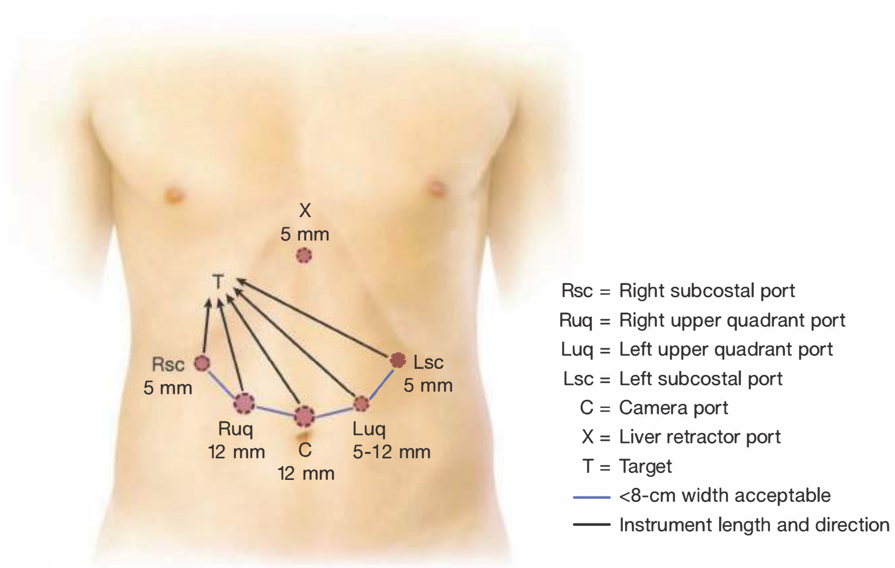


FIG 1 ● Laparoscopic access ports. The surgeon is positioned on the patient's right. The liver is retracted anterior with a fixed retractor. The first assistant on the patient's left facilitates the procedure by maintaining tension on the running suture at all times and assisting in the positioning of the Roux limb to facilitate accurate placement of sutures.

- Next, visualize the Roux limb mesenteric edge and travel down toward the root of the mesentery to ensure the mesentery is not twisted (this is worth double- or triple-checking as peripheral visualization is limited during laparoscopic surgery).
- Create a defect in the transverse mesocolon with the tissue-sealing device to the right of the right branch of the middle colic artery. Preserve the left space in case a future pancreatic Roux limb is needed.
- Mark the Roux limb staple line with a stitch or a Penrose drain/colored tourniquet to make passing the bowel through the mesenteric defect to the porta hepatis easier (optional).
- Attention is turned to the mobilization of the common bile duct within the hepatoduodenal ligament.
    - If cholecystectomy has not been previously performed, identify the cystic duct and dissect proximally toward the common hepatic–bile duct junction; if the gallbladder is surgically absent, start the dissection using a lateral to medial approach to the soft tissues of the hepatoduodenal ligament. Incise the peritoneum overlying the anterior aspect of the hepatoduodenal ligament to expose the bile duct and hepatic arterial supply. The bile duct will be lateral to the hepatic proper artery. Be mindful that the right hepatic artery travels anterior to the common hepatic duct in 10% of patients.
    - Mobilize the ligament further by incising the peritoneum laterally, extending the dissection down toward the inferior vena cava. Anterior retraction of the bile duct will facilitate exposure of the plane between the common bile duct and portal vein. This step is important to facilitate the next step, the blind passage of an instrument from the medial side, between the hepatic artery and the bile duct while staying anterior to the portal vein.
    - Encircle the bile duct with a vessel loop or Penrose drain; use metallic clips to secure the tails together.
    - Pass a right-angle instrument posterior to the bile duct and sharply divide the bile duct. Careful application of cautery or fine absorbable sutures can be used to obtain hemostasis at the 3 o'clock and 9 o'clock arterial supply at the cut edge of the proximal bile duct. The bile duct should bleed briskly; if it does not, then consider shortening the bile duct proximally to better perfused tissue.
    - If a biliary endoprosthesis or percutaneous biliary drain is across the bile duct, it should be removed at this time. If stenting the biliary-enteric anastomosis is desired, the ideal situation is to place a new 8- to 12-Fr biliary endoprosthesis across the anastomosis after the posterior row has been completed.
    - A laparoscopic bulldog clamp is commercially available and can be used to clamp the proximal cut edge of the bile duct; in some cases, this may allow for a slight dilatation of a smaller bile duct and minimize biliary soilage of the peritoneum.
- Biliary-enteric anastomosis
    - Most surgeons prefer the Trendelenburg position at the time of an intracorporeal hand-sewn choledochojejunostomy to take tension off of the anastomosis by way of the small bowel mesentery using gravity to bring the Roux limb closer. Reverse Trendelenburg position is useful in obese patients by using gravity to retract the hepatic flexure away from the porta hepatis. The Roux limb is usually supported with a grasper from one of the assistant port sites in either scenario.
    - For larger bile ducts (>5 mm in diameter), a running suture technique is appropriate. Tie two separate, 15- to 20-cm long, 4-0 absorbable sutures together to create a double-armed suture. For small bile ducts, interrupted 4-0 absorbable sutures are used for the posterior and anterior rows.
    - An enterotomy is made in the antimesenteric border of the Roux limb. Keep this enterotomy shorter than the diameter of the bile duct—it will stretch.
    - A stay suture is placed at 12 o'clock position on the bile duct for retraction of the anterior wall during creation of the posterior row (optional).
    - The "double-armed" suture that was created is introduced into the peritoneum; one arm is passed "outside-in" on the bowel and the other outside-in on the bile duct (starting at 3 o'clock position). Thus, both needles are "inside" and the knot is "outside" (**FIG 2A,B**).
    - The posterior row is created first by taking the suture inside the bile duct and going "inside-out" on the bowel, then outside-in on the bile duct, and so forth, advancing 2 to 3 mm with each passage of the suture across entire posterior row.
    - Upon completion of the posterior row, tension must be maintained on the posterior suture. A bulldog clamp or equivalent instrument is placed on the posterior row stitch to maintain this tension (**FIG 3A,B**).
    - The optionally placed 12 o'clock stay suture should be removed now to prevent confusion.
    - Stenting the biliary-enteric anastomosis would occur either now or midway through completing the anterior row.
    - Similarly, the anterior row is completed by taking the suture inside the bowel and going inside-out on the bile duct, then outside-in on the bowel, and then end-over-end across entire anterior row (**FIG 4A,B**).
    - The anastomosis is completed by tying the two sutures on the outside at the 9 o'clock position.
    - After completion of the anastomosis, the redundant Roux limb is pulled back through the mesocolon defect toward the jejunojejunostomy; it is important to minimize the risk of an afferent limb obstruction or biliary stasis in the Roux limb. The limb is secured directly to the peritoneum at the mesenteric defect with 3-0 nonabsorbable suture to prevent future herniation.
    - Surgical drainage of the anastomosis is by surgeon preference.

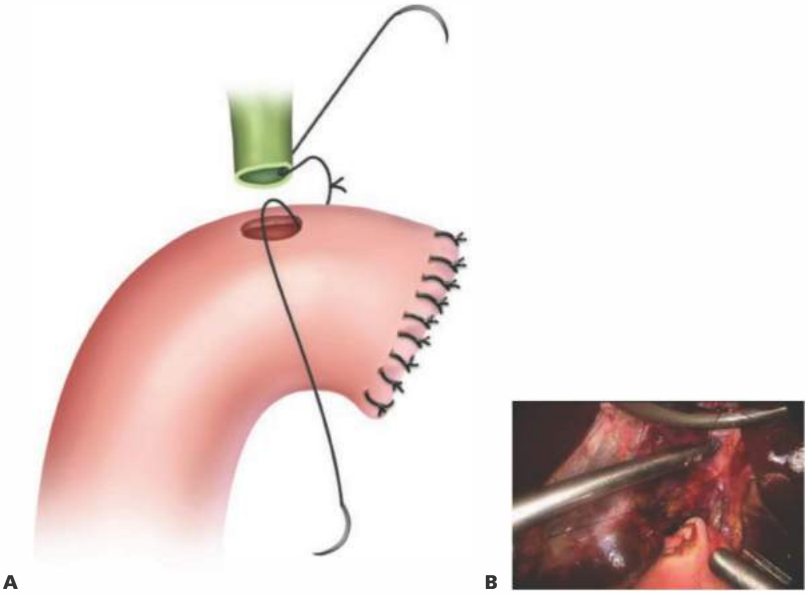


FIG 2 ● **A.** The initial suture is placed in the 3 o'clock position, such that the knot used to form the double-armed suture is external to the planned anastomosis. **B.** Intraoperative photograph of the 3 o'clock suture.

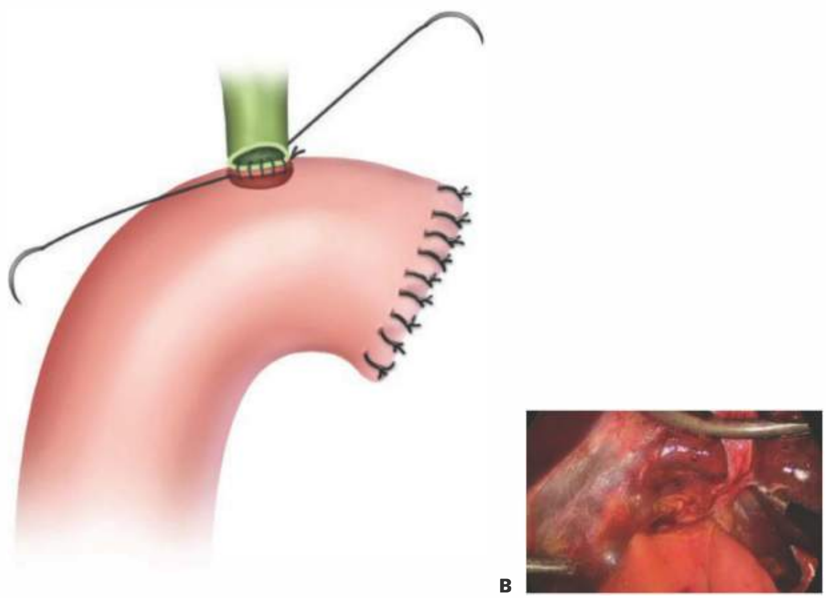
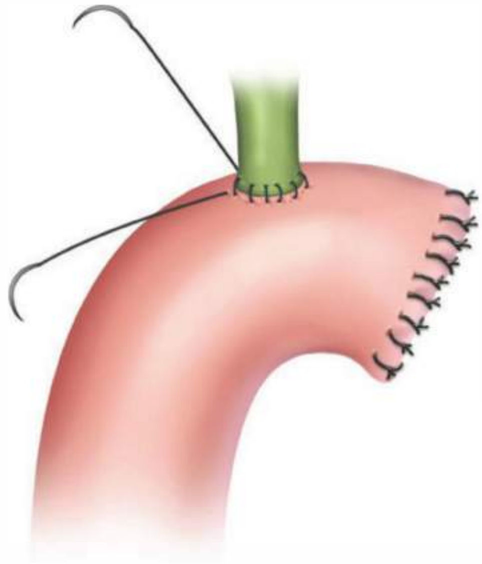


FIG 3 ● **A.** Artist's rendition of the posterior suture line. Note that the final suture will be on the jejunal side (outside the bowel) to facilitate tying this arm to the anterior suture row arm. **B.** Intraoperative photograph of the anastomosis at the completion of the posterior suture line.



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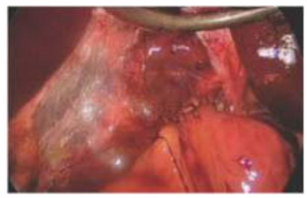

B

FIG 4 ● **A.** Artist's rendition of the complete anastomosis prior to tying the two arms of suture. **B.** Intraoperative photograph of the anastomosis at the completion of the anterior suture line. This arm of the suture will finish on the outside of the bile duct.

ROBOTIC CHOLEDOCHOJEJUNOSTOMY

- Overall technique is similar to that of the laparoscopic choledochojejunostomy.

First Step

- Port placement for robotic choledochojejunostomy as seen in **FIG 5**.
  - Port placement is set further away from the target of dissection due to the long robotic instruments and inability of the robot to optimally articulate when the arms approach greater than or equal to 90-degree angle to the patient.
  - Additionally, the robotic ports should be placed wider than the laparoscopic ports. This helps avoid "conflict" or collisions between the robotic arms.
- Mobilization of the hepatic flexure, creation of the Roux limb, creation of the jejunojejunostomy, and introduction of the Roux limb through the transverse mesocolon are performed with conventional laparoscopy before docking the robot.
- The patient is placed in a steep reverse Trendelenburg position with the right side tilted slightly up.
- The robot is docked as follows:
  - Robot is positioned over the patient's right shoulder.
  - Place a foam pad over the patient's arm and face.
  - Position the robot correctly in terms of both maintaining it centered in its "sweet spot" (the arrow must point to the area within the blue stripe visible on the front of the robot) as well as creating sufficient distance between the robotic arms.
  - The function of the robotic arms is optimal when the arm number is facing directly out.
- The biliary enteric anastomosis is performed robotically as described previously.

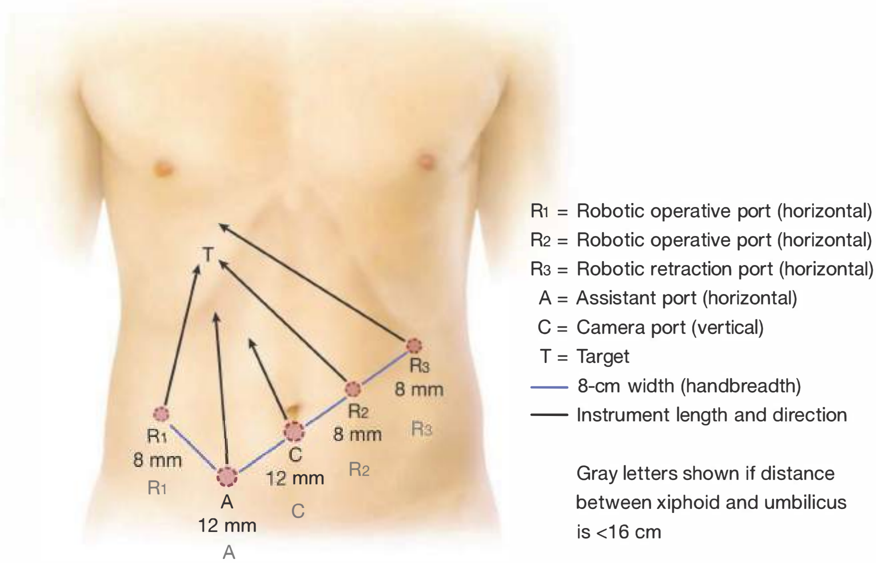

FIG 5 ● Robotic access ports. R1 serves as the surgeon's left hand and R2 serves as their right hand. R3 provides liver retraction. The assistant provides tension on the running suture or provides additional exposure via retraction of the jejunal limb.

POSTOPERATIVE CARE

- Depending on the extent of the resection, the return of bowel function will be variable but can be virtually immediate. The authors remove the nasogastric tube on postoperative day 1. Liquids are initiated on postoperative day 2.
- Monitor the patient for signs of biliary fistula; a lack of bile in an operatively placed drain does not ensure the absence of an evolving fistula.
  - Fevers
  - Tachycardia
  - Right upper quadrant pain
  - Leukocytosis
  - Persistent ileus
- CT with percutaneous drainage of any identified fluid collections is employed if fistula is suspected.

OUTCOMES

- Biliary-enteric reconstruction patency rate
  - Open: 70% to 90%
  - Minimally invasive: no data
- Follow-up
  - Four weeks postoperatively with laboratory studies (complete blood count [CBC], complete metabolic panel [CMP]). An elevation in the alkaline phosphatase is usually the earliest and most sensitive indicator of biliary obstruction or stricture.
  - Twelve weeks postoperatively with a right upper quadrant US to examine for dilated intrahepatic ducts or postoperative fluid collections, or sooner if liver function tests are abnormal.
  - Twenty-four weeks postoperatively with a technetium-99m Choletech scan in nuclear medicine to assess filling of the Roux limb with radiotracer (optional).
  - The risk of stricture persists for 10 years. The authors recommend obtaining liver injury tests every 3 months for the first year, and then semiannually until the fifth anniversary of the operation.

COMPLICATIONS

- Mortality: 1%
- Morbidity: 10% to 20%
  - Biliary fistula (early)
  - Biliary stricture (late)
  - Jejunojejunostomy leak or stricture (<1%)
  - Afferent limb obstruction (<1%)

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Chapter 10 Choledochoduodenostomy

Katherine A. Morgan   David B. Adams

DEFINITION

- Choledochoduodenostomy (CDD) describes an anastomosis between the extrahepatic biliary tree and the duodenum undertaken to provide internal drainage of an obstructed distal common bile duct (CBD).

DIFFERENTIAL DIAGNOSIS

- Choledocholithiasis
- Autoimmune-induced biliary strictures
- Chronic pancreatitis
- Periampullary malignancy

PATIENT HISTORY AND PHYSICAL FINDINGS

- The primary indications for CDD are benign causes of biliary obstruction including chronic pancreatitis and distal biliary stricture related to choledocholithiasis. In the current era of endoscopic retrograde cholangiography, the frequency of operative biliary bypass has decreased; nonetheless, CDD remains an important part of the general surgeon's armamentarium.
- Patients with distal biliary obstruction will typically present with right upper quadrant abdominal pain and associated jaundice. If cholangitis is attendant, fever and chills (Charcot's triad) or, in more severe cases, hypotension and altered mental status (Reynolds' pentad) may be evident.
- Elevated serum hepatic chemistries are essential to the diagnosis of significant biliary obstruction. Total and direct bilirubin, alkaline phosphatase, and gamma-glutamyltransferase are elevated preferentially to the hepatic transaminases in cases of biliary obstruction as contrasted to intrinsic hepatic disease.
- Patients with chronic pancreatitis who present with biliary obstruction may have a reversible component to the inflammatory obstruction, and thus are often best managed initially with endoscopic stenting. In cases with persistent biliary obstruction due to constricting fibrosis in the pancreatic head, marked by elevated serum hepatic chemistries and a dilated CBD, surgical intervention is warranted. In patients with an accompanying inflammatory pseudotumor in the head of the pancreas or a concern for malignancy, pancreatic head resection may be indicated. When resection is not indicated, CDD is an excellent means of biliary bypass while minimizing perioperative morbidity and preserving pancreatic parenchyma.
- Patients with a terminal biliary stricture due to long-standing choledocholithiasis do well with CDD. Common indications include a dilated CBD (>1.5 cm); multiple CBD stones; and primary, recurrent, or recalcitrant choledocholithiasis.

IMAGING AND OTHER DIAGNOSTIC STUDIES

- Right upper quadrant ultrasound is the frontline test for biliary obstruction, visualized as dilated intrahepatic and extrahepatic biliary ducts. It is highly sensitive, noninvasive, inexpensive, readily available, and requires no radiation.
- Contrast-enhanced computed tomography (CT) is a useful modality to evaluate abdominal pain. CT will demonstrate a dilated biliary tree and can help in the evaluation for causative-associated pathology including choledocholithiasis, chronic pancreatitis, and periampullary malignancy.
- Magnetic resonance cholangiopancreatography (MRCP) can give detailed information about biliopancreatic ductal anatomy and pathology (T2 weighted images) and soft tissue abnormalities related to pancreatitis or neoplasm (T1 weighted images). MRCP is an important tool for assessment of biliary obstruction because of the advanced ductal imaging capability.
- Endoscopic retrograde cholangiopancreatography (ERCP) is the primary initial therapeutic approach to biliary obstruction in the current era. ERCP can be both diagnostic and therapeutic in the management of biliary obstruction. It can be used to identify stones and apply a variety of maneuvers that facilitate stone clearance:
  - Sphincterotomy
  - Balloon cholangioplasty and sweeping
  - Basket retrieval
  - Lithotripsy
- Strictures can be dilated and stented endoscopically. Even with alternative strategies (metal stents, multiple plastic stents), endoscopic stenting lacks durability in the management of chronic, longer segment CBD strictures due to chronic pancreatitis and stone disease and CDD is often employed in these cases.
- Endoscopic ultrasound (EUS) can be helpful in the careful evaluation of the terminal biliary tree for the diagnosis or exclusion of malignant obstruction and the assessment for occult cholelithiasis. EUS has also been more recently used for an endoscopic-directed choledochoduodenal stent.
- Percutaneous transhepatic cholangiography (PTC) is undertaken to study the biliary tree and allow for biliary drainage in cases where endoscopic transampullary access is not possible. Maturation and dilation of the tract after PTC can allow for percutaneous instrumentation to be used under radiographic guidance to clear stones from the biliary tree.

SURGICAL MANAGEMENT

- CDD is indicated in patients with a benign terminal biliary stricture, with an associated dilated CBD (>1.5 cm diameter), most commonly due to chronic pancreatitis or choledocholithiasis. CDD has been effectively used in the management of malignant biliary obstruction.
- When planning a biliary bypass procedure, a neoplastic cause for biliary obstruction should be sought out and recognized, as a malignant (or potentially malignant) process may call for a divergent operative approach.
- When biliary bypass is indicated in unresectable periampullary malignancy, CDD may be selected as an alternative to hepaticojejunostomy.
- Classically, the CDD anastomosis is performed in a side-to-side fashion but may also be performed with an end

(bile duct) to side (duodenum) technique, particularly when using a laparoscopic approach. Both methods are presented.

Preoperative Planning

- CDD is best undertaken in an elective setting. Acute pancreatitis should be allowed to settle and cholangitis should be properly treated. Often, endoscopic stenting can be helpful to temporize patients and allow for medical optimization.
- Particular attention should be taken to the nutritional status of the patient, as patients with chronic inflammation are often malnourished. Enteral or parenteral supplementation may be appropriate to condition the patient for surgery.
- Hepatic function should also be assessed prior to surgery, as it may be compromised in patients with long-standing biliary obstruction. Vitamin K supplementation, in particular, may be useful.
- Patients with terminal biliary stenosis due to chronic pancreatitis may have associated duodenal stenosis, pancreatic ductal obstruction and dilation, or splanchnic venous obstruction, which may require operative management and should be confirmed with preoperative evaluation.
- Patients with terminal biliary stenosis and cavernous transformation of the portal vein may undergo CDD safely, although additional emotional and physical work is demanded in the conduct of the procedure.

CHOLEDOCHODUODENOSTOMY, SIDE-TO-SIDE

Incision and Exposure

- An upper midline incision or a right subcostal incision may be used for this operation (FIG 1). The abdomen is explored for unexpected findings including evidence for distant malignancy. Caudal mobilization of the hepatic flexure of the colon is undertaken to aid in adequate duodenal exposure.
- Use of self-retaining retractors facilitates exposure of the terminal bile duct and the first and second portions of the duodenum (FIG 2).
- An extensive Kocher maneuver is performed to optimally mobilize the duodenum. This mobilization is a critical step for the success of a tension-free anastomosis. The pancreatic head and terminal bile duct are palpated and examined to assess for extent of disease and unexpected findings.
- If the gallbladder remains in place, a cholecystectomy is performed (FIG 3).
- The porta hepatis is examined and the CBD clearly identified for the course of greater than 3 cm along its anterior wall. In cases with significant inflammation and fibrosis, the anatomy can be distorted. Palpation of the hepatic artery can be helpful in orientation, as can palpation of an intraductal biliary stent or aspiration of bile with a fine needle and syringe.
- Incision of the peritoneum at the cephalad aspect of the first portion of the duodenum can facilitate the establishment of a plane between the posterior wall of the

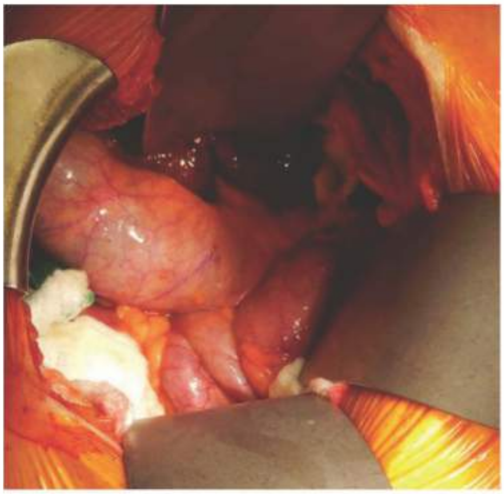


FIG 2 ● A fixed retractor facilitates exposure.

FIG 1 ● The authors favor a right subcostal incision.

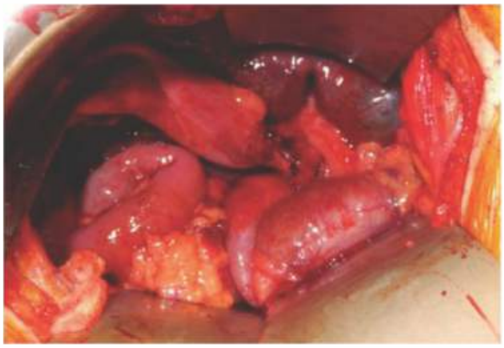
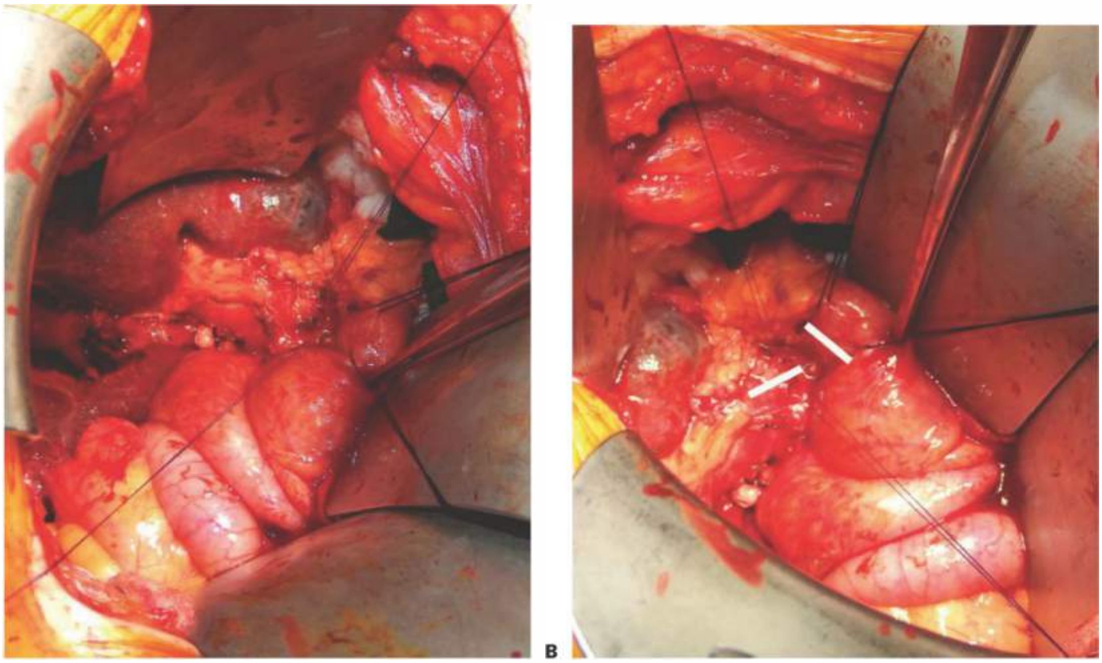


FIG 3 ● When present, retrograde dissection of the gallbladder facilitates identification of the cystic duct confluence and distal CBD.



A B

FIG 4 ● **A.** After caudal mobilization of the duodenum, stay sutures are placed in the distal CBD (fine monofilament sutures) and the duodenum (larger braided sutures) to facilitate exposure. **B.** Additional view from the patient's right further demonstrates how this mobilization facilitates an anastomosis free of tension. Planned ductotomy and duodenotomy *(white lines)*.

duodenum and the anterior wall of the CBD, providing additional length and improving the proximity of the planned ductotomy and duodenotomy sites, thus reducing potential tension on the anastomosis (**FIG 4**).

Choledochoduodenal Anastomosis

- Identification of the CBD is confirmed by aspiration with a 21-gauge needle.
- An anterior ductotomy is made sharply, typically with a no. 11 blade at the site of the needle aspiration, large enough to permit entrance into the duct with the tip of a fine hemostat. An anterior longitudinal choledochotomy is then extended with scissors or electrocautery for 1.5 cm in length. The ductotomy is made on the distal CBD as close as safely possible to the duodenum. Arterial bleeding on the distal ductotomy means "far enough."
- The distal CBD and common hepatic duct should be irrigated with an 8-Fr catheter to clear the duct of stones and sludge. If ductal lithiasis is present, choledochoscopy should be undertaken to confirm clearance of the duct of stones. Residual stones may require balloon catheter or basket extraction.
- When cavernous transformation of the portal vein is present, the venous network surrounding the common duct will require a combination of suture ligation, coaptive electrocautery, and argon beam coagulation to achieve hemostasis.
- The mobility of duodenum is assessed to determine where an anastomosis will most suitably lie without tension. A duodenotomy is then made with electrocautery, with cutting current in the postbulbar duodenum. The angle of the duodenotomy will vary from patient to patient, depending on the underlying disorder and variation from normal anatomy. In pancreatitis, the mobility of the duodenum varies with the underlying peripancreatic fibrosis so the location of the duodenotomy will vary accordingly. The duodenotomy is usually an oblique incision, with the goal of a comfortable anastomosis without distortion of the duodenal flow. The duodenotomy should be cut at a length of about 1.0 cm as it will always stretch more than expected (**FIG 5**).
- If a preoperative prograde or retrograde stent has been placed, it may be prudent to leave it in place to serve as a postoperative stent, particularly in the difficult anastomosis in the presence of severe peripancreatic fibrosis, recognizing the risk of stent-induced postoperative biliary sepsis related to the sialomucin stent biofilm harboring gram-negative bacteria.
- A single layer of interrupted sutures with fine 4-0 or 5-0 monofilament absorbable suture is used for this anastomosis. Full-thickness corner sutures are placed through the duodenum and then the bile duct at either end of the anastomosis such that the tails are outside the lumen. They are marked with a hemostat and act for exposure and for conceptual planning (**FIG 6**).
- The posterior row of sutures is placed with the tails on the inside of the lumen, beginning with the middle suture to aid in spatial planning. This suture will be at the

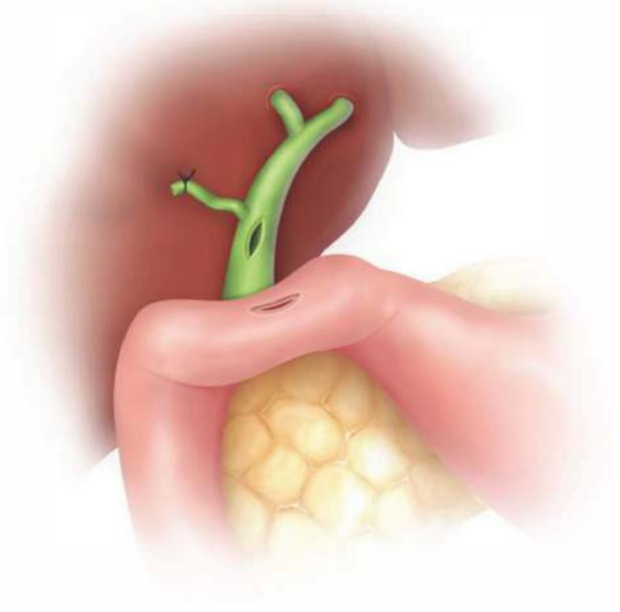


FIG 5 ● An anterior choledochotomy is performed in an oblique manner, at least 1.5 cm in length. An oblique duodenotomy is made in a configuration that will allow for a tension-free anastomosis without distortion of the duodenum, approximately 1.0 cm in length as it will stretch.

end of the choledochotomy and at the middle of the duodenotomy. The individual sutures are tagged and then tied down at the completion of the posterior row, except the corner stitches, which remain untied to aid in exposure (**FIG 7**).

- The anterior row of sutures is then placed, beginning with the middle suture, with the tails on the outside of the anastomotic lumen. All remaining sutures are then tied securely in place (**FIG 8**).
- When the anatomy is favorable, particularly with a thickened bile duct, a large anastomosis, and easy duodenal mobility, the anastomosis can be constructed with continuous sutures.
- A closed suction drain is placed near the anastomosis.

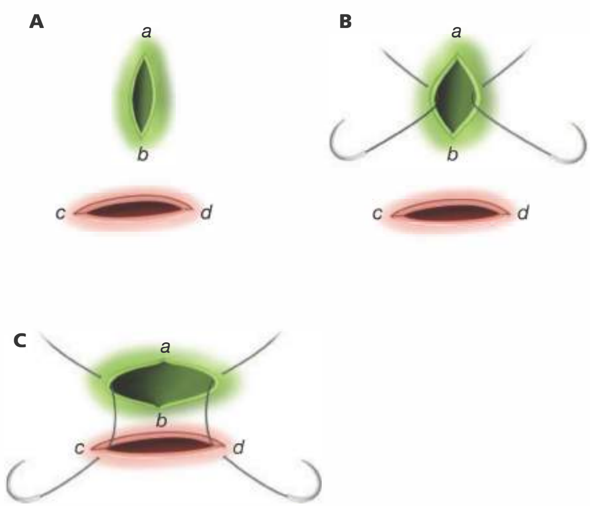


FIG 6 ● Schematic drawing of how the two ostomies are oriented for the anastomosis. **A.** Depiction of the ostomies as they lie perpendicular to one another. **B.** Stay sutures are placed on both sides of the midpoint of the choledochotomy (halfway between *a* and *b*). **C.** These stay sutures are then used to take full-thickness bites of the duodenum at the ends of the duodenotomy. This aligns the structures for placement of the posterior suture line.

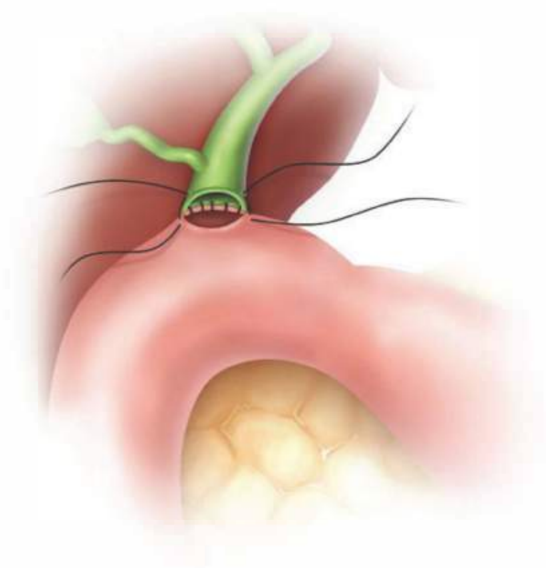


FIG 7 ● Anatomic depiction of the corner sutures that are placed with tails outside the lumen and tagged to aid for exposure and spatial planning. The back row of sutures is performed in an interrupted fashion, with tails on the inside.

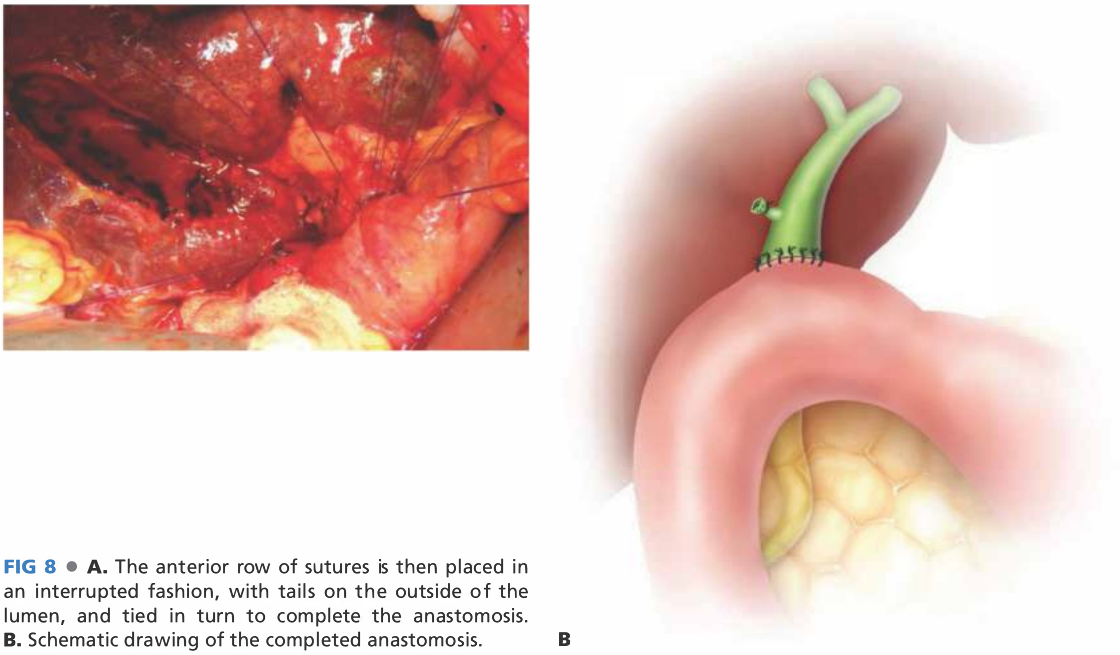


FIG 8 ● **A.** The anterior row of sutures is then placed in an interrupted fashion, with tails on the outside of the lumen, and tied in turn to complete the anastomosis. **B.** Schematic drawing of the completed anastomosis.

CHOLEDOCHODUODENOSTOMY, END-TO-SIDE

Incision and Exposure Including Portal Dissection

- The incision and exposure are similar to that for the side-to-side technique, including an extensive Kocher maneuver to mobilize the duodenum. In the end-to-side technique, however, circumferential dissection of the CBD is necessary. In cases with severe inflammation and fibrosis of the porta hepatis, a side-to-side technique may be prudent to avoid vascular injury. Medial to lateral dissection of the posterior CBD away from the hepatic artery and portal vein is the safest technique. Once the CBD has been encircled, it is divided as distally as possible, with attention to precise control of the radial blood supply of the duct, avoiding excessive use of cautery. The distal end of the divided bile duct is then oversewn in a running fashion using an absorbable suture.

Choledochoduodenal Anastomosis, End-to-Side

- A longitudinal incision is made in the second portion of the duodenum near where the divided bile duct is located. A single layer of fine (4-0) absorbable suture is also used for this anastomosis. Full-thickness corner sutures first through the bowel, then through the bile duct, and are placed at either end of the anastomosis for exposure and spatial planning.
- If an anastomosis with interrupted suture is planned, the conduct of the anastomosis is identical to that of the side-to-side technique. If an anastomosis with a running suture is planned, the corner sutures are tied and left long with needle in place. On one end, the needle is passed to the inside and run along the posterior wall inside the lumen and tied to the other corner's tail. The other suture is then run along the anterior wall and tied to the other corner's tail.
- A closed suction drain is placed near the anastomosis.

LAPAROSCOPIC CHOLEDOCHODUODENOSTOMY

Patient Positioning and Port Placement

- The patient is positioned supine and in reverse Trendelenburg with a left side down tilt.
- Laparoscopic port sites are placed in an arc above the level of the umbilicus with a right-sided bias. Port site placement similar to a laparoscopic cholecystectomy.

Initial Dissection

- The conduct of the operation is similar to that for the open technique, including mobilization of the hepatic flexure of the colon and an extensive Kocher maneuver to mobilize the duodenum. A laparoscopic liver retractor is necessary to expose the porta hepatis. Portal dissection is carried out with care using the hook electrocautery.

Choledochoduodenal Anastomosis

- When possible, an end-to-side technique is favored laparoscopically, as this anastomosis without tension is often technically easier to perform. In cases with severe inflammation and fibrosis of the porta hepatis, however, circumferential bile duct dissection may be treacherous and a side-to-side technique is favored.
- A fine absorbable suture is used for the anastomosis. The anastomosis is begun with corner sutures placed and tied without cutting the needle. The posterior row is run from medial to lateral and tied to the tail of the other corner suture. The anterior row is then similarly run, now lateral to medial and tied to the other corner's tail.
- A closed suction drain is placed near the anastomosis.

PEARLS AND PITFALLS

Indications	■ A thorough preoperative evaluation of the cause for biliary obstruction is important, specifically recognizing neoplasia if present to allow for proper operative decision making.
Preoperative planning	■ Inflammation associated with acute pancreatitis and infection and inflammation related to cholangitis on presentation should be properly treated and allowed to resolve prior to proceeding with this elective operation. ■ Patient nutritional status should be optimized prior to surgery to minimize morbidity.
Incision and exposure	■ An extensive Kocher maneuver should be performed to mobilize the duodenum and minimize tension potentially leading to anastomotic failure.
Choledochoduodenal anastomosis	■ The choledochotomy and duodenotomy should be configured in a way so as to minimize anastomotic tension and duodenal distortion. Careful intraoperative planning and an oblique bias to the incisions are useful. ■ The anastomosis should be greater than 1.5 cm in length to avoid stenosis resulting in cholangitis, hepatic abscess, stones, and potentially sump syndrome.

POSTOPERATIVE CARE

- Nasogastric decompression should be undertaken in the initial postoperative period.
- The closed suction drain is removed once diet is tolerated and there is no evidence of anastomotic leak.

OUTCOMES

- Outcomes following CDD are limited to small, retrospective, single institution case series, including both open and laparoscopic approaches. Postoperative morbidity following CDD is reported as 9.8% to 28%, with the most common complications being wound infection and anastomotic leak.
- A phenomenon known as "sump syndrome" has been described following CDD where food debris or stones accumulate in the terminal portion of the CBD, resulting in episodes of abdominal pain, fever, and cholangitis. The incidence of sump syndrome after CDD appears to be relatively uncommon, reported as 0% to 9% in case series, and presents in a delayed fashion, typically years after the procedure. Anastomotic stenosis has been implicated as the cause for sump syndrome as well as for the rare occurrence of recurrent stones, cholangitis, and hepatic abscess, and therefore, generous anastomotic girth is encouraged to prevent these complications.

COMPLICATIONS

- Intraoperative hemorrhage from portal vein or proper hepatic artery
- Anastomotic leak, duodenal fistula
- Anastomotic stricture
- Cholangitis
- Hepatic abscess
- Choledocholithiasis or intrahepatic ductal stones
- Sump syndrome

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Chapter **11**

Resection of Hilar Cholangiocarcinoma

Ryan T. Groeschl   T. Clark Gamblin

DEFINITION

- Hilar cholangiocarcinoma (HC), also referred to as Klatskin's tumor, is an extrahepatic cancer of biliary epithelial origin near the confluence of the right and left hepatic ducts. The hepatic artery and portal vein are in close proximity to the bile duct, and vascular involvement is common. Given the limited effectiveness of other therapies, margin-negative resection is the optimal treatment. Although multimodal therapy combined with transplantation is also a potential approach to HC,[1] this chapter focuses on the resection technique for this biliary disease.

DIFFERENTIAL DIAGNOSIS

- Growth patterns for HC may be exophytic, infiltrative, polypoid, or any combination thereof (**FIG 1**). The differential diagnosis includes pathologies that may mimic any of these appearances.
  - Papilloma—composed of vascular connective tissue and covered with columnar epithelium; low-grade malignant potential
  - Adenoma—glandular tissue surrounded by fibrous stroma; low-grade malignant potential
  - Benign biliary stricture from recurrent pyogenic cholangitis, primary sclerosing cholangitis, choledocholithiasis, Mirizzi's syndrome, previous surgery, or trauma.

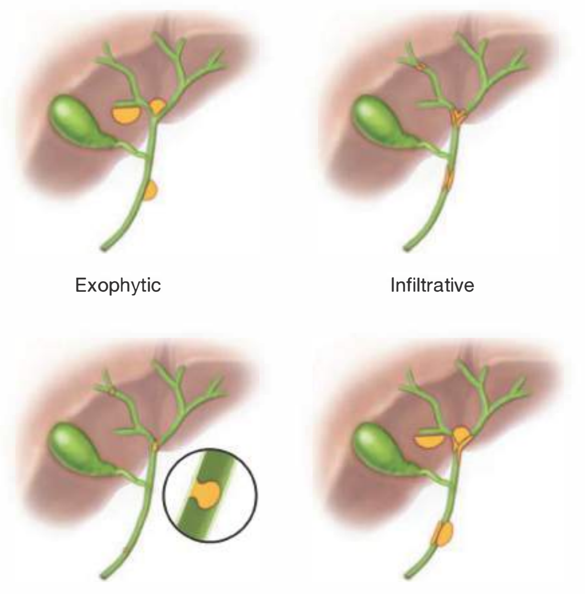

FIG 1 ● Various growth patterns of extrahepatic cholangiocarcinoma.

PATIENT HISTORY AND PHYSICAL FINDINGS

- Successful hepatectomy must maintain an adequately healthy liver remnant. Initial assessment of the patient must not only focus on the malignancy itself but also on general liver function. Underlying liver dysfunction (due to chronic alcohol exposure, viral hepatitis, fatty liver disease, etc.) may alter operative planning and the minimum remnant required.
- History
  - Symptoms: jaundice, itching, unintentional weight loss, abdominal pain
  - Broader aspects of patient history: gallstones, cholangitis, primary sclerosing cholangitis, ulcerative colitis, previous surgery or trauma, viral hepatitis, cirrhosis, alcohol consumption, international travel, obesity, diabetes, hyperlipidemia, bruising, immune deficiency
- Physical exam
  - Jaundice or scleral icterus; muscle wasting may be present.
  - If disease occludes cystic duct, gallbladder may be palpable (Courvoisier's sign).
- Assess for stigmata of cirrhosis, portal vein thrombosis, or portal hypertension: ascites, encephalopathy, spider angiomata, skin telangiectasias, palmar erythema, bruising.

IMAGING AND OTHER DIAGNOSTIC STUDIES

- Transabdominal ultrasound
  - May identify duct dilation and large hilar tumors, but primarily functions as a screening tool
  - Doppler may identify narrowing or thrombosis of the hepatic artery or portal vein.
- Cross-sectional imaging: computed tomography and magnetic resonance
  - Good visualization of mass lesions and ductal dilation
  - Staging: may identify intraabdominal lymphadenopathy and/or metastases
  - Contrast enhancement allows assessment of vascular involvement and identification of anomalous hepatic inflow, which are critical to operative planning.
  - Signs of cirrhosis or portal hypertension may be present: irregular hepatic capsule, caudate hypertrophy, cavernous transformation, hypersplenism, ascites, recanalized umbilical vein.
- Cholangiography
  - Magnetic resonance cholangiopancreatography
    - Noninvasive; allows visualization and three-dimensional reconstruction of ductal anatomy
    - Does not provide opportunity to sample tissue
  - Endoscopic retrograde cholangiography
    - Allows visualization of ductal anatomy, provides opportunity for brushing or biopsy, and allows stenting in case of biliary obstruction
    - Invasive; risk of procedure-induced pancreatitis

- Cholangiography via percutaneous catheters
  - If percutaneous biliary drainage catheters have been placed, contrast can be used to delineate ductal anatomy and also allow brushings.
  - Ideally, such catheters are placed in the future remnant liver or bilaterally.
- Endoscopic ultrasound
  - Allows evaluation of the duct and regional lymph nodes, which may also be sampled with fine needle aspiration or core biopsy when available (19 gauge to 22 gauge)
  - Intraductal fiberoptic direct visualization (with biopsy) and intraductal ultrasonography are available at some centers.
- Positron emission tomography
  - Fluorodeoxyglucose (FDG) avidity is typically limited to mass lesions greater than 1 cm but provides poor quality for identifying cancers with infiltrative growth; hence, limited use beyond standard cross-sectional imaging for assessing primary tumor.
  - May identify occult metastatic disease
- Laboratory evaluation
  - Cholestasis may be indicated by elevated bilirubin, alkaline phosphatase, and gamma-glutamyltransferase levels.
  - Albumin and prothrombin time evaluate synthetic function.
  - Aspartate and alanine aminotransferase levels are often normal.
  - Low platelet levels may reflect hypersplenism due to portal hypertension.
  - Elevations in carbohydrate antigen 19-9 (CA 19-9) or carcinoembryonic antigen may be elevated in patients with HC.
    - CA 19-9 may be spuriously elevated in the setting of jaundice.
    - When workup reveals tumor marker elevation, these levels may be followed after resection to assess for disease recurrence.

SURGICAL MANAGEMENT

Preoperative Planning

- Patients with jaundice should be drained either endoscopically or percutaneously to optimize liver remnant function.
- Operations for HC involve the dissection of critical structures, biliary and vascular reconstruction, and adaptation to intraoperative findings. Expertise in hepatobiliary anatomy and surgical technique is essential. In particular, familiarity with common patterns of anomalous ductal and arterial hilar anatomy (**FIG 2**) will prevent injury to unintended structures. Features of unresectability are shown in Table 1.
- When a diminutive liver remnant is anticipated, preoperative angioembolization of the contralateral (tumor-supplying) portal vein should be pursued in an attempt to hypertrophy the potential remnant.
- The Bismuth-Corlette classification is used to describe the extent of right and left duct involvement (**FIG 3**). Careful review of cholangiography and cross-sectional imaging will identify resectable patients and aid in operative planning.

Table 1: Liver-Specific Criteria for Unresectable Klatskin Tumors

Tumor extension to bilateral secondary branches of hilar structures
Portal vein
Hepatic artery
Bile duct
In patients with normal background liver
Future remnant liver <25%
Inability to preserve two adjacent segments
In cirrhotic patients
If resection is considered, preservation of a large remnant is essential to prevent postoperative liver failure.
These patients can be considered for transplantation in the context of an established multimodal treatment protocol or clinical trial.

- Right hepatectomy or trisectionectomy is generally indicated for types II and IIIa tumors.
- Left hepatectomy, and especially left trisectionectomy, is uncommonly performed and often carries a higher complication rate. This type of resection is usually reserved for type IIIb tumors, or those cases where the future left-sided remnant would be inadequate for type II tumors.
- Type IV tumors are unresectable unless a full sectoral branch is uninvolved and free of tumor.
- Type I HC may occasionally be amenable to local biliary resection alone; however, R0 rate and thus survival have been directly linked to the use of hepatic resection.[2]
- Apparent invasion of the portal vein or vena cava does not preclude resection. Large tumors can narrow adjacent vessels on imaging; however, this may be mass effect and not necessarily represent invasion.
- Contraindications to resection include distant metastatic disease and bilobar liver involvement.
- Although enthusiasm has grown for laparoscopic liver surgery, the dissection and reconstruction required for resection of HC currently requires laparotomy in most cases. However, a preliminary laparoscopy (performed immediately before planned resection) will identify occult disease in at least half of unresectable patients, who are then spared laparotomy.[3]
- Intraoperative ultrasound should be used liberally throughout the operation to assess extent of disease, location of ducts, and location/patency of vessels.

Positioning

- Supine position with arms perpendicular to body axis (**FIG 4**)
- Sterile skin preparation extends cranially beyond the nipple line, caudally to the groins, and laterally to the posterior axillary lines (particularly on the right side).
- If the need for portal vein reconstruction with autologous internal jugular vein is suspected, a sterile field is also prepared at the neck.
- If preoperative biliary catheters were placed, they are prepped into the field.
- Both groins are prepped if venovenous bypass is an anticipated strategy.

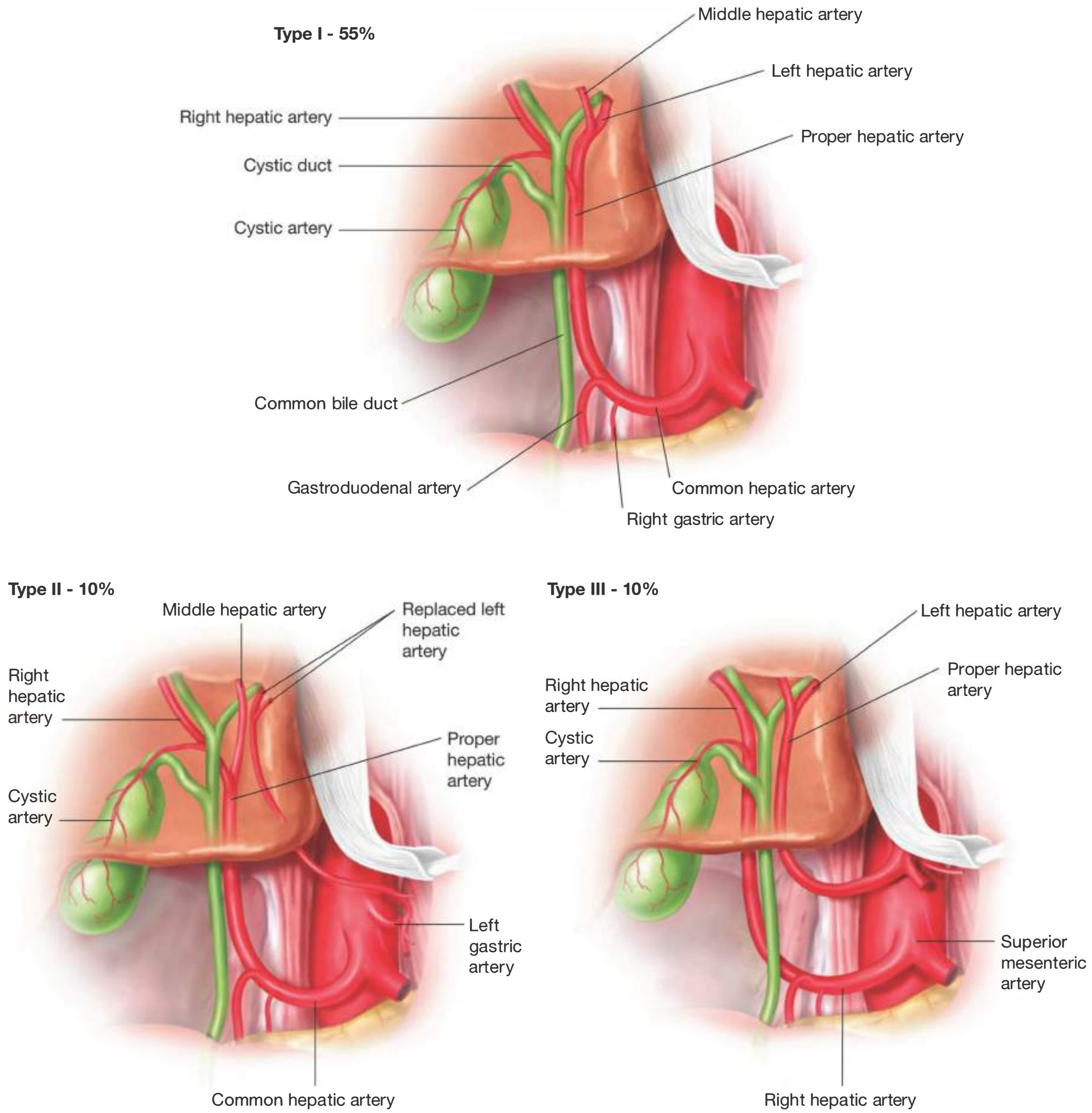

FIG 2 ● Common variations of hilar arterial anatomy. Although the usual course of the right hepatic artery is from the common hepatic artery and crossing laterally posterior to the bile duct confluence, a replaced (or accessory) right artery may originate from the superior mesenteric artery. A replaced (or accessory) left artery may be found in the gastrocolic ligament originating from the left gastric artery.

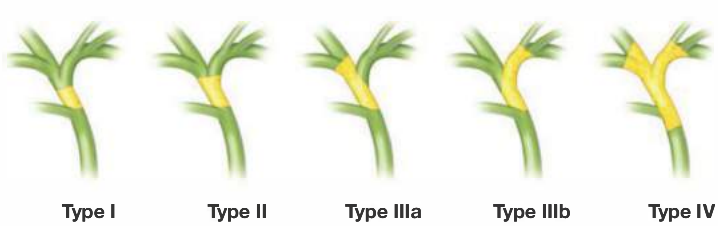

FIG 3 ● Bismuth-Corlette classification of Klatskin tumors.

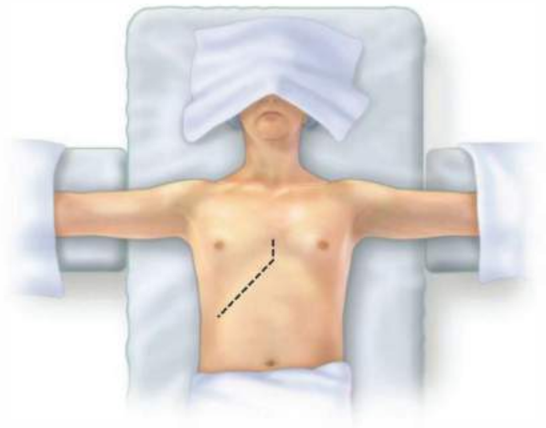

FIG 4 ● Proper positioning of the patient in the supine position with arms perpendicular to the body axis. The right subcostal incision with subxiphoid extension is also shown.

PRELIMINARY LAPAROSCOPY

- Using the Hasson method, a 10- to 12-mm periumbilical port is placed. A 10-mm 30-degree laparoscope is used to inspect the abdomen for evidence of metastases: peritoneal cavity, liver surface, porta hepatis, gastrohepatic ligament.
- If necessary, an additional 5-mm port is placed under direct visualization in the subxiphoid midline (to be included in the potential laparotomy incision).
- Potential metastases should be biopsied for immediate pathologic analysis.
- If distant metastatic disease or bilobar liver disease is noted, the operation is terminated.
- If there are no signs of unresectability, proceed to laparotomy.

LAPAROTOMY

Incision and Abdominal Inspection

- The abdomen is entered with a right subcostal incision with subxiphoid extension (FIG 4).
- The ligamentum teres hepatis (round ligament) is divided and falciform ligament taken down from the anterior abdominal wall.
- The abdomen is inspected thoroughly to confirm absence of distant disease. The liver is inspected with bimanual palpation and intraoperative ultrasonography.
- Along with control of the hilar vessels, circumferential control of the supra- and infrahepatic vena cava with a tape can be used selectively, which allows for nearly complete vascular control of the liver should venovenous bypass be necessary.

Paraaortic Node Assessment and Biliary Dissection

- The omentum is freed from the transverse colon, allowing access to the omental bursa.
- The hepatic flexure of the colon is mobilized and rotated medially until the duodenum and vena cava are identified.
- A Kocher maneuver is performed, retracting the duodenum to the left until the aortocaval groove is exposed.
- Firm or enlarged paraaortic nodes are sampled for immediate pathologic examination.
  - If nodes are grossly positive, the operation is terminated.
  - If nodes show microscopic disease, all exposed paraaortic fibrofatty and nodal tissue is resected.
  - If nodes are negative, no further paraaortic dissection.
- The gallbladder is dissected from the liver and left attached to the specimen via the cystic duct.
- Segment 4b is lifted to expose the hilar plate. Connective tissue investing the bile duct, hepatic artery, and portal vein in this area is additionally covered by a tissue confluence from Glisson's capsule on the liver surface. Fine scissor dissection here will expose hilar structures and clear fascial and lymphatic tissue from the field (FIG 5). A "no-touch" approach is recommended for handling the tumor and hilar vessels. Instead, manual manipulation should target periadventitial and other noncritical connective tissues.
  - The hepatic artery is identified proximally. Its bifurcation typically is caudal to the bile duct and portal vein confluences. The right hepatic artery most often courses posterior to the proximal common bile duct. Careful examination of high-quality cross-sectional imaging should allow the surgeon to anticipate the course of the artery and protect it.
  - Replaced or accessory arteries may originate from the left gastric artery through the gastrohepatic ligament (lesser omentum) on the left or from the superior mesenteric artery posterior to the common bile duct on the right.
  - Although the middle hepatic artery most often arises from the left hepatic artery and crosses anterior to the left duct, its origin and orientation are highly variable.

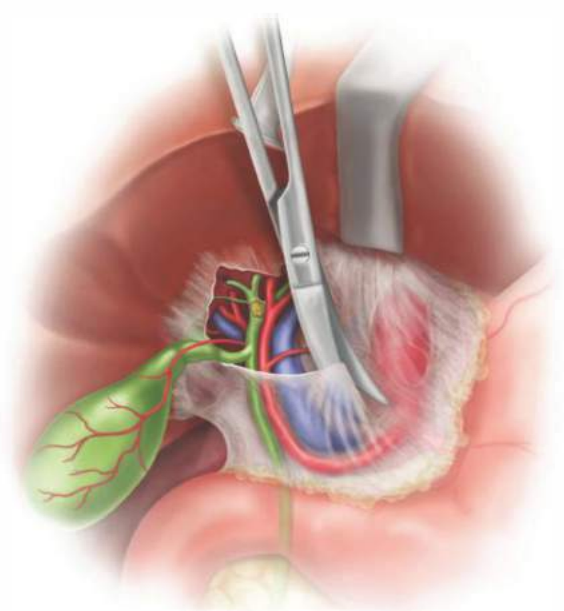

FIG 5 ● Dissection of the hilar plate begins with proximal identification of the bile duct and hepatic artery, which lie anterior to the portal vein. The gallbladder has been removed from the base of the liver and is used for retraction. A no-touch technique should be observed when dissecting near the tumor.

- The proximal extent of tumor is determined by caudal retraction of the bile duct and gallbladder. This step is critical as it will determine whether right or left hepatectomy is undertaken. Some liver parenchyma may need to be transected to adequately assess either duct. Dividing connective tissue between the base of segment 4 and the bile duct confluence (tumor) will often facilitate lowering the hilar plate.
  - To adequately inspect the left hepatic duct, the narrow bridge of liver parenchyma under the umbilical fissure can be divided. The left duct has a longer extrahepatic course and lies perpendicular to the common duct before entering the liver parenchyma at the base of the umbilical fissure. The length of the extrahepatic portion of the left duct is the primary reason that a right liver resection is most often performed in pursuit of an R0 resection.
  - The extrahepatic right hepatic duct is typically shorter and rapidly ascends laterally into the parenchyma. In nearly one-fourth of patients, a right segmental duct will cross Cantlie's line to join the main left hepatic duct. Due to its short length and orientation, the right duct is prone to inadvertent injury. Intraoperative cholangiogram serves as a valuable tool to clarify the anatomy.
  - If gross disease extends to all four hepatic sectional ducts, the tumor is unresectable and further operative exploration is not warranted.
- The right gastric artery is ligated and divided at its origin from the common hepatic artery.
- The posterior superior pancreaticoduodenal artery (PSPD) crosses the common bile duct near the superior aspect of the pancreatic head. The common bile duct will be ligated and transected in this area:
  - If no tumor involvement nearby, the PSPD may be left in situ.
  - If adherent to tumor, the PSPD should be ligated and resected en bloc with tumor specimen.
  - If tumor extends into pancreatic head but the PSPD is not involved, then the PSPD is divided and retracted to allow dissection of tumor inferiorly into pancreatic parenchyma. In rare cases of HC, a pancreaticoduodenectomy may be necessary for margin-negative resection.
- The distal common bile duct is transected just above the pancreas and a distal margin sent for immediate pathologic assessment.
  - The distal peripancreatic stump is oversewn with running 5-0 Prolene.
  - If biliary drainage catheters are in place, they are retracted into the hepatic parenchyma, allowing for the proximal duct to be tied off and retracted superiorly.
- Caudate resection is recommended.[4,5] Exploration commences by exposing the inferior vena cava (IVC) posterior to the liver. The most inferior hepatic veins are ligated and divided to allow posterior exposure of the caudate.
  - Veins less than 5 mm in diameter can be divided with standard suture ligation or clips.
  - Commonly, there will be at least one vein greater than 5 mm in diameter behind the caudate. Such veins should be controlled with a Satinsky clamp on the vena cava, tie ligated at the caudate aspect, divided, and the caval stump oversewn with running 5-0 Prolene suture (**FIG 6**).
  - Figure-of-eight stay sutures placed in the caudate are a useful means of retracting the caudate off the vena cava (**FIG 7**).
  - The left aspect of the hepatocaval ligament may have to be divided to allow visualization.
- Portal vein involvement is assessed by retracting the bile duct anterior and cranial.

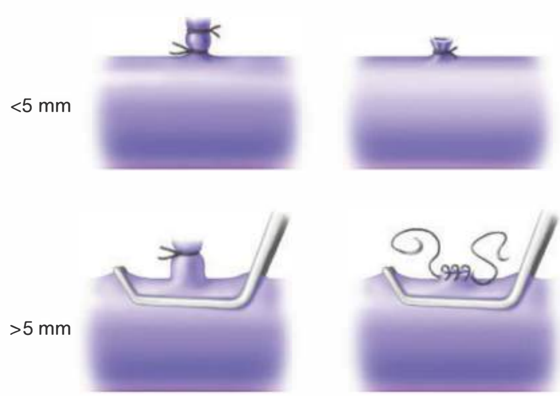

FIG 6 ● Technique of dividing short hepatic veins from segment 1, 4, 5, or 8.

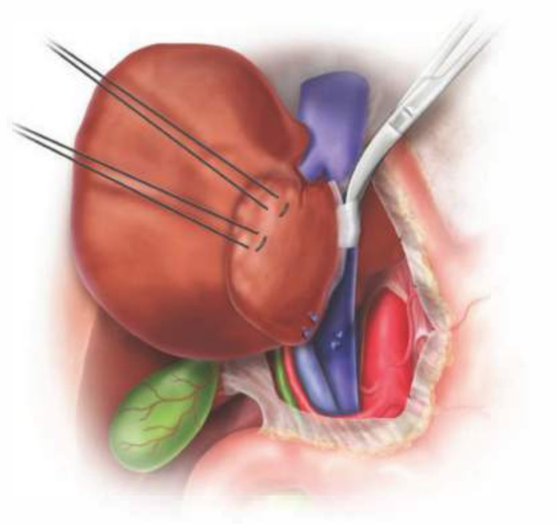

FIG 7 ● To assist with caudate retraction, figure-of-eight stay sutures can be placed in the caudate parenchyma and gently retracted.

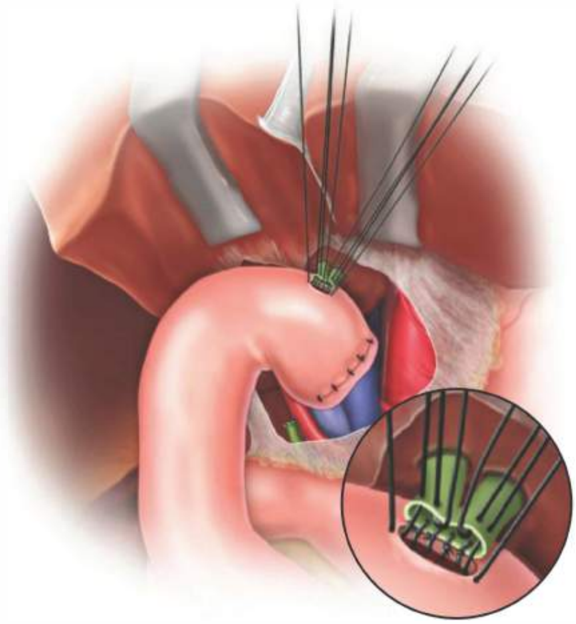

FIG 8 ● Hepaticojejunostomy.

- Caudate preservation is only possible if sufficient biliary outflow can be spared. Although variability exists, the caudate will typically have at least two ducts, which most often drain to the main left duct, the main right duct, or the right posterior sectional branch.
- If caudate resection is performed, then small portal vein branches (posterior aspect of both right and left main portal veins) must be ligated and divided.
- Caudate mobilization is assisted by approaching from both the right side and left side of the vena cava.

Hepatectomy

- As previously described, the choice of hepatectomy is directly related to the extent of ductal, portal venous, and hepatic arterial involvement.
  - Right hepatectomy is described in Part 3, Chapter 23.
  - Left hepatectomy is described in Part 3, Chapter 25.
  - Right trisegmentectomy is described in Part 3, Chapter 30.
  - Left trisegmentectomy is described in Part 3, Chapter 31.
- Portal vein considerations are unique during hepatectomy for HC, however, and described here.
- En bloc hepatic arterial resection and reconstruction is rarely needed, as this extent of tumor is generally deemed unresectable.

Biliary Resection and Reconstruction

- The duct is cut sharply without cautery artifact. Periductal bleeding is controlled with digital pressure.
- Frozen section pathologic analysis guides the extent of biliary resection into the remnant liver. Stay sutures (5-0 Prolene) in the duct allow further retraction and dissection if a more proximal margin is necessary.
- A Roux-en-Y jejunal limb is brought through the colonic mesentery to the right of the middle colonic vessels (retrocolic), with sufficient mobilization to allow for tension-free hepaticojejunostomy.
- An enterotomy is created on the antimesenteric border of the Roux limb, size-matched to the target hepatic duct. When practical, multiple adjacent ductal branches can be incorporated en masse to the anastomosis (**FIG 8**).
- Interrupted, double-armed 5-0 Prolene sutures are initially placed in the anterior wall of the duct and gently retracted with shods to facilitate exposure.
- Anastomosis begins along the posterior wall, where a single layer of 5-0 Prolene sutures incorporate the full-thickness wall of both duct and Roux limb. Knots are tied once all posterior sutures are successfully placed.
- If already present, percutaneous transhepatic stents are advanced and left in place across the bilioenteric anastomosis.
- As an alternative, a 4- to 6-Fr transanastomotic tube can be placed through the antimesenteric wall of the Roux limb with the Witzel technique, placed proximally into the remnant biliary tree, brought out through the abdominal wall, and connected to a drainage bag. This allows access to the biliary tree without placing retrograde biliary catheters through the liver (**FIG 9**).
- The previously shod-retracted anterior ductal 5-0 Prolene sutures are incorporated into the bowel wall and tied to complete the anastomosis.
- The final hilar margin should be marked with clips (or gold fiducial markers) to guide subsequent needs for external beam radiation.
- Closed suction drains are placed adjacent to the bilioenteric anastomosis and under the right diaphragm before abdominal closure.

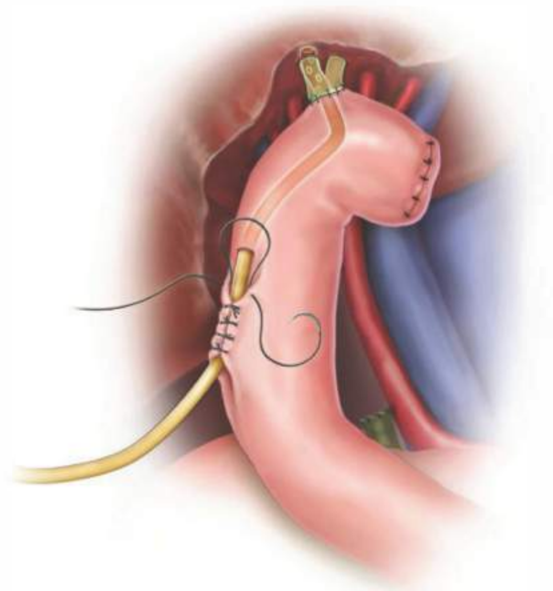

FIG 9 ● Alternative placement of transanastomotic tube.

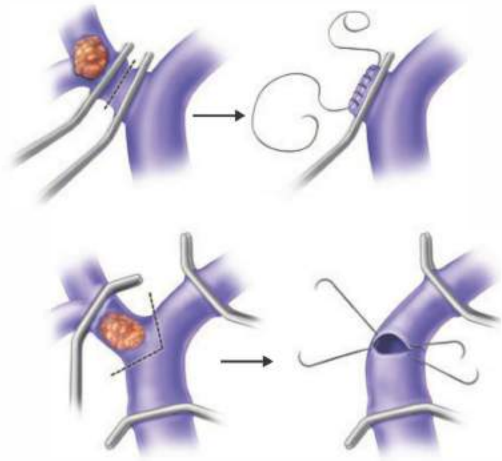

FIG 10 ● Various approaches to portal vein resection. When complete tumor resection encroaches on the portal vein confluence, closure should be performed in a transverse fashion, as longitudinal suture lines may cause stenosis of the remaining vessel.

Division of Portal Vein

- If the portal vein is free of tumor, then the portal vein is divided in standard fashion as for routine hepatectomy.
- If the right or left portal vein transection plane encroaches into the confluence due to tumor involvement (**FIG 10**)
  - Clamp the main and contralateral portal vein branch separately and transect the vein as necessary to achieve tumor-free margins.
  - Close the portal defect in a transverse orientation with running 6-0 Prolene. Longitudinal closure results in unnecessary narrowing and skewing of the remaining portal vein.
- If tumor involves the portal confluence, vein resection and reconstruction is performed later in the operation (after liver parenchyma has been fully transected and left hepatic duct dissected).
- Portal vein resections of up to 3 cm can be repaired primarily.
  - Clamp the main and contralateral portal vein, and excise the portal vein en bloc with tumor. Heparin is administered systemically prior to clamping the main portal vein and is reversed at the completion of the operation.
  - After ensuring proper mobilization of remaining vein, running 6-0 Prolene suture is used to approximate ends.
- Portal vein resections greater than 3 cm in length typically require interposition autograft (the authors prefer either left renal vein or internal jugular vein).

PEARLS AND PITFALLS

Indications	■ Multidetector cross-sectional imaging should accurately stage most patients and will often reveal anomalous hilar vascular anatomy. Careful preoperative review of these images is essential.
Skeletonizing the hepatoduodenal ligament	■ Observe a no-touch technique when mobilizing the tumor, ducts, and arteries. ■ Grasping adjacent connective tissue (such as periadventitium or neural plexus) will avoid iatrogenic injury and tumor capsule violation.
Variable anatomy	■ Complexity of ductal and vascular dissection increases with the presence of tumor bulk and infiltration in the hilum. ■ Review of imaging and knowledge of common anatomic variants will expedite a safe operation.
Caudate resection	■ Should be routinely performed and can be approached from either side ■ The caudate and right posterior section should be divided by parenchymal transection toward the right caval edge.

POSTOPERATIVE CARE

- Standard thromboprophylaxis should be given immediately.
- Early ambulation and pulmonary toilet are mandatory.
- Early ultrasound is a vital tool for any suspected insult to the remnant liver.
- High-volume ascites may signify postoperative hepatic failure and is an early sign of portal thrombosis.
- Bilious drain output may indicate a disconnected biliary duct in the remnant or an anastomotic leak. This should be evaluated with cholangiogram and cross-sectional imaging.
- Closed suction drains are typically removed after biliary tree catheters are clamped, provided there is no substantial bile leak or ascites. This typically occurs prior to discharge.

OUTCOMES

- After curative intent resection for HC, 5-year survival is 25% to 30%.[6]
- Rate of R0 resection is typically 64% to 71%.
- Postoperative morbidity and mortality rates range up to 50% and 10%, respectively.
- Bile leaks may occur in up to 20% of resected patients.
- Left liver resection (particularly left trisectionectomy) is associated with greater morbidity and a higher rate of positive margins.

COMPLICATIONS

- Bile leak
- Bilioenteric anastomotic stricture
- Torsion of liver remnant
- Thrombosis of portal vein, hepatic vein, hepatic artery, or vena cava
- Cholangitis or abscess
- Liver failure

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Chapter 12

Intrahepatic Biliary-Enteric Anastomosis

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DEFINITION

- Intrahepatic biliary-enteric anastomosis is defined as biliary reconstruction at the level of the hepatic hilum (biliary confluence) or more proximal bile ducts.
- Intrahepatic biliary-enteric anastomoses are indicated for definitive treatment of hilar biliary strictures; rarely, they may be indicated for palliation of malignant hilar obstruction.

DIFFERENTIAL DIAGNOSIS

- Biliary strictures at the hepatic hilum can be due to benign or malignant processes. Common malignant etiologies include hilar cholangiocarcinoma and gallbladder carcinoma; benign strictures typically are a result of prior biliary tract surgery or intervention.
- Uncommon benign etiologies include inflammatory or autoimmune diseases such as primary sclerosing cholangitis or IgG4 immune-mediated sclerosis.

PATIENT HISTORY AND PHYSICAL FINDINGS

- The most common presentation is jaundice. Associated symptoms may include pruritus, cholangitis, or less commonly, pain. If the patient has had biliary surgery, they may present with an acute abdomen or sepsis due to a biloma or biliary fistula.
- In the absence of prior biliary surgery, stone disease should be suspected.
- If a history of prior biliary surgery or instrumentation is present, a benign stricture should be suspected. Postoperative strictures present within the first 6 months in approximately 70% of patients. However, benign strictures can present years after biliary surgery.
- In the absence of stone disease and prior biliary surgery, a malignant stricture should be suspected.
- A complete history and physical examination is required to ensure the patient does not have evidence of infection or symptoms suggestive of metastatic disease. This assessment also should assess whether the patient is a candidate for major surgery.

IMAGING AND OTHER DIAGNOSTIC STUDIES

- A fundamental knowledge of biliary anatomy and the adjacent vascular structures is critical for success, both in deciding whether operative intervention is indicated, and if so, the type of procedure and an approach to ensure it is safe and effective. Biliary anomalies are frequent and should be expected; imaging studies should clearly define these structures and their relationship to each other. Hepatic vasculobiliary anatomic details are reviewed in Part 3, Chapter 15, Surgical Anatomy.
- The aim of the diagnostic evaluation is to define the anatomy for restoration of biliary-enteric continuity in patients with benign strictures or plan appropriate palliative care in patients with malignant disease not amenable to curative resection. Magnetic resonance cholangiopancreatography (MRCP) is the initial diagnostic study of choice in patients with obstructive jaundice thought to be due to stone disease. Otherwise, magnetic resonance imaging (MRI) with intravenous contrast and MRCP is the initial study of choice for patients with obstructive jaundice due to a stricture (**FIG 1**). Ideally, it should be performed prior to any biliary interventions such as endoscopic retrograde cholangiography (ERC) or percutaneous transhepatic cholangiography (PTC). However, most patients come for referral with prior invasive studies or biliary stents in place; these can make image interpretation challenging and/or lead to cholangitis in obstructed segments.
- MRI/MRCP gives a detailed view of the biliary tract and the level or type of obstruction when a stricture is the cause (**FIG 2**). The vascular phases allow assessment of hepatic artery and portal vein involvement in the case of malignant processes and whether the hepatic arteries are intact and patent in cases of benign strictures related to prior biliary surgery. Finally, it allows for the assessment of direct hepatic involvement or metastatic disease.
- When contrast for MRI cannot be given or the vascular anatomy is not adequately assessed, B-mode and Doppler ultrasonography (US) is highly accurate in assessing vascular patency and/or involvement.[1,2] It is important to note whether lobar atrophy is present, as this dictates treatment options.
- ERC and PTC are supplementary techniques for defining the anatomy of the biliary tract and the extent of a stricture

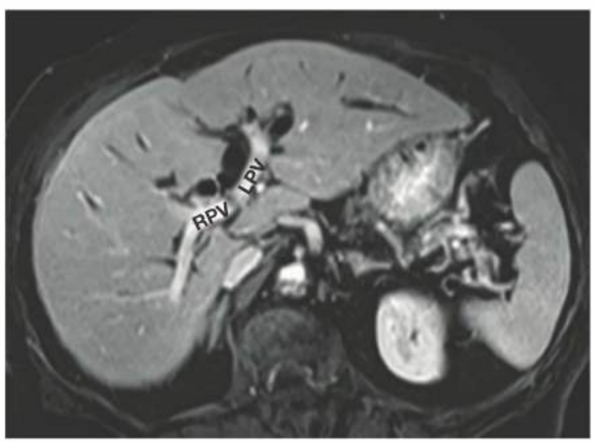

FIG 1 • MRI during the portal venous phase showing the right portal vein *(RPV)* and left portal vein *(LPV)*. The dilated left hepatic duct (LHD) lies anterior and superior to the LPV.

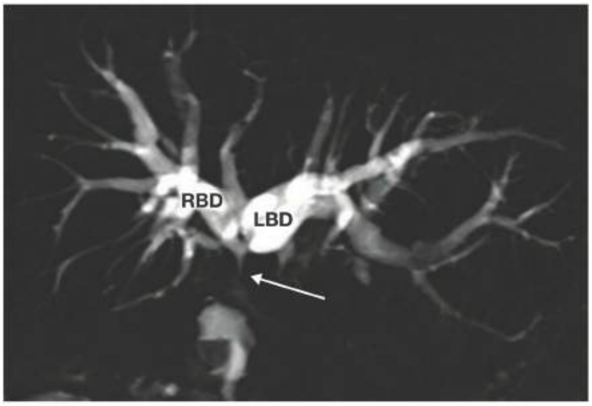

FIG 2 ● This MRCP shows a dilated right biliary duct *(RBD)* and left biliary duct *(LBD)*, leading to a type II hilar stricture at the proximal most common hepatic duct *(white arrow)*.

when these are not clear from the MRCP. Either or both may be used to obtain a tissue diagnosis in unresectable patients or for stent placement to treat symptoms and/or for preoperative preparation. There is considerable debate as to which technique is optimal for treating hilar biliary strictures and this discussion is beyond the scope of this chapter.

- To effectively relieve jaundice, approximately 30% of the functioning liver volume must be drained.[3] The functioning and proposed drained volumes can be estimated using calculated liver volumes from preoperative cross-sectional imaging (computed tomography [CT] or MRI).[4] Conversely, drainage of an atrophied hepatic lobe or segment is not effective.

SURGICAL MANAGEMENT

- Issues associated with repair of benign strictures are discussed separately from malignant strictures.
- Intrahepatic biliary-enteric anastomoses are complex procedures that require experienced, multidisciplinary, hepatobiliary team care. If this is not available at your institution, the patient should be referred to an appropriate institution for definitive repair.
- All procedures are done with 2.5× magnification using loupes. This allows for meticulous surgical technique and allows precise dissection and reconstruction.
- It is important to establish a standardize approach for biliary-enteric anastomoses. Use this each time and the high intrahepatic anastomosis will be easier to perform.

Preoperative Planning

Benign Stricture

- The goal for benign strictures is definitive restoration of biliary-enteric continuity. The type of stricture will dictate the nature of the biliary-enteric anastomosis (**FIG 3**).[5] Types E1 to E3 strictures are amenable to a Hepp-Couinaud approach.[6] E4 and E5 strictures require a modified Hepp-Couinaud approach and generally two separate anastomoses to reconstruct the right and left ducts separately.[7]
- Prior to undertaking surgery, sepsis and biliary fistulae must be resolved and all the biliary segments drained. Biliary drainage usually requires a PTC for hilar (high) strictures or injuries.
- In the clinical setting of sepsis, operative repair should not be undertaken until a minimum of 6 to 12 weeks have passed. This waiting period allows for resolution of active inflammation and evolution of any ischemic injury. Both of these are critical issues, as repair prior to resolution of these processes will decrease the success of the repair.
- Prior to operative repair, each isolated segment of the biliary system ideally should have a PTC placed. Just prior to surgical repair, the PTC drain(s) is exchanged such that the tip is guided into the distal most part of the intubated duct(s) to intraoperatively facilitate localization.

Malignant Stricture

- For this group, the preoperative evaluation focuses on whether the patient is a candidate for potentially curative resection. If so, they are approached as outlined in Part 3, Chapter 11.
- With unresectable disease, current percutaneous and endoscopic techniques (drainage with plastic or expandable metallic stents and intraductal photodynamic therapy or radiofrequency ablation) provide excellent palliation; thus, there is little to no role for a planned palliative intrahepatic biliary-enteric bypass.
- Consequently, intrahepatic biliary-enteric anastomosis generally is reserved for patients with biliary obstruction found to be unresectable at the time of exploration and who are expected to survive more than 6 months. Otherwise, the morbidity and mortality associated with bypass is not justified. For instance, patients with unresectable gallbladder carcinoma have a median survival of 20 weeks. Thus, stenting is a better choice for palliation. On the other hand, the median survival for unresectable hilar cholangiocarcinoma is 52 weeks and a bypass may be reasonable under these circumstances.[8] Even this circumstance is questionable, as there appears to be no survival advantage between surgical and

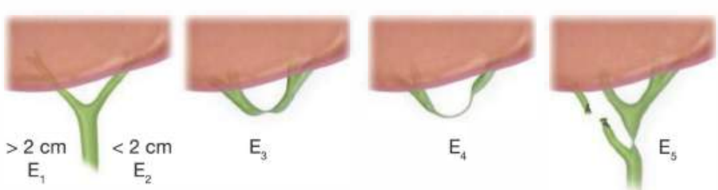

FIG 3 ● Strasberg classification of biliary strictures.

nonsurgical drainage approaches and the morbidity and mortality for surgical approaches are significant in comparison.[9]

- Other intrahepatic biliary-enteric anastomotic approaches are not included in this discussion as they are primarily of historical interest. These include the Longmire approach, mucosal graft operation, and right duct approaches. Current alternatives provide better palliation with lower risks.
- This discussion, therefore, is limited to the segment 3 bypass (round ligament or ligamentum teres approach) as the primary practical option for these patients. Although a right sectorial duct bypass can be done, the circumstances where it might be applicable are quite limited and the results relatively poor.[8] As such, it has little practical value and the best palliation for these patients is stenting and possibly tumor ablation to prevent liver failure and cholangitis.
- Patients eligible for a segment 3 bypass are limited to those with unresectable Bismuth types I, II, or IIIa strictures without atrophy of the left hepatic lobe; to be effective, at least 30% of the functioning liver volume must be drained. Types IIIb and IV lesions are not effectively drained by a segment 3 approach. Importantly, there is no role for this bypass if the right ductal system has been contaminated by prior right duct intubation, as these patients will require continued right duct drainage to prevent cholangitis.

FIG 4 ● Operative positioning is supine with arms extended. Position the percutaneous transhepatic catheters *(black arrows)*, leaving them intact during the procedure. Sterilely prep those portions left in the field and cover them with an adherent drape.

Positioning

- The patient is placed in the supine position with both arms extended (**FIG 4**).
- The percutaneous drains are aseptically prepped but positioned out of the field as much as possible (i.e., under additional sterile draping) and ideally left to drain. The catheters will need freedom of movement from within the abdominal cavity during the procedure, thus, extreme care must be taken to ensure that this is feasible without undue risk of inadvertent dislodgement of the drains.

HILAR HEPATICOJEJUNOSTOMY (HEPP-COUINAUD APPROACH)

Preparation

- This approach takes advantage of the extrahepatic course of the left hepatic duct as it runs along the base of segment 4 for approximately 2 to 3 cm from the biliary confluence to the umbilical fissure (**FIG 5**). It is the anterior–superior most structure in the hilum, and this position facilitates its exposure and the anastomosis while minimizing injury to the portal vein and hepatic artery (**FIGS 6** and **7**).

Incision

- A right subcostal incision allows access to the hepatic hilum. Often, a midline extension facilitates full exposure (**FIG 8**).

Exposure

- Identify, doubly clamp, and divide the falciform ligament. Ligate each end and leave a long tie on the superior side to use as a handle. Divide the falciform ligament superiorly to the superior edge (diaphragm) of the liver. When the patient has extensive adhesions, the ligamentum teres is an invaluable guide to locating

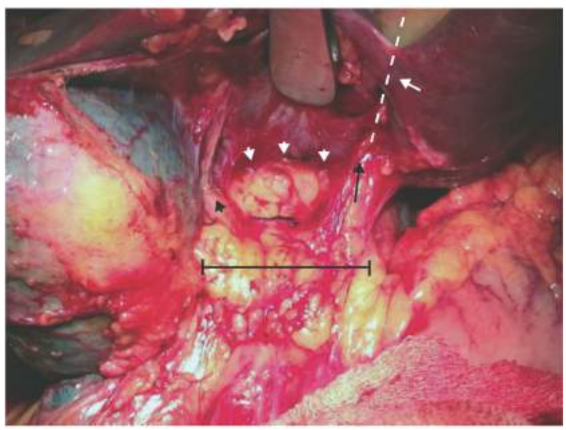

FIG 5 ● The left hepatic duct runs in the hilar plate. Find it just posterior to the base of segment 4 *(white arrowheads)* at its junction with the hepatoduodenal ligament *(black line)*. The base of the gallbladder fossa is shown *(black arrowhead)* as well as the base of the umbilical fissure *(black arrow)*. The left hepatic duct runs approximately 1 to 2 cm to the patient's left of the base of the gallbladder fossa to the base of the umbilical fissure. The umbilical fissure *(dotted white line)* runs between segment 4 and the segments 2 and 3 of the left lobe. A bridge of liver tissue *(white arrow)* between segment 4 and segment 3 frequently covers a portion of the umbilical fissure.

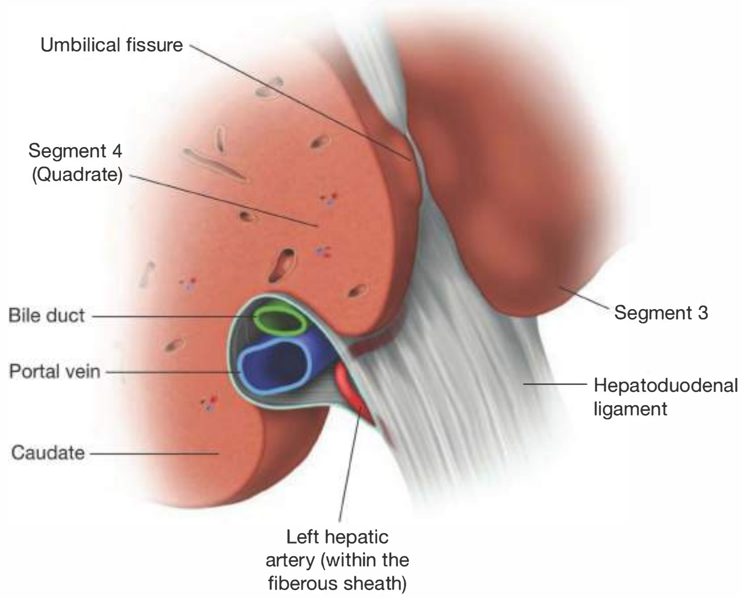

FIG 6 ● This oblique sagittal section shows the relationship of the left hepatic duct and portal vein in the hilar plate (superior most portion of the hepatoduodenal ligament) and the plate's relationship to segment 4 (quadrate lobe). The base of segment 4 covers the anterior–superior most portion of the hilar plate. At this location, the left hepatic duct lies anterior–superior to the left portal vein. The left hepatic artery usually is not present at this site as it runs along the left lateral edge of the hepatoduodenal ligament and joins these structures at the base of the umbilical fissure. As segment 4 lies over the anterior hilar plate, this necessitates incising Glisson's capsule at this site to push segment 4 superiorly and anteriorly, thereby exposing the hilar plate and the left hepatic duct.

the umbilical fissure. During dissection, follow it posteriorly to locate the umbilical fissure; this assists in identifying the anterior surface of the hepatoduodenal ligament.

- Take down adhesions to the inferior surface of the liver and the anterior surface of the hepatoduodenal ligament to expose the gallbladder fossa and the base of segment 4 (**FIG 9**). It is easiest to work from the right edge of the liver back toward the hilum when taking down adhesions. There often is a free space at the right edge of the liver that allows access posteriorly around the lateral edge of the adhesions.
- Place a clamp behind the usually present liver bridge joining segments 4 and 2 or 3, and divide it with electrocautery. This exposes the umbilical fissure and facilitates exposure of the left hepatic duct (**FIG 10**).
- Carry the dissection to the base (posterior aspect) of segment 4 and its junction with the hepatoduodenal ligament (**FIG 5**). Retract the base of segment 4 superiorly and anteriorly with a malleable retractor if necessary for exposure.

FIG 7 ● Coronal MRI showing the relationship between the left hepatic duct *(bent white line)* and the left portal vein *(asterisk)*. The duct lies anterior–superior to the left portal vein at the base of segment 4. The left hepatic artery *(white arrowhead)* runs along the left side of the hepatoduodenal ligament and joins the duct and vein at the base of the umbilical fissure *(black arrow)*.

FIG 8 ● A right subcostal incision *(solid line)* often allows sufficient exposure to the hepatic hilum. If not, a midline extension to the xiphoid facilitates access to the hilum and superior liver. The right subcostal incision typically is two fingerbreadths (~4 cm) below the right costal margin *(white arrows/dotted line)*. This image shows the two PTC tubes secured off the field except at the level of the xiphoid process (solid "V").

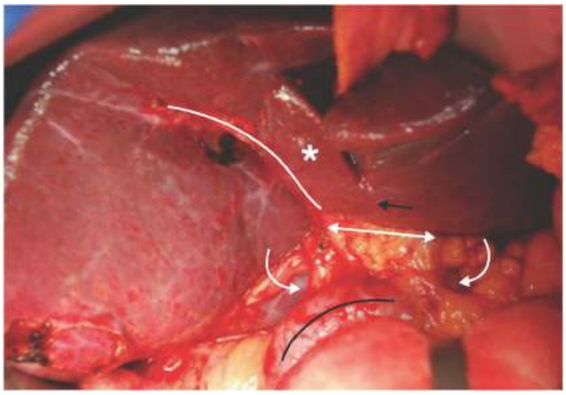

FIG 9 ● Incise adhesions to expose the inferior surface of the liver and anterior surface of the hepatoduodenal ligament *(white double-headed arrow)*. This exposes the gallbladder fossa *(curved white line)*. The base of segment 4 is not apparent in this image, as an exophytic lobe of segment 4 *(asterisk)* covers it. The bridge of liver tissue connecting segment 4 with segment 3 *(black arrow)* limits access to the base of segment 4. The foramen of Winslow (*curved arrow*, patient's right) allows access posterior to the hepatoduodenal ligament. Opening the gastrohepatic ligament to the left of the hepatoduodenal ligament (*curved arrow*, patient's left) connects with the space posterior to the ligament and superior to the duodenum *(curved black line)*.

- Caution is warranted if the patient has right hepatic lobe atrophy and left lobe hypertrophy. The hepatoduodenal ligament anatomy often is distorted with the bile duct complex and hepatic arteries rotated to the right and posteriorly. Consequently, the main portal vein often is the anterior-most structure in the ligament in this situation.

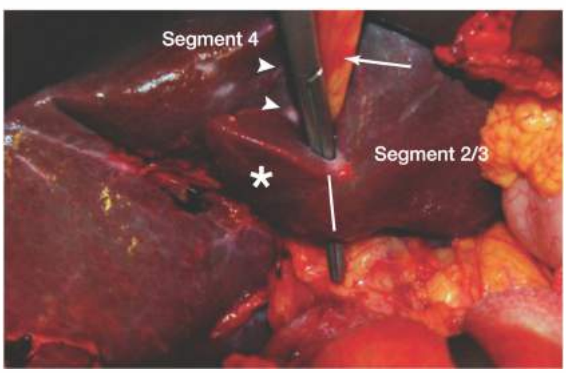

FIG 10 ● To open the bridge of liver connecting segment 4 and segment 2 or 3 *(white line)*, place a clamp between it and the ligamentum teres *(white arrow)*. This can be divided with electrocautery because there are rarely vessels of any size within this structure. This opens the umbilical fissure exposing portal structures for segment 4 *(white arrowheads)*. This patient has an exophytic portion of segment 4 *(asterisk)*. A small portal pedicle connected this exophytic lobe. It was divided and the lobe removed to facilitate exposure to the base of segment 4.

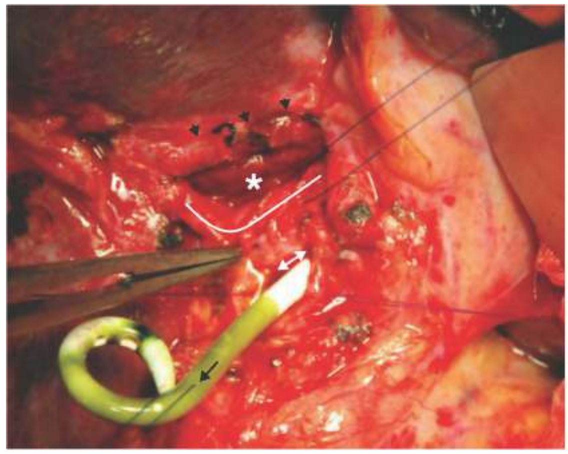

FIG 11 ● At its junction with the hepatoduodenal ligament, incise Glisson's capsule *(black arrowheads)* to expose the hepatic parenchyma *(asterisk)* superior to the hilar plate *(curved white line)*. The anterior surface of the left hepatic duct *(white double-headed arrow)* is incised longitudinally, exposing the PTC tube within the duct. Pull the PTC from within the duct and place a nylon suture through the straight portion of the tube *(black arrow)* to manipulate the tube during the procedure.

Lower the Hilar Plate

- Incise Glisson's capsule at its junction with the hepatoduodenal ligament at the base of segment 4. This leads to entry into the hepatic parenchyma adjacent to the hilar plate (**FIG 11**). Venous bleeding will occur; it is easily controlled with pressure. Once the base of segment 4 is released, it is retracted further superiorly and anteriorly, exposing the hilar plate and providing access to the left hepatic duct (**FIG 11**). This is the Hepp-Couinaud approach or "lowering the hilar plate" to expose the left and right hepatic ducts.[6]

Locate the Left Hepatic Duct

- Palpate the stent in the left duct to locate it within the fibrous sheath of the hepatic plate. Intraoperative ultrasound can help locate the stent within the duct. Likewise, aspiration of bile using a 25-gauge needle and syringe can assist in locating the duct and verifying its position.

Incise the Hepatic Ducts

- Once located, make a longitudinal incision in the anterior surface of the duct until the lumen is entered (**FIG 11**). The lumen will be evident from the stent within it. The stent serves as a guide, delineating the lumen and course of the duct. Use a blunt probe to explore the left and right hepatic ducts and identify the confluence of the two.
- Grasp the stent and pull it out of the duct. Place a monofilament suture through the straight portion of the stent above the curved end (**FIG 11**). Cut the stent just distal to the suture, thus removing the self-retaining end of the stent. The suture through the stent serves as a "handle" to move the stent in and out of the opened duct. Allow

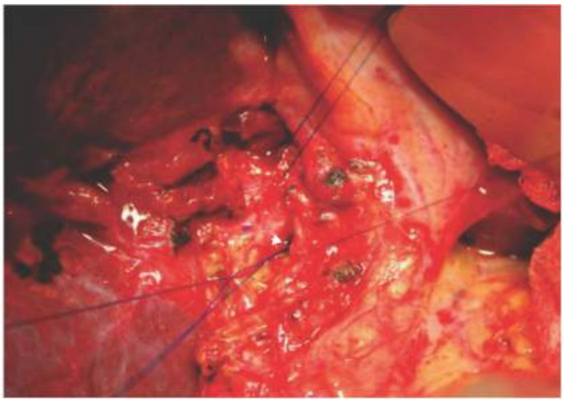

FIG 12 ● Cut the PTC tube distal to the nylon suture, allowing it to retract above the site of the anastomosis. The left duct orifice is shown *(white arrowhead)*.

it to retract above the distal left duct (**FIG 12**). Removing the distal end of the stent facilitates probing and opening of the duct. Having the stent out of the opened duct makes suture placement easier during the anastomosis.

- With a right-angle instrument, the stent, or a probe within the duct as a guide, use a knife to sharply open the duct a minimum of 1 cm for the anastomosis; open it longer if the patient's anatomy allows. Alternatively, angled (e.g., Potts) scissors can be used to open the duct. The duct is opened toward the patient's left to the base of the umbilical fissure or just to the right of the segment 4 (middle) hepatic artery, which often lies along the right edge of the umbilical fissure. This artery runs anterior to the left hepatic duct; take care to avoid injury to it. Reverse the direction of the incision and open the duct to the patient's right to the base of the gallbladder fossa. This will open the distal right hepatic duct (**FIG 13**). The goal is exposure of viable duct and healthy mucosa for the anastomosis.

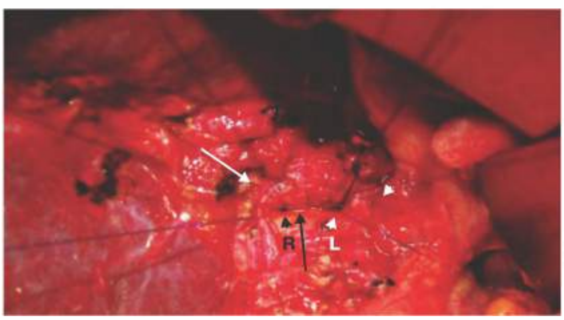

FIG 13 ● Incising the duct toward the base of the umbilical fissure *(white arrowhead)* exposes a portion of the left hepatic duct (between *black arrow* and *white arrowhead*, *L*) along the base of segment 4. Incising the duct toward the base of the gallbladder fossa *(white arrow)* opens the very short extrahepatic portion of the right hepatic duct exposing its orifice (*black arrowhead*, *R*). The septum between the right and left ducts *(black arrow)* is shown illustrating the longer extrahepatic course of the left hepatic duct. The left duct orifice is shown (*white arrowhead*, *L*).

Roux-en-Y Jejunal Limb Construction

- Identify the ligament of Treitz. Further distally, find the first jejunal arcade by transilluminating the small bowel mesentery. Divide the bowel at this site with a linear stapler.
- Divide the mesentery between clamps to develop a pedicle of sufficient length to reach the right upper quadrant.
- Approximately 55 to 60 cm distal to the end of the Roux limb, construct a side-to-side enteroenterostomy with the linear stapler. Close the resulting enterotomy with running absorbable sutures. Oversew this suture line with interrupted absorbable sutures in a Lembert fashion.
- Close the mesenteric defect with running absorbable suture.
- Bring the Roux limb into the right upper quadrant through the transverse mesocolon in the avascular space to the right of the middle colic vessels. This results in a retrocolic Roux limb that passes anterior to the second portion of the duodenum.
- Imbricate the Roux limb staple line with interrupted absorbable sutures in a Lembert fashion (**FIG 14**). This prevents dense adhesions to the staple line in the event reoperation is necessary.

Hepaticojejunostomy

- Make an antimesenteric jejunotomy near the end of the Roux limb that is approximately two-thirds the length of the longest diameter of the ductal opening.
- Using 6-0 monofilament absorbable sutures, tack the jejunal mucosa to the serosa around the circumference of the jejunotomy (**FIG 14**). We believe this step is critical to ensure the jejunal mucosa is in apposition with the bile duct mucosa upon completion of the anastomosis. Furthermore, this technique is much easier than trying to find the mucosa during each stitch of the anastomosis, especially if the duct is small or it is difficult to see well in the depth of the field. This technique is particularly helpful to ensure the mucosa is incorporated in the anterior layer when placing the anterior row of sutures in the bowel after the posterior layer has been tied.

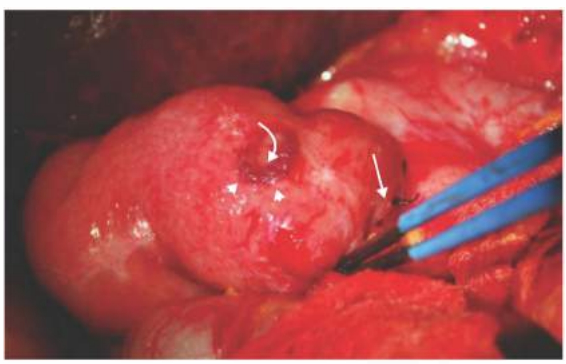

FIG 14 ● Imbricate the staple line *(white arrow)* of the Roux limb in a Lembert fashion. Tack the jejunal mucosa to the edge of the serosa *(white arrowheads)* at the jejunotomy (*curved white arrow* indicating the lumen) to ensure a mucosal-to-mucosal anastomosis with the bile duct.

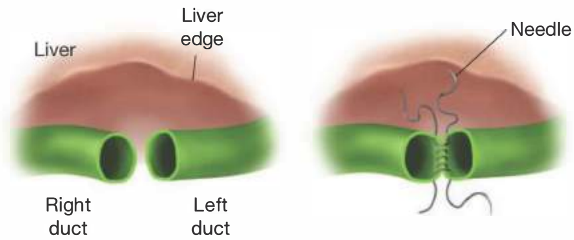

FIG 15 ● When two separate duct openings are in close approximation, a single lumen is constructed as this facilitates a single biliary-enteric anastomosis. Use fine (5-0 or 6-0) absorbable suture to approximate the adjacent bile duct walls to form a common septum. The corner sutures are tied on the outside and the remaining sutures are tied in the interior.

- If two separate ducts are present and they are close enough to be joined into a single anastomosis, this is desirable. Interrupted absorbable monofilament sutures are used to approximate the ducts (**FIG 15**).
- Typically, 5-0 or 6-0 (depending on duct size, thickness/friability of the tissue) interrupted monofilament absorbable sutures on a small needle are used for the anastomosis. Place the corner sutures in the bile duct first (9 o'clock and 3 o'clock positions) such that the knot will be tied on the outside of the anastomosis. Place the anterior row sutures through the bile duct next such that the knot will be tied on the outside of the anastomosis (**FIG 16**). Place sutures approximately 4 to 5 mm apart. Leave the needle on and secure each suture with a fine clamp, placing it on moderate tension. It is essential to establish a system to keep the sutures organized (**FIG 17**). Placing the anterior row first and keeping it under tension opens the duct to facilitate the remaining portions of the anastomosis and ensure precise suture placement.

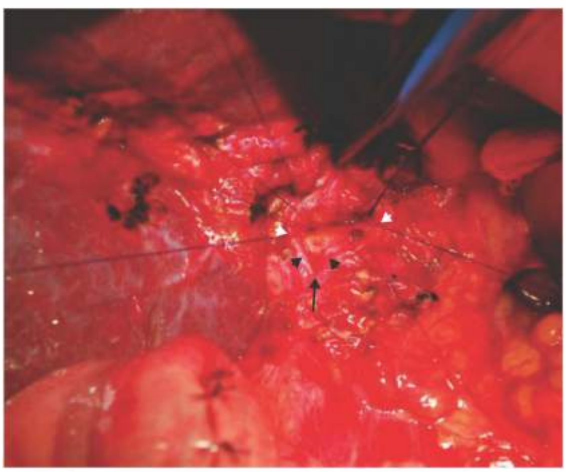

FIG 16 ● Place the corner sutures initially in the bile duct *(white arrowheads)* so they will be tied on the exterior. Place the remaining anterior sutures such that they will be tied on the exterior. Place the first suture to bisect the distance between the corners. Then place the remaining sutures to bisect each half until the sutures are 4 to 5 mm apart. The scarred and obstructed proximal common hepatic duct *(black arrow)* is seen at its junction *(black arrowheads)* with the left and right hepatic ducts.

- In the event two anastomoses are required, treat them as one and place all the anterior sutures first. Trying to perform each anastomosis separately makes construction of the second one very difficult. When two anastomoses are required, place the anterior sutures into the first duct in a similar fashion to that described previously. Once they are laid out under tension, place a white towel over these sutures and clamps. Place the anterior row sutures in the second duct. Using this method, the two sets of sutures will not get confused when it is time to complete the anterior row sutures.
- Keep the bowel and bile duct apart while placing the posterior row sutures. It is easier to precisely place each suture using this technique. Start by placing the corner sutures through each corner of the jejunotomy, then place a clamp on the suture and put it under tension (**FIG 18**). To start the posterior row, place a suture through the posterior wall of the jejunotomy and then the posterior duct halfway between each corner stitch, thereby bisecting the distance between the two. This places the posterior row sutures so the knots will be tied on the inside of the anastomosis. Place this suture and each subsequent one on a clamp and organize the sutures as done for the anterior row to prevent tangling. Complete the right half of the posterior row by placing sutures to sequentially bisect the remaining distance between the right corner and middle sutures until there are no gaps of more than 4 to 5 mm. Complete the left half of the posterior row in a similar fashion.
- Slide the bowel to the bile duct while keeping each of the sutures taut. Tie the corner suture furthest from the

FIG 17 ● After each anterior suture is placed in the bile duct, attach a fine clamp and organize each suture to prevent tangling. Placing each suture under moderate tension and arranging them on white towels as shown facilitates this. The white towels make the sutures easier to see on the field.

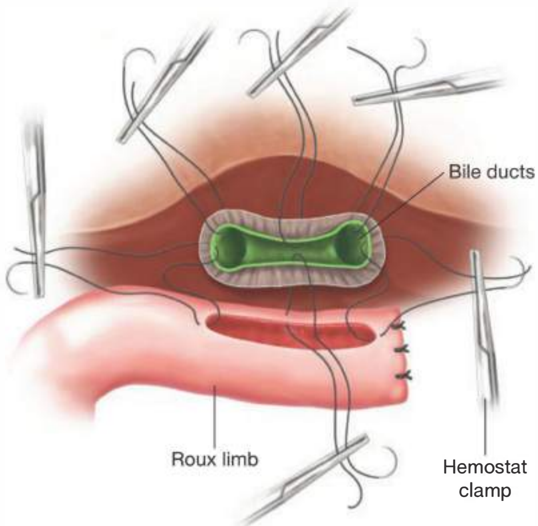

FIG 18 ● Place the posterior suture row by placing each corner suture in the corresponding corner of the jejunotomy. Place each of these under tension as shown in **FIG 17**. Keep the bowel and bile duct separated by 5 to 10 cm while placing the remaining posterior sutures. Place the remaining sutures so they will be tied on the interior. The first suture is placed to bisect the distance between the corner sutures. Next, the right half sutures are placed, again by bisecting the distance between the corner and the middle suture. This is done until the distance is 4 to 5 mm between the sutures. Finish the posterior row by placing the left half sutures.

surgeon first. Sequentially tie each next suture, working from the tied corner to the other corner suture. The assistant can use forceps to hold the anterior lip of the bowel inferiorly, opening the anastomosis and allowing the surgeon to observe each suture as it is tied, thus ensuring apposition of the bowel and bile duct mucosa (**FIG 19**).

- Once the posterior row sutures are tied, place a right-angle clamp into the lumen of the jejunotomy and gently open the clamp. This ensures that none of the anterior mucosa is trapped in the posterior sutures while tying them. This prevents webs or strictures in the anastomosis as a result of trapped mucosa.
- If the intraductal stent is protruding into the anastomosis, pull the retaining suture down and cut the stent so the end will rest proximal to the anastomosis. If it is already in good position above the anastomosis, cut the retaining suture. We never stent our anastomoses. There are two primary reasons why stents are not left traversing the anastomosis. First, if the anastomosis is done as described, a stent in the anastomosis provides no technical advantage in assuring a precise anastomosis. Second, one only has to observe the intense inflammation, tissue injury, and thickening associated with biliary stents to be concerned that a stent placed across an anastomosis will cause similar changes and lead to a postoperative stricture. Finally, there is no evidence that stenting a surgically constructed anastomosis improves outcomes.
- Complete the anastomosis by placing the anterior row sutures through the bowel, tying the knots on the outside (**FIG 20**). Place the suture closest to each corner first, then the adjacent suture next, working toward the center of the anastomosis. It is easier to see each suture placed in this fashion rather than working from one corner to the other.

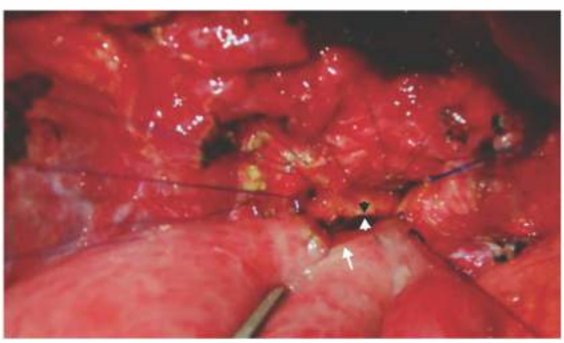

FIG 19 ● Tie the posterior row sutures by pushing the bowel into apposition with the bile duct. Start by tying the corner furthest from the surgeon, tying each next suture in succession. Forceps retracting the anterior edge of the jejunotomy *(white arrow)* allow examination of the posterior wall of the anastomosis to ensure a mucosal-to-mucosal anastomosis (opposing *black* and *white arrowhead*).

Final Steps

- Upon completion of the anastomosis, use sutures to tack the Roux limb to the cystic plate or other fibrous tissue to prevent tension on the anastomosis.
- Tack the Roux limb to the transverse mesocolon with interrupted absorbable sutures to prevent it from herniating into the right upper quadrant.
- Place a 19-Fr round Blake drain through a separate incision and place the end in the subhepatic space.
- If the PTC tubes were manipulated and the fibrous sheath around them was disrupted, place a silk purse string in the liver and tie it around the tube at the exit site to prevent bile leakage.
- After closing the incision, suture the PTC to the skin to prevent dislodgement. Although the anastomosis is not stented by the PTC, it is left in place postoperatively to gravity drainage until the patient is ready for discharge. Just prior to discharge, a cholangiogram is completed. If no leak or stricture is seen, the tube is removed.

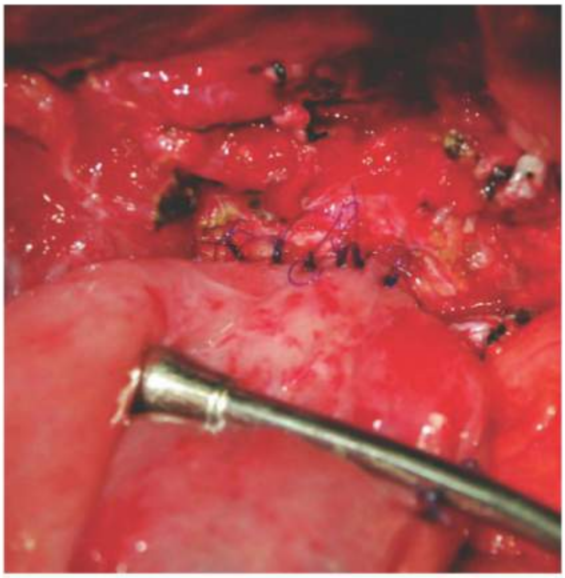

FIG 20 ● Complete the anastomosis by placing the anterior row sutures through the bowel and tying them on the exterior of the anastomosis.

SEGMENT 3 HEPATICOJEJUNOSTOMY (LIGAMENTUM TERES OR ROUND LIGAMENT APPROACH)

Preparation

- This approach takes advantage of the position of the segment 3 duct, which lies cranial to the left portal vein (**FIG 21**) at the anterior–inferior aspect of the umbilical fissure (**FIG 22**). The ligamentum teres (remnant of the umbilical vein, which joined the terminal left portal vein in utero) runs in the dorsal portion of the falciform ligament as it passes into the umbilical fissure. Advantage is taken of the relationship between the ligamentum teres and the left portal vein to facilitate identification of the segment 3 bile duct.

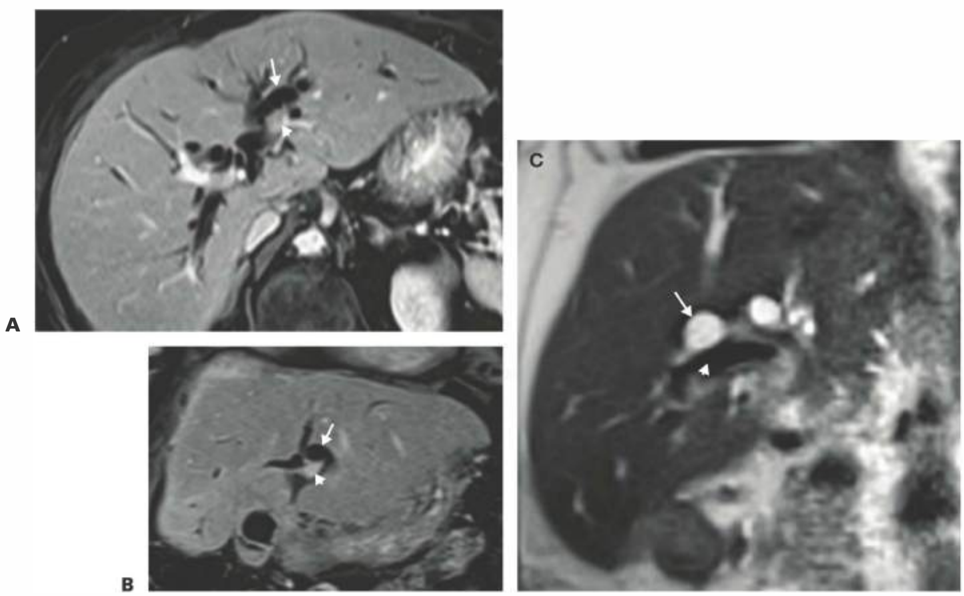

FIG 21 ● The segment 3 duct *(white arrowhead)* is located cranial to the left portal vein *(white arrow)* within the umbilical fissure. **A.** Axial contrast-enhanced portal phase MRI. **B.** Coronal contrast-enhanced portal vein phase MRI. **C.** Sagittal T2 weighted MRI.

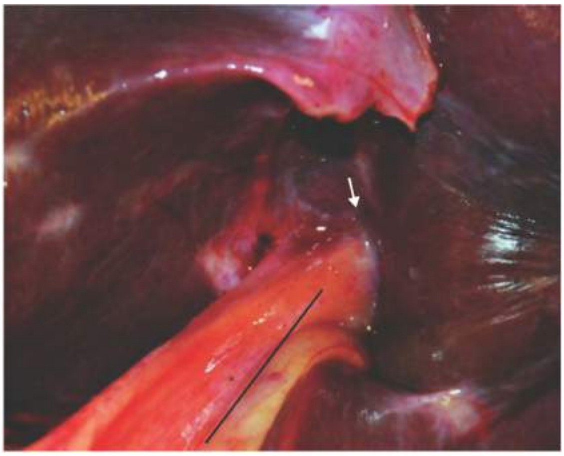

FIG 22 ● The ligamentum teres *(black line)* runs in the dorsal portion of the falciform ligament and its junction with segment 3 *(white arrow)* helps locate the approximate position of the segment 3 duct.

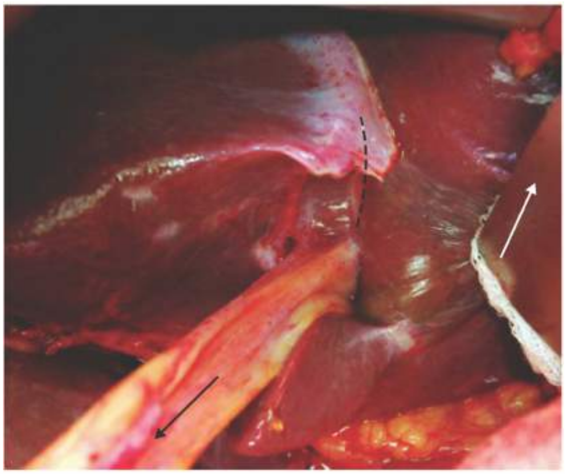

FIG 23 ● Retracting the ligamentum teres *(black arrow)* inferiorly and to the right while retracting the lateral segment of the liver *(white arrow)* superiorly and anteriorly opens the umbilical fissure and facilitates exposure to the segment 3 portal pedicle. The liver is divided just to the left of the falciform ligament *(dotted black line)* to access the segment 3 duct.

- Contraindications to the segment 3 approach include an isolated right ductal system that is infected or has been instrumented by an endoscopically or percutaneously placed drain, atrophy of the left hepatic lobe, metastatic disease, or tumor involvement of the secondary bile ducts of the left lobe or posterior to the base of the umbilical fissure.

Locate the Segment 3 Duct

- The initial steps including positioning, incision, exposure, and construction of the Roux limb are the same as described in the prior section. Likewise, constructing the hepaticojejunostomy follows the principles outlined earlier.
- Retraction of the ligamentum teres inferiorly and to the right while retracting the adjacent liver superiorly and anteriorly facilitates exposure to the segment 3 duct (**FIG 23**).
- Divide the liver just to the left of the falciform ligament starting superior to the umbilical fissure and incise the liver inferiorly and posteriorly toward the junction of the left portion of the ligamentum teres with segment 3 of the liver (**FIG 23**). If necessary, remove a small wedge of hepatic parenchyma to expose the segment 3 duct (**FIG 24**). This approach avoids dividing the portal vein

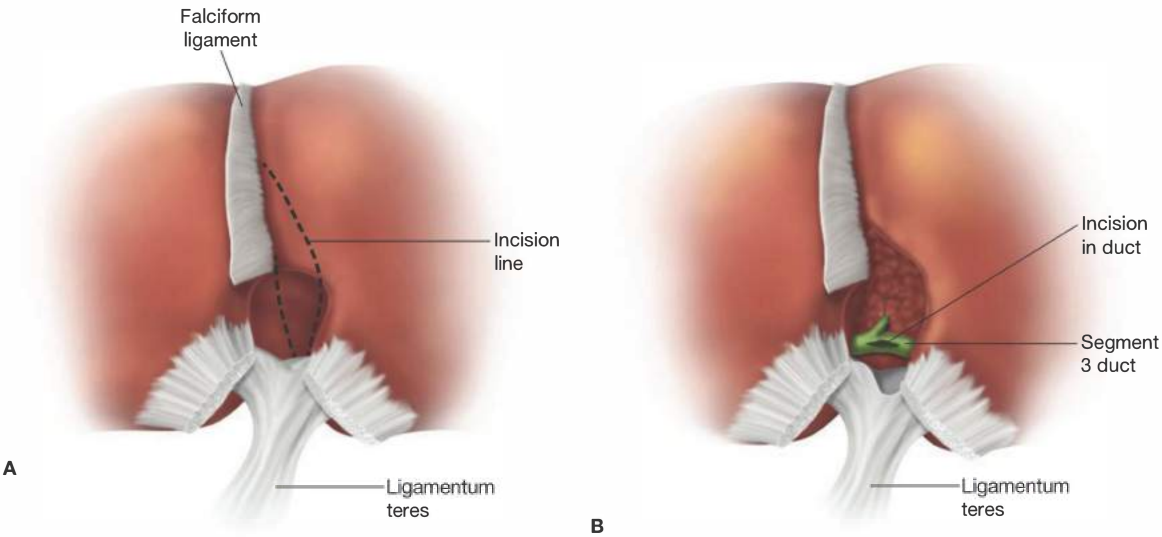

FIG 24 ● **A.** Removing a wedge of liver just to the left of the falciform ligament will expose the segment 3 duct. **B.** Once the segment 3 duct is exposed, place stay sutures superior and inferior to the proposed ductotomy and longitudinally incise the duct. Once the lumen is identified, probe the duct in each direction and open the duct for a minimum of 1 cm for the anastomosis.

branches to segment 3. Avoid dissection of more than the anterior surface of the duct to avoid devascularization of the duct.

- Intraoperative ultrasound can help locate the duct. Likewise, aspiration of bile using a 25-gauge needle and syringe can assist in locating the duct and verifying its position.

Incise the Hepatic Ducts, Biliary-Enteric Anastomosis, and Final Steps

- Once located, place fine stay sutures in the anterior duct wall, elevate them, and make a longitudinal incision in the exposed surface of the duct until the lumen is entered (**FIG 24**). Use a blunt probe to explore the duct.
- With a right-angle instrument inside the duct, use a knife to sharply open the duct a minimum of 1 cm for the anastomosis; open it longer if the patient's anatomy allows. Alternatively, angled (e.g., Potts) scissors can be used to open the duct. Reverse the direction of the incision and open the duct to the patient's right to the extent feasible.
- The biliary-enteric anastomosis to the Roux limb is constructed as described in the previous section. Place the anterior row sutures first followed by the posterior row.
- The final steps are similar to those described previously.

PEARLS AND PITFALLS

Indications	■ Biliary-enteric anastomosis may be necessary for benign or malignant disease. ■ The stricture etiology (benign or malignant) dictates the anastomotic location and options.
Preoperative evaluation	■ MRCP/MRI is the initial imaging study of choice. ■ Endoscopic/percutaneous cholangiography is a supplementary study for defining biliary anatomy. Biliary stenting often is necessary for preoperative preparation.
Benign	■ Allow 6 to 12 weeks following resolution of sepsis and/or control of biliary fistulae before proceeding with repair. ■ Ensure all ducts are accounted for and each isolated biliary segment has a PTC within it.
Malignant	■ Nearly all patients with unresectable disease can be effectively palliated without a biliary-enteric anastomosis. ■ A segment 3 bypass is reasonable for patients with malignant hilar obstructions that do not extend to the secondary radicles of the left hepatic duct.
Identifying the hilar bile duct	■ At the base of segment 4 and its junction with the hepatoduodenal ligament, incise Glisson's capsule at this junction to "lower" the hilar plate. ■ The left hepatic duct lies anterior and superior in the hilar plate.
Segment 3	■ Identify the duct at the superior–posterior portion of the segment 3 portal triad by ultrasound or aspirating bile. ■ The duct lies cranial to the left portal vein in the anterior–inferior portion of the umbilical fissure. ■ Incise the liver just to the left of the falciform ligament and carry this inferiorly to the superior portion of the ligamentum teres. Remove a small wedge of liver if necessary. ■ Incise the duct longitudinally.
Constructing the biliary-enteric anastomosis	■ Tack the mucosa to the serosa at the jejunotomy site. ■ Cut the PTC tube(s) above the level of the anastomosis. ■ Place each corner suture first in the bile duct and then the anterior row so the sutures will be tied on the exterior. ■ Place a clamp in the intestinal portion of the anastomosis and open to ensure the anterior mucosa is not trapped.
Final steps	■ Tack the Roux limb to the hilar plate and transverse mesocolon. ■ Secure any PTC tube to the liver to prevent a bile leak. ■ If present, perform a cholangiogram through the PTC prior to discharge. If no leak or stricture, remove the PTC.

POSTOPERATIVE CARE

- If a preexisting PTC is left in place following biliary reconstruction, leave it to gravity drainage. Just prior to discharge, perform a cholangiogram. If there is no leak and the anastomosis is patent, remove the PTC prior to discharge.
- If no bile is present in the Blake drain, remove it prior to discharge. Otherwise, leave it until the leak has ceased.
- Long-term follow-up is necessary to assess for early and late anastomotic stricture. This includes symptom assessment for pruritus, jaundice, or cholangitis and serial serum liver studies (LFTs). Liver tests typically are done every 4 months in the first year, every 6 months in years 2 and 3, and if stable, annually for life.

OUTCOMES

- Approximately 80% to 90% long-term excellent results are reported for hilar hepaticojejunostomy. The more complex the injury (E4, E5), the lower the success rate.
- Approximately 70% of anastomotic strictures occur in the first 3 years following surgery and 80% within the first 5 years. Follow-up longer than 5 years is important as late strictures may develop in up to 5% of patients even after

more than 12 years.[10] A recent study confirmed improved results in recent patient cohorts undergoing biliary-enteric anastomosis.[11]

- Modest serum liver test elevations are seen following biliary-enteric anastomosis in patients with excellent results. Caution is warranted when interpreting these tests and trends over time are more useful than individual data points.[12] Rising values, particularly in the alkaline phosphatase, should lead to investigation for an anastomotic stricture.

COMPLICATIONS

- Bile leak, fistula, or biloma
- Cholangitis
- Anastomotic stricture
- Infection—organ space or wound abscess

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Chapter 13

Operative Management of Choledochal Cyst

Charles S. Cox, Jr. Robert Hetz

DEFINITION

- Choledochal cyst represents a spectrum of cystic abnormalities of the extrahepatic biliary tree. It is not an isolated defect of the choledochus, rather, it also includes a constellation of abnormalities of the pancreaticobiliary system/junction.
- The classification of the cystic structural abnormalities (types I to V) as originally described by Alonso-Lej[1] and modified by Todani[2] is typically used (**FIG 1**).
    - Type I is the predominant type of cyst (90% to 95% of cases) and is a fusiform, solitary dilation of the common bile duct (CBD) and hepatic duct. Type I is further subdivided into a, b, and c subtypes.
    - Type II is a cystic diverticulum of the CBD.
    - Type III (subtypes 1 and 2) is called a choledochocele and is a cystic dilation of the duct at the junction with the duodenum (intraduodenal subtype 1), with the CBD and pancreatic duct entering the intraduodenal choledochocele separately and draining into the duodenum via a stenotic/inflamed opening; and rarely, the intrapancreatic subtype 2, the choledochocele, is a diverticulum off the CBD at the level of the ampulla of Vater.
    - Type IV is a combined dilation of the intra- and extrahepatic biliary tree and is the second most common type of cyst.
    - Type V is also known as Caroli's disease and is single or multiple intrahepatic cyst(s).

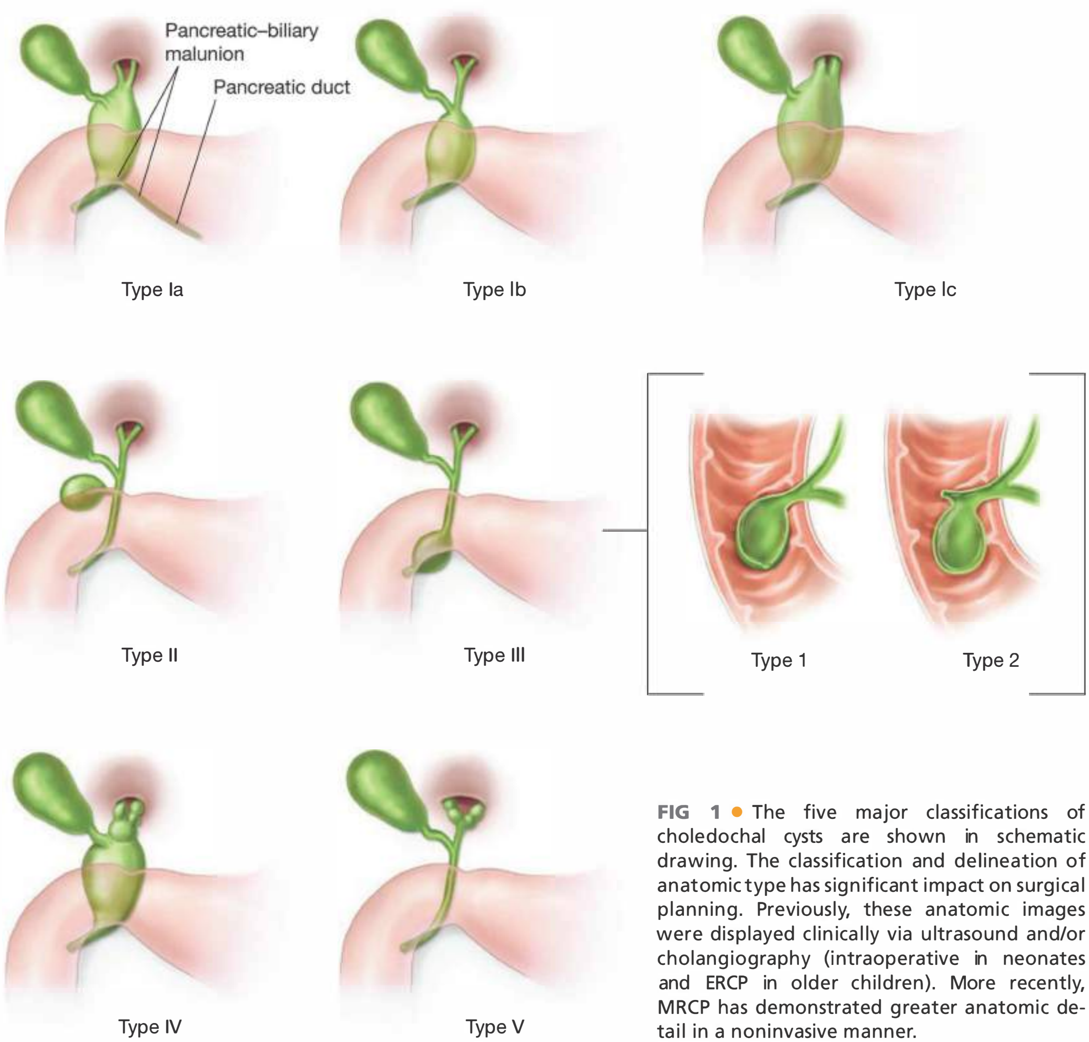

FIG 1 • The five major classifications of choledochal cysts are shown in schematic drawing. The classification and delineation of anatomic type has significant impact on surgical planning. Previously, these anatomic images were displayed clinically via ultrasound and/or cholangiography (intraoperative in neonates and ERCP in older children). More recently, MRCP has demonstrated greater anatomic detail in a noninvasive manner.

- In terms of anatomy of the distal CBD, symptomatic infants often have a stenotic opening, and older patients have a patent communication. The types II, III, and V are all very rare, representing only a few percent of the total number of cysts.

DIFFERENTIAL DIAGNOSIS

- The differential diagnosis of choledochal cyst is age-dependent.
- In infants, the differential of most concern is cystic variants of biliary atresia; other abdominal cysts, including renal, are in the infant differential.
- For older children, cystic lesions of the pancreas, hepatic tumors, rhabdomyosarcoma of the biliary tree, and cystic neuroblastoma are considerations. Most of these are distinguished on more advanced imaging, once the issue is raised with ultrasound.

PATIENT HISTORY AND PHYSICAL FINDINGS

- Patients with choledochal cysts are usually characterized as either infantile (now includes fetal or in utero diagnoses) or noninfantile forms.
- Infantile (in utero): The infantile patient with an in utero diagnosis is an increasing cohort of patients; the cystic mass adjacent to the liver is usually noted on prenatal ultrasound in midgestation. There have been reports of cystic lesions visualized as early as 15 weeks, but most are in the 20 to 24 weeks of gestation range. The antenatal abnormality should be confirmed by ultrasound postnatally. The issue that arises is timing of surgical intervention, as even the infantile forms are often asymptomatic for months.
- Infantile forms that are not in utero diagnoses are by definition symptomatic—abdominal pain/mass, jaundice-mixed hyperbilirubinemia, acholic stools, and/or signs and symptoms of pancreatitis or cholangitis. In general terms, the infantile forms do not present with an abdominal mass or other signs of inflammation, rather, these patients are increasingly identified in utero with prenatal ultrasound and/or on postnatal ultrasound as part of the initial evaluation for mixed hyperbilirubinemia. Other presentations include failure to thrive and vomiting with mixed hyperbilirubinemia.
- Noninfantile forms: Symptoms and signs of the noninfantile forms of choledochal cyst are classically described as right upper quadrant pain, jaundice (direct hyperbilirubinemia), and a mass. Pain and jaundice are the major symptoms, and it is rare that a right upper quadrant mass is palpable. The triad is present in fewer than 10% of patients. A bigger issue is the cause for delayed diagnosis/referral. The principal cause is either misdiagnosis of mixed hyperbilirubinemia as hepatitis and an incomplete evaluation of an episode of pancreatitis or hyperamylasemia with abdominal pain. Rarely, children can present with cyst rupture; there is no correlation between cyst size and risk of rupture.

IMAGING AND OTHER DIAGNOSTIC STUDIES

- Ultrasound is the initial imaging study of choice. Ultrasound is the least invasive and most cost-effective method of investigating the biliary tree after an episode of pancreatitis or abnormal elevations in liver enzymes in association with abdominal pain (with or without jaundice). This modality will suffice in the setting of calculus disease, but additional imaging with greater resolution is required when dilation of the biliary tree is identified.
- Endoscopic retrograde cholangiopancreatography (ERCP) versus magnetic resonance cholangiopancreatography (MRCP) (**FIGS 2** and **3**): Both types of imaging of the biliary tree can be useful. ERCP was more frequently used in older children to obtain direct contrast injection into the extrahepatic biliary tree under fluoroscopic guidance. It provides excellent detail of the structural anatomy of the cyst but very

FIG 2 ● ERCP in an older child demonstrating a type I cyst with fusiform morphology and moderately dilated right and left hepatic ducts.

FIG 3 ● MRCP in an older child demonstrating a type I cyst. This image demonstrates a greater detail in the anatomic relationship of the pancreatic duct. This also shows how there is a relative continuum between types I and IV cysts.

FIG 4 ● Intraoperative cholangiogram demonstrating a type IV cyst with multiple proximal ductal cysts that have areas of narrowing between the dilated regions (as opposed to the type I cyst).

little input into the relationship to structures other than the pancreatic duct. ERCP has the advantage over MRCP in that it can also be therapeutic in the setting of obstructive jaundice. MRCP provides a similar level of detailed imaging of the ductal relationships with 3-D reconstruction of the anatomy of adjacent structures as well. MRCP also has the advantage of being noninvasive and thus is associated with less risk. **FIG 4** shows an intraoperative cholangiogram of a type IV cyst that can be an adjunct to the other imaging modalities.

- Computed tomography (CT): CT imaging is most commonly used when investigating abdominal pain of an undetermined etiology and when the findings suggest a choledochal cyst. With the more advanced CT imaging and 3-D reconstruction /multiplanar imaging now available, MRCP or ERCP is rarely required if a CT has been obtained.

SURGICAL MANAGEMENT

- The technique described in the following text represents the principal management of types I and IV cysts, which represents over 95% of choledochal cyst cases. Timing of intervention: The debate surrounding immediate (first 2 weeks of life) versus delayed (6 weeks to 3 months of age) surgical intervention hinges on whether there is a risk for progressive liver dysfunction developing in the interim time of waiting. There are no solid data to support either approach. The rationale for not waiting indefinitely is due to the fact that it can be somewhat difficult to distinguish the cystic variant of biliary atresia from a choledochal cyst in infancy. Missing the window to surgically correct a patient with biliary atresia is a potentially devastating complication that is avoidable. A reasonable intermediate approach is to follow the asymptomatic, anicteric patient serially with serum biochemical studies and ultrasound with a planned operation at 6 weeks of age to earlier if worsening. Symptomatic patients or patients with a mixed hyperbilirubinemia undergo early operation if other comorbidities are manageable. Older patients can undergo operation when physiologically stable. If these patients present with cholangitis/pancreatitis, they can typically be managed akin to an adult with gallstone pancreatitis. Once the acute inflammatory response has subsided, an operation is performed during that admission, as early recurrent pancreatitis is the norm.

Preoperative Planning

- We advise the use of an epidural catheter for perioperative pain management, and this is placed after the induction of anesthesia. Two peripheral intravenous lines, radial arterial line, Foley catheter, and nasogastric tubes are routinely inserted under aseptic conditions. Any coagulopathy is corrected preoperatively (unusual), and 20 mL/kg body weight of packed red blood cell (PRBC) are crossmatched and available for the procedure. Preoperative cefoxitin (40 mg/kg body weight) is used as antibiotic prophylaxis and redosed at 4 hours if needed.

Positioning

- The patient is placed supine on the operating room table such that fluoroscopic cholangiography can be performed if needed. A small towel "bump" is placed under the right flank. The right arm is on an armboard at 90 degrees (**FIG 5**).

FIG 5 ● The patient is placed supine on the operating table with the abdomen available for fluoroscopic imaging. A small towel bump is placed under the right flank. The right arm is at 90 degrees and is the site for a radial arterial catheter for blood pressure monitoring/sampling.

- The rationale for total cyst excision is to minimize the risk of malignant degeneration in the future. Roux-en-Y cyst jejunostomy is favored over cyst duodenostomy because of poor long-term results associated with the latter, namely recurrent cholangitis and anastomotic stenosis leading to insidious biliary cirrhosis. We exclusively use an open laparotomy with total cyst excision for types I and IV lesions (over 95% of cases) with Roux-en-Y hepaticojejunostomy.
- The use of minimally invasive approaches has been described and is technically feasible. There are no long-term data on this approach; laparoscopic portoenterostomy for biliary atresia has been abandoned not due to technical issues but rather due to exacerbation of hepatic insufficiency that is thought to be due to either technical dissection of the portal plate or more recently, a reduction of hepatic/portal blood flow for the time of operation.[3]

INCISION AND EXPOSURE

- A standard right subcostal incision is made to enter the abdomen. For larger cysts, the incision is extended to a partial chevron to gain adequate exposure. A self-retaining retractor (Bookwalter or Thompson) is used. The right colon and hepatic flexure are mobilized from lateral to medial, taking down the peritoneal reflection to expose the porta hepatis and duodenum.
- Next, the duodenum is fully mobilized (Kocher maneuver). Be prepared for the potential severe acute and/or chronic inflammation including saponification of these tissue planes, making dissection tedious, bloody, and potentially hazardous. If the anatomy is difficult to discern, an intraoperative cholangiogram can be very helpful. This can be performed in the usual manner at the cystic duct using Omnipaque 300 and fluoroscopy. A 5-Fr infant feeding tube is used to cannulate the cystic duct, and real-time fluoroscopy can identify the anatomy and help resolve any anatomic questions.

GALLBLADDER AND ARTERIAL DISSECTION

- Mobilization of gallbladder—"top-down approach": Once the self-retaining retractor is in place and the anatomic field is identified in general terms, the gallbladder is mobilized from the fundus down to the cystic duct/cyst junction. The cystic duct and gallbladder are dilated. The cystic artery is identified and traced back to the right hepatic artery (RHA) or its origin. The gallbladder is then available for traction and can be rotated medially to facilitate exposure and identification of the portal vein (PV), posteriorly. **FIGS 6** and **7** demonstrate the dissection

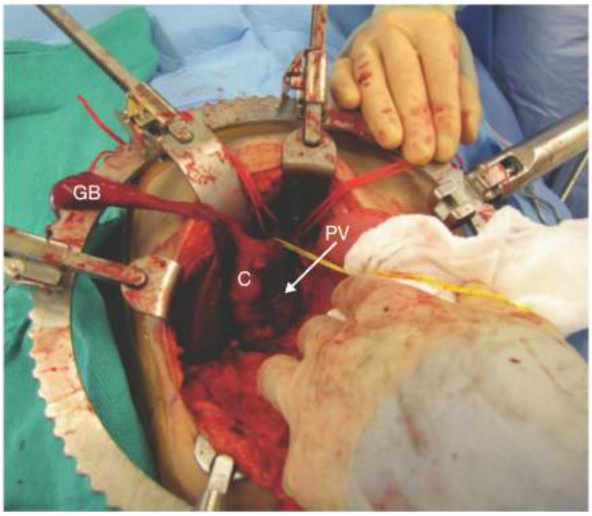

FIG 6 ● This intraoperative photograph (type I cyst MRCP in **FIG 3**) demonstrates the circumferential dissection of the cyst (yellow vessel loop, *C*), with the RHA and LHA looped *(red)*. The gallbladder *(GB)* has been completely mobilized and the duodenum Kocherized. The cyst is partially dissected posteriorly from the portal vein *(PV)*.

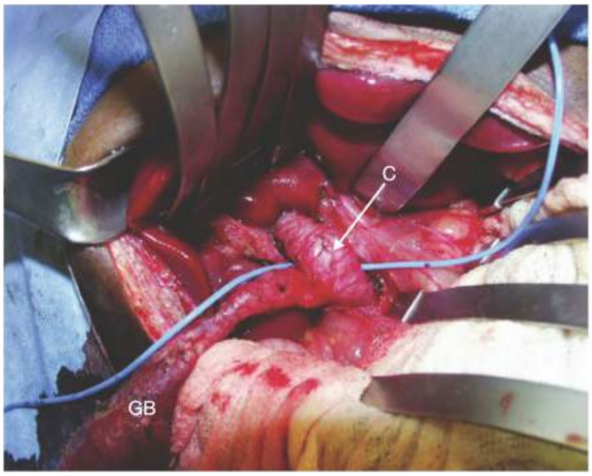

FIG 7 ● This intraoperative photograph of another type I cyst *(C)* demonstrates using the same operative approach of gallbladder *(GB)* mobilization and circumferential dissection of the cyst cephalad to the cystic duct confluence (blue vessel loop). The duodenum is completely Kocherized and under the retractor/laparotomy pad. There is minimal inflammation in this case.

of the gallbladder and circumferential dissection of the cyst in separate patients.

- RHA identification and further dissection of hepatic artery and left hepatic artery (LHA): Once the RHA is identified, the hepatic arterial anatomy can be dissected off of the cyst. The ease of this dissection is dependent on the degree of pericystic inflammation. Vessel loops can be placed around the hepatic arteries, and then, the dissection can proceed directly on the cyst wall anterior and lateral to the artery.

CIRCUMFERENTIAL DISSECTION OF CYST

- Typical approach: The goal of the dissection is a radical excision of the complete cyst from the level of the confluence of the hepatic ducts to the junction with the pancreatic ducts distally. To achieve this, the arterial anatomy is isolated anteriorly as described in the previous text, and then the back wall of the cyst is dissected free from the PV. Identify the PV just before it bifurcates, and circumferentially dissect on the undersurface of the cyst until the cyst is encircled with an umbilical tape or vessel loop. Dividing the cyst at the confluence of the right and left ducts allows anterior traction on the cyst and provides exposure of the anterior aspect of the PV as the dissection is carried distally toward the superior mesenteric vein (SMV). Once the cyst is off of the PV and divided proximally, then the biliary tree is retracted anteriorly as dissection directly on the cyst wall toward the junction with the pancreatic duct.
- Alternative approach: In the setting of extensive pericystic inflammation that obscures the anatomy and precludes safe circumferential dissection, Lilly[4] described an alternative approach of intramural dissection that leaves the posterior wall in place, akin to abdominal aortic aneurysm repair. The cyst is opened transversely, and the plane within the cyst wall that allows separation of the mucosa from the thinner exterior cyst wall is developed. There are numerous perforating small vessels that can be controlled with cautery. This dissection proceeds superiorly and inferiorly, leaving the back wall in place and adherent to the PV. This approach allows removal of all of the potentially malignant mucosa and prevents the potential catastrophic complication of injury to the PV.

CYST EXCISION

- Level of distal resection: As the cyst is circumferentially dissected down toward the pancreas, it invariably tapers down to a narrow neck. Preoperative imaging provides guidance as to the site of the confluence with the pancreatic duct; it can be quite high in cases of pancreatic–biliary malunion. This dissection typically dives into the head of the pancreas and it is critical to stay directly on the cyst wall for the dissection and not inadvertently violate the pancreatic duct—a catastrophic error that invariably leads to pancreatic fistula. **FIG 8** demonstrates the upward traction on the divided extrahepatic biliary tree and dissection down to the distal end of the cyst. Once the distal extent of the cyst is determined, it is divided at this level and oversewn with monofilament suture (3-0 or 4-0 Prolene), using care to preserve the pancreatic duct.

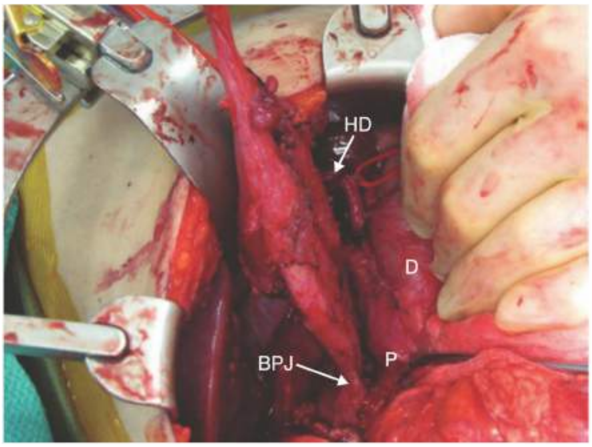

FIG 8 ● This intraoperative photograph demonstrates the extrahepatic biliary tree retracted anteriorly, after the proximal cyst has been divided at the junction of the confluence of the hepatic ducts *(HD)*, and the gallbladder is used as the point of traction. The duodenum *(D)* is fully Kocherized, exposing the posterior aspect of the pancreas *(P)*, and the red vessel loop is on the LHA. Stay sutures are on the transected duct. The cyst is tapering down to the junction with the pancreatic duct in an intrapancreatic position *(BPJ)*. The transition to an intramural dissection is noted on the anterior wall of the cyst halfway down the dissection.

BILIARY-ENTERIC RECONSTRUCTION

- Typical approach: retrocolic Roux-en-Y hepaticojejunostomy—The standard approach is to create a 40-cm Roux limb that originates 10 cm from the duodenojejunal junction. This is illustrated in the drawings in **FIG 9** and the initial anastomosis is shown in photographs in **FIG 10**.
- Numerous techniques are commonly used for the jejunojejunostomy. Most pediatric surgeons prefer an end (proximal jejunum) to side (distal jejunum), two-layered, hand-sewn anastomosis in older children. The inner row of sutures is placed using 4-0 Vicryl and hemi-Connell technique and the outer row thrown using Lembert technique and using 3-0 silk. In infants/small children, a single-layer anastomosis of interrupted 5-0 or 4-0 Vicryl is most often employed.
- The end of the Roux limb is closed in two layers and then brought through a defect created in the transverse mesocolon, just to the right of the middle colic vessels. The antimesenteric side of the Roux limb is used for the anastomosis to the confluence of the hepatic ducts.

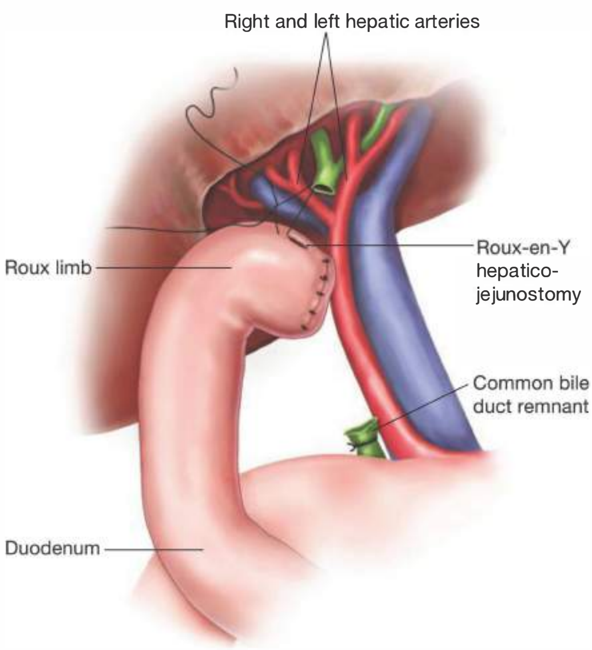

FIG 9 ● This drawing is a schematic diagram of the Roux-en-Y hepaticojejunostomy. The side jejunotomy is matched to the size of the hepatic duct, leaving a small distance of "j" configuration to the limb. This is not left more than a few centimeters to prevent sumping of bile, as this will grow with the child.

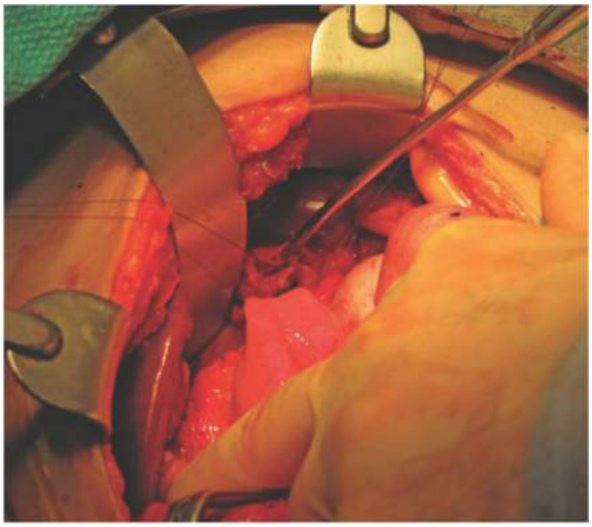

FIG 10 ● This is an intraoperative photograph of the Roux limb on stay sutures at 3 o'clock and 9 o'clock positions and the suction tip in the hepatic duct confluence. The duct was irrigated with saline to ensure no debris/stones were in the proximal ducts. After the sutures were laid in the back wall of the anastomosis, it was "parachuted" down, and then the anterior row was completed.

Interrupted 4-0 or 5-0 polydioxanone (PDS) or equivalent monofilament, absorbable sutures are placed to create a single-layer anastomosis. This should be tension free and care should be taken to ensure that the limb is not kinked or twisted in the final anatomic configuration. **FIG 11** demonstrates a completed anastomosis. The limb is secured to the mesocolic defect with interrupted sutures and the mesenteric defect of the jejunal anastomosis is closed as well.

- In cases that are complicated due to multiple previous bouts of pancreatitis and/or cholangitis, most surgeons prefer to leave a drain; in straightforward cases (usually the infantile forms), most omit the drain. Admittedly, there are no data to support either approach.
- Alternative approach: hepaticoduodenostomy—The group at Children's Hospital of Philadelphia has presented an alternative to the Roux-en-Y reconstruction, using a direct hepaticoduodenostomy.[5] The rationale for this approach is that there is a more physiologic end point for bile drainage and a simpler reconstruction. In their hands, the operations were shorter by approximately 1 hour, and there were fewer complications requiring reintervention. The long-term follow-up is not yet available. Of note, these patients were selected and not randomized patients with hepatico-duodenostomy being used in those patients in whom there would not be a tension at the anastomosis.
- Other approaches: There have been a number of other reconstructive options forwarded by others, such as valved Roux-limb conduits to the duodenum or use of the appendix as a pedicled graft.[6] These approaches are unnecessarily complex and in the case of the appendix, have worse long-term outcomes.

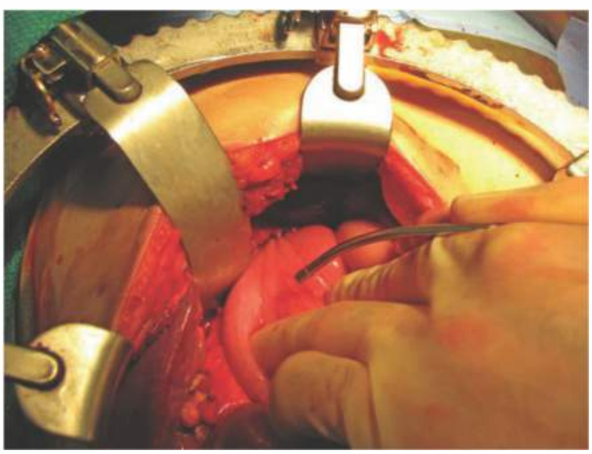

FIG 11 ● The completed hepaticojejunostomy is in the proper anatomic orientation.

LAPAROSCOPIC APPROACH

- The laparoscopic approach to choledochal cyst excision and reconstruction has been described by numerous authors. Monitor positioning and port placement are shown in **FIG 12**.
- The laparoscopic technique is much more amenable to the patient who has not experienced multiple bouts of cholangitis/pancreatitis.
- Unlike the open procedure, the gallbladder is divided at the cystic duct and then it is used to retract cephalad to expose the cyst/porta hepatis; the gallbladder is removed at the conclusion of the procedure.
- The procedure is otherwise performed in the sequence of events as described in the previous text. The hepatic flexure is mobilized to facilitate a Kocher maneuver. The cyst dissection is as described for the open approach starting with cephalad, superior exposure of the cyst and subsequent dissection of the vessels from proximal to distal.
- The jejunojejunostomy can be performed via an extended umbilical incision in infants to allow an extracorporeal jejunojejunal anastomosis.
- Early results are similar between open and laparoscopic cases.

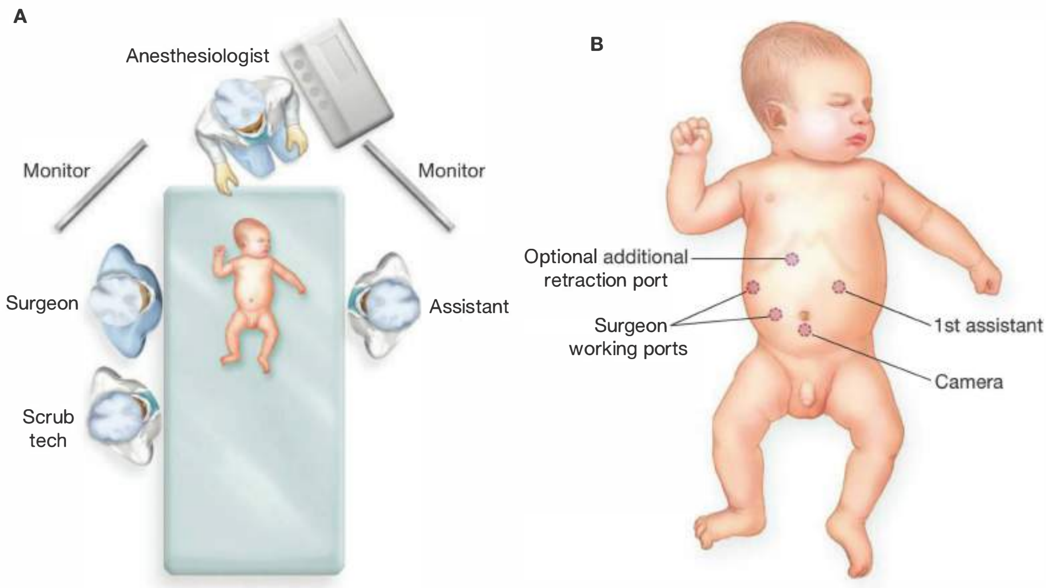

FIG 12 ● Laparoscopic approach: display arrangement and port placement. **A.** The surgeon is positioned on the patient's right side with a monitor over the patient's left shoulder. **B.** A 5-mm umbilical port and 30-degree camera are employed. Two subsequent ports are placed in the right midabdomen as shown. Another left-sided port is placed in the midclavicular line above the umbilicus; this is the right-handed working port of the assistant. An optional retraction port is in the right upper quadrant, below the costal margin in the midaxillary line.

OTHER CYST TYPES (II, III, V)

- Type II: The type II cyst is a diverticulum of the CBD. This configuration, especially with a long, narrow neck, is most amenable to a minimally invasive approach.[7] Most surgeons recommend removal of the gallbladder at the same operation.
- Type III: The type III cysts or choledochoceles are more complex procedures that are best addressed by transduodenal resection and sphincteroplasty. Once the duodenum is fully Kocherized, it is opened transversely along the antimesenteric border. The intraduodenal, stenotic ampulla is cannulated and opened. An intraoperative cholangiogram is useful, at times, and usually best done through the openings of the bile duct and pancreatic duct via the duodenum. Excision and then reapproximation of the duct to duodenal mucosa with 5-0 or 6-0 Vicryl is standard. This can be done over a calibrating stent of a 5- to 7-Fr catheter. The intrapancreatic lesions should be managed with internal drainage, and conceivably, this could not be accomplished and require a pancreaticoduodenectomy. The gallbladder is traditionally removed at the same operation.
- Type V: Caroli's disease is characterized by unilateral or bilateral cystic dilation of the intrahepatic biliary tree. This is surgically treated by lobectomy if there is disease isolated to a single anatomic lobe. Palliation is often done by interventional radiology by dilation of multiple strictures and stone retrieval. Liver transplantation may be required to effectively treat this problem.

PEARLS AND PITFALLS

Timing of operation	■ Delaying operation in the infantile form can potentially allow biliary cirrhosis to progress due to either stasis or biliary atresia misdiagnosis. Operation by 6 weeks of age should mitigate this risk and allow any other comorbidities to be addressed. ■ Operating during acute pancreatitis in the noninfantile form can increase the difficulty of dissection and lead to increased complications such as vascular injury and anastomotic leak.
Cyst excision	■ Too distal of a dissection with a high union of the pancreatic duct to the CBD/cyst can result in pancreatic duct injury or ligation. Appreciation of preoperative imaging with the pancreaticobiliary malunion (PBM) in mind can avoid this complication.
Biliary-enteric reconstruction	■ Ensure proper anatomic orientation of the Roux limb. Disorientation can create a loop of proximal jejunum–hepatic duct anastomosis or kinking of a properly corrected Roux limb.

POSTOPERATIVE CARE

- The postoperative care of the patient who undergoes resection of a choledochal cyst is similar to many patients undergoing major hepato-pancreato-biliary operations. As stated in the preoperative management, we use nasogastric decompression early in the perioperative period (usually 48 hours) and epidural analgesia with a combination of narcotic/local anesthetics. The postoperative pain management is augmented with scheduled intravenous Toradol and/or acetaminophen. No prophylactic, postoperative antibiotics are given. With return of bowel function, diet is slowly advanced. Serum chemistries (bilirubin, amylase/lipase) are followed in the first few days to ensure progressive decline.
- If present, the drain posterior to the hepaticojejunostomy is monitored for the character and volume of the output. Once the patient is tolerating a diet, and the drain effluent is serous, then the drain is removed prior to discharge.
- Some surgeons maintain these patients on suppressive antibiotics against cholangitis as with biliary atresia.
- Postoperative follow-up is at 2 weeks as part of routine care. Long-term follow-up is every 3 months for year 1, then annually in asymptomatic patients. This includes monitoring of serum liver enzymes (aspartate aminotransferase [AST], alanine aminotransferase [ALT], γ-glutamyltransferase [GGT]), bilirubin, and amylase/lipase. Patients with elevations in their chemistries or clinical symptoms will undergo either a screening ultrasound with a focus on intrahepatic dilation or possibly a hepatobiliary iminodiacetic acid (HIDA) scan to evaluate functional bile excretion into the Roux limb. If there is a question about the Roux limb, a CT scan of the abdomen may be helpful. The long-term issue is related to anastomotic stricture and/or late stone formation as the etiology of the obstructive symptoms.

OUTCOMES

- The long-term outcomes for the surgical resection of choledochal cyst with Roux-en-Y hepaticojejunostomy are excellent (symptom free and overall survival over 90%).

The historical issue of malignancy and high rates of cholangitis/stones (90%) due to retained cysts has largely been eliminated due to the approach of complete excision and reconstruction, although there are rare cases after cyst excision. These cases probably represent incomplete excision of proximal or distal margins of the cyst. In broad terms, 2% to 10% of patients develop intrahepatic stones as follow-up goes out to 20 years. Stone formation can be associated with cholangitis, stricture, or both.

COMPLICATIONS

- Hemorrhage: PV or branches of the hepatic artery
  - Hepatic artery anastomotic leak pancreatitis
  - Late stricture
    - Cholangitis
    - Recurrent stones
  - Adhesive bowel obstruction

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Chapter 14

Operative Treatment of Biliary Atresia

Charles S. Cox, Jr. *Robert Hetz*

DEFINITION

- Biliary atresia is an inflammatory process of unknown etiology that results in obliteration of the extrahepatic bile ducts in newborn infants. The incidence of biliary atresia is quoted as 1 per 10,000 live births, which in most U.S. referral centers should translate into approximately 4 to 5 cases per year.
- The Japanese Society of Pediatric Surgeons has classified the anatomic configurations of biliary atresia (**FIG 1**). The most common pattern is obliteration of the ducts from the porta to the common bile duct (CBD) (type I).
- Other variants not shown include fibrotic ducts and porta with a patent gallbladder and distal CBD.

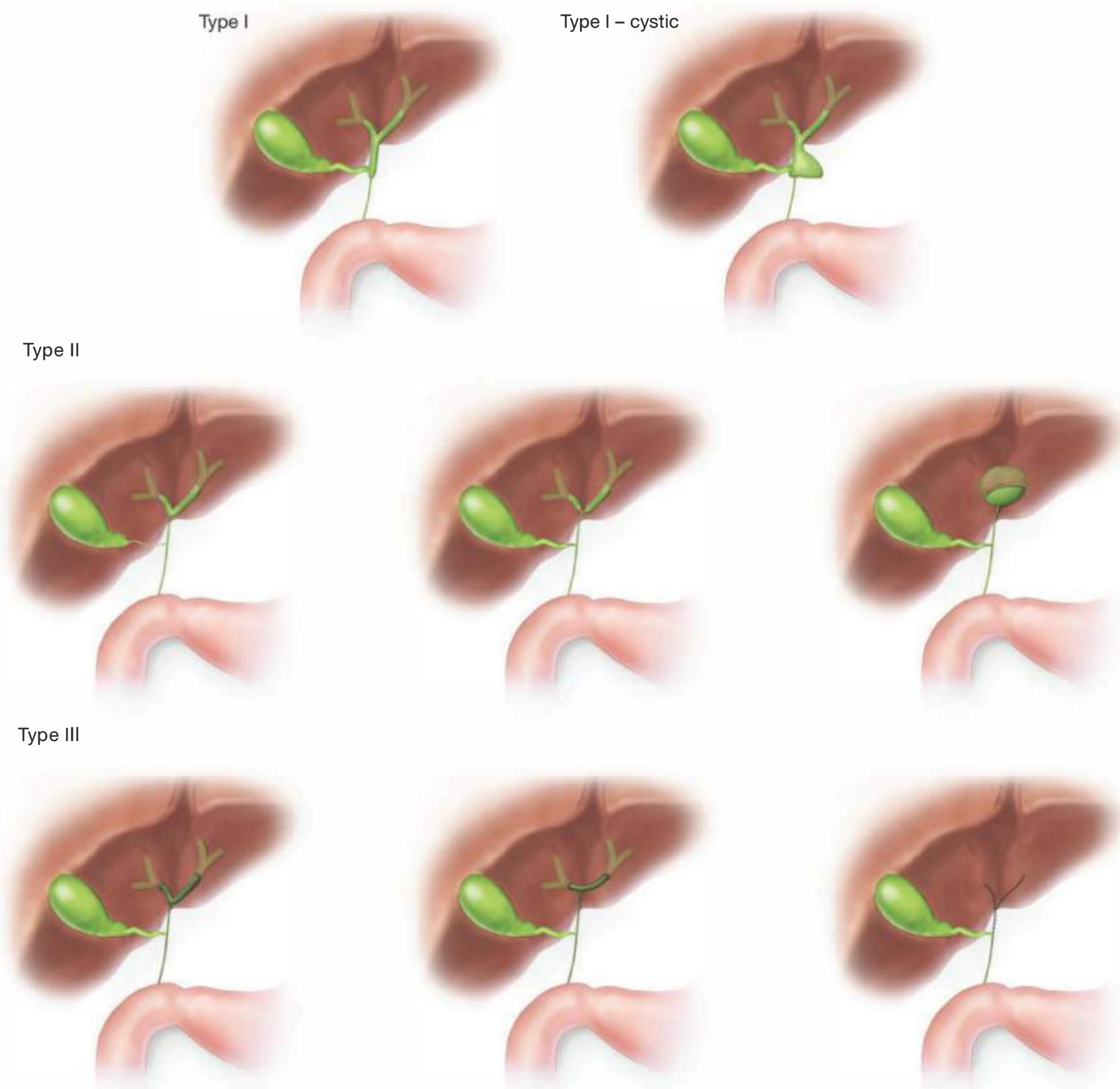

FIG 1 ● Classification of biliary atresia. Type I is associated with atresia at the level of the CBD; in type II, the atresia is at the level of the hepatic duct; in type III, atresia occurs at the porta hepatis.

- The "surgically correctable" form of biliary atresia is rare (10% of cases). In this situation, there is patency of a proximal segment of hepatic and/or common duct.

DIFFERENTIAL DIAGNOSIS

- The differential diagnosis of a mixed hyperbilirubinemia in an infant includes the following:
  - Biliary atresia
  - Neonatal hepatitis
  - α1-Antitrypsin deficiency
  - Other metabolic deficiencies
  - Alagille's syndrome (biliary hypoplasia, pulmonary stenosis, vertebral anomalies, and elfin facies)
  - Choledochal cyst

PATIENT HISTORY AND PHYSICAL FINDINGS

- Infants are usually referred at approximately 6 to 8 weeks of age, placing a premium on rapid evaluation, diagnosis, and scheduling of operation. They typically present for evaluation of a mixed hyperbilirubinemia and the primary physical findings are jaundice and hepatomegaly. They also have acholic stools and dark urine.

IMAGING AND OTHER DIAGNOSTIC STUDIES

- Laboratory: The hallmark of the laboratory evaluation is a mixed hyperbilirubinemia. Investigations will be focused on excluding neonatal hepatitis, metabolic diseases, and α1-antitrypsin deficiency.
- Nuclear medicine: Technetium-based hepatobiliary scans are often used in the evaluation of infants with a mixed hyperbilirubinemia. Pretest preparation with phenobarbital for 3 to 5 days is useful. Visualization of the tracer in the duodenum/small intestine excludes biliary atresia. Slow uptake is indicative of a global hepatocyte dysfunction.
- Ultrasound: Imaging is usually supportive of the diagnosis of biliary atresia but is not definitively diagnostic. Usually, there is a thickened, contracted gallbladder and difficulty visualizing the extrahepatic biliary tree.
- Percutaneous liver biopsy: Recently, percutaneous needle biopsy has become one of the most definitive diagnostic tests in the evaluation of biliary atresia. The histologic appearance is that of any bile duct obstruction: portal tract edema and fibrosis, bile duct proliferation, and stasis. Mimics of biliary atresia are giant cell hepatitis, as it has some similar findings, most notably multinucleated giant cell infiltrates that can also occur with biliary atresia. Similar findings occur with Alagille's syndrome, which is characterized by biliary hypoplasia but associated with a characteristic elfin facies, pulmonary stenosis, and vertebral anomalies.

SURGICAL MANAGEMENT

- An important issue in the surgical management of patients with biliary atresia is the timing of the operation. In general terms, earlier is better. Results are better if the operation is performed before the infant reaches 6 weeks of age. Portoenterostomy may be reasonable up to 120 days of age, recognizing that the prognosis declines rapidly with delayed intervention.

Preoperative Planning

- Ensure that there is no coagulopathy. If present, must be treated with vitamin K (phytomenadione, 1 mg per day intramuscularly) and/or fresh frozen plasma replacement. Typically, a central vascular catheter or arterial line is not necessary. Epidural catheter anesthesia is a useful adjunct to intra- and postoperative pain management. A second- or third-generation cephalosporin should be administered prior to incision and continued until transition to oral cholangitis prophylaxis can be achieved.

Positioning

- The patient is placed in the supine position. A small towel roll is positioned transversely under the patient at the level of the lower chest/abdomen.

TECHNIQUES

- The authors recommend proceeding directly to an open exploration and cholangiogram. If positive, a classic Kasai portoenterostomy biliary drainage procedure is performed. The use of a laparoscopic approach has been associated with significantly worse outcomes.[1,2]

INCISION

- Initially, a small right-sided subcostal incision is made to perform the cholangiogram and then extended to facilitate the procedure once confirmation of the diagnosis has occurred. (**FIG 2**).

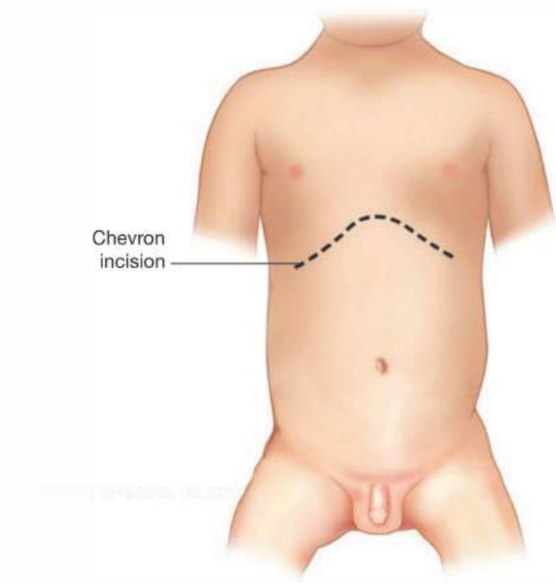

FIG 2 ● Incision. A modified hemi-chevron incision is used. Some centers use a more limited right subcostal incision, but to fully mobilize the liver requires a larger incision.

CHOLANGIOGRAM

- The gallbladder is identified; it is usually small and contracted with clear or milky bile in the lumen. A purse-string suture of 5-0 silk on a TF needle (or equivalent) is used and a cholecystotomy is made of a size to admit a 5-Fr infant feeding tube (**FIG 3**). Nondiluted Omnipaque 300 is injected under fluoroscopic visualization. If there is no visualization of the intrahepatic biliary tree, the distal porta hepatis should be occluded to promote visualization of the proximal hepatic ducts. If there is nonvisualization of the intrahepatic biliary tree, this typically confirms the diagnosis of biliary atresia.

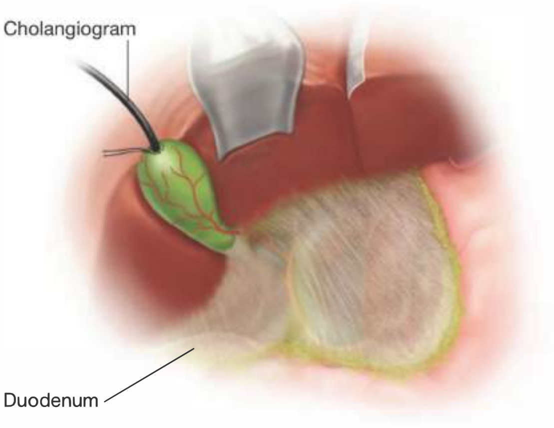

FIG 3 ● Intraoperative cholangiogram. A 5-Fr infant feeding tube is used to cannulate the dome of the gallbladder via a purse-string suture. Omnipaque 300 is used as a full-strength contrast agent to visualize the extrahepatic biliary tree. Aspiration of clear bile usually is indicative of biliary atresia. It can be difficult to be certain that the cannula is truly within the lumen of the gallbladder.

LIVER BIOPSY

- With more liberal use of percutaneous biopsy, there is little need for a redundant biopsy at the time of portoenterostomy. However, a classic biopsy that provides a larger sample is often informative regarding degree of liver injury and is essential when a percutaneous biopsy has not been obtained. This is performed as depicted in **FIG 4**. Using a 2-0 chromic suture on an SH or equivalent needle, two mattress-type sutures are placed in a "V" configuration from which the wedge biopsy will be

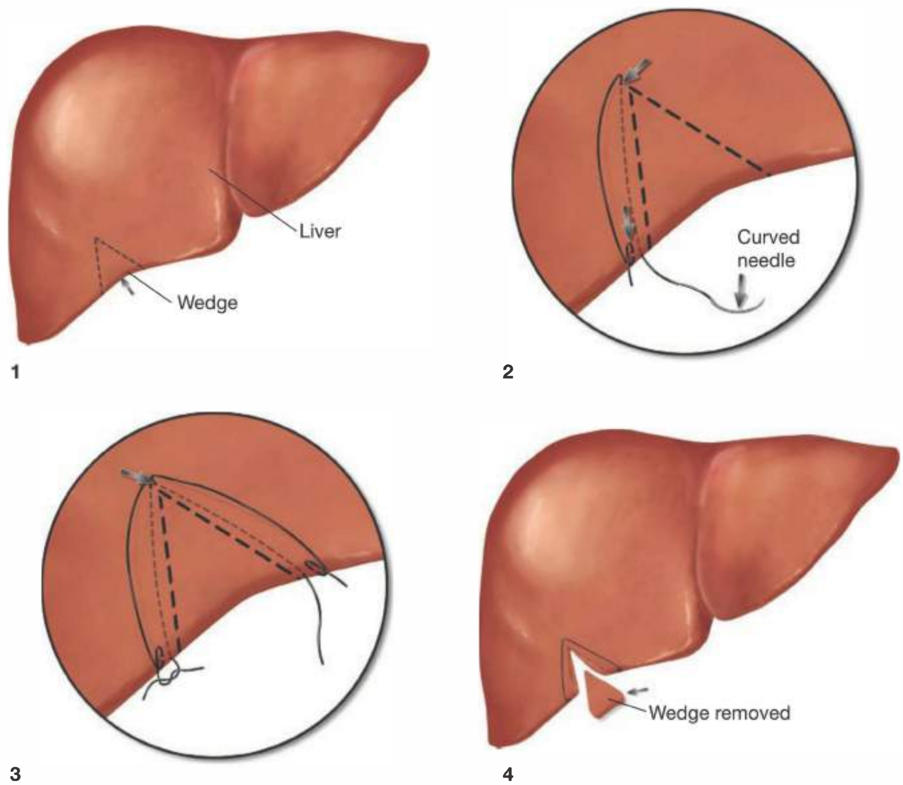

FIG 4 ● Liver biopsy. A V-shaped incision is made between two mattress sutures of 2-0 chromic that are then tied together over a Gelfoam bolster for hemostasis.

obtained. A no. 15 blade knife is used to excise a wedge of liver, and the bed is coagulated with the cautery. The tails of the chromic suture are left long and used to reapproximate the edges of the liver over a Gelfoam bolster that renders the field hemostatic. This should be done immediately after the cholangiogram to optimally ensure the site is hemostatic at the conclusion of the procedure and to prevent inadvertent omission of the biopsy following the main portion of the procedure—the portoenterostomy.

HEPATIC MOBILIZATION

- To fully expose the porta hepatis, a full mobilization of the liver is performed. Both triangular ligaments and the falciform ligament are divided, and the liver is rotated up into the wound. This is far more effective in infants and children than in adults. Laparotomy pads are placed behind the liver to maintain the exposure. However, care must be taken to not allow excessive tension to be placed on the portal vascular structures. An assistant's hand can further splay open the porta during critical elements of the dissection. Some authors have advocated against this maneuver arguing that it increases retrohepatic scarring in case of future transplantation. The authors are of the opinion that the value of optimum exposure to provide the greatest precision of the portal dissection and anastomosis outweighs the additional dissection that will be required should liver transplant ultimately be required (**FIG 5**).

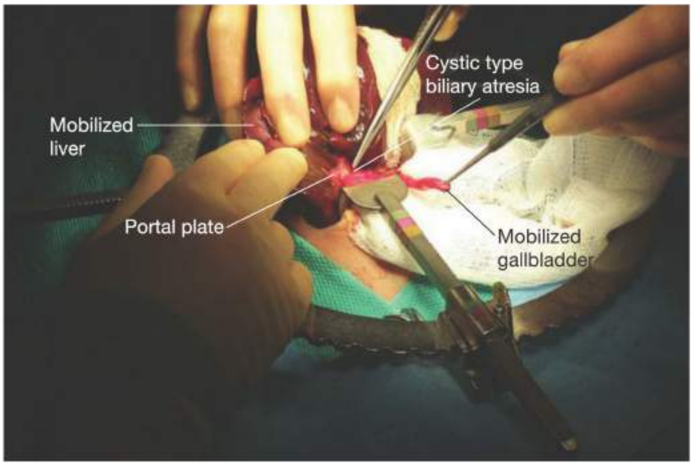

FIG 5 ● Intraoperative photographs of the hepatic and gallbladder mobilization. The left and right triangular ligaments and the ligamentum teres are all divided up to the hepatic venous hilum. This allows complete mobilization of the liver up into the incision, thus providing excellent exposure of the porta hepatis. The gallbladder is mobilized after the cholangiogram and used for a traction "guide" to the atretic extrahepatic biliary tree. The veil of peritoneum overlying the portal structures is divided with cautery and the vascular structures are identified and separated from the atretic bile ducts.

PORTAL DISSECTION

- Identification of vascular structures: The gallbladder is mobilized in a retrograde fashion using electrocautery until the cystic artery is identified. This is then traced back to the right hepatic artery. Further antegrade dissection beginning near the celiac artery trifurcation first identifies the common hepatic artery and then origin of the left and right hepatic arteries. Aberrant arterial anatomy must be considered. Expect disproportionately enlarged lymph nodes in the region. The left and right hepatic arteries should be isolated with vessel loops or 0 silk suture. Posterior and left in the porta, the anterior aspect of the portal vein (PV) is exposed.
- Division of distal extrahepatic biliary tree: With the hepatic vessels identified, the gallbladder is used for traction to dissect the posterior aspect of the atretic extrahepatic biliary tree from the vessels (**FIG 6A**). This dissection is carried distally to the head of the pancreas. The distal segment is ligated and sharply divided. The dissection is then followed proximally revealing a cone of tissue in the porta (**FIG 6B**).
- Proximal dissection: The outline of the portal plate dissection is the crescent-shaped boundary of the PV and the right and left hepatic arteries from which the atretic, extrahepatic biliary tree exits the hepatic parenchyma. As dissection enters the liver, there should be a transition from fibrotic, atretic, pale structures to softer, darker liver.
- Portal transection: The critical element of the operation is the depth and boundaries of the portal dissection. The confluence of the PV must be retracted inferiorly and the left and right branches must be retracted laterally with small tributaries ligated or cauterized (bipolar electrocautery can be useful). The entire liver plate is sharply transected either with angled scissors or a beaver-blade knife (**FIG 6C**). The optimal level is to be just at but not into the liver parenchyma. The optimal level for the portoenterostomy is represented by the virtually translucent, thin layer that is left in place. Bleeding is controlled with 1:100,000 epinephrine-soaked Gelfoam and pressure using cotton tip applicators. Very minimal needle tip/low-setting cautery can be used judiciously if absolutely necessary. The Gelfoam can be left in place and the liver returned to the abdomen as the Roux limb is created and the jejunojejunostomy performed. Some surgeons send this proximal margin of the portal dissection for specific evaluation of ductal diameter to guide further dissection and/or prognosis; however, the authors have not found this to be particularly useful intraoperative information.

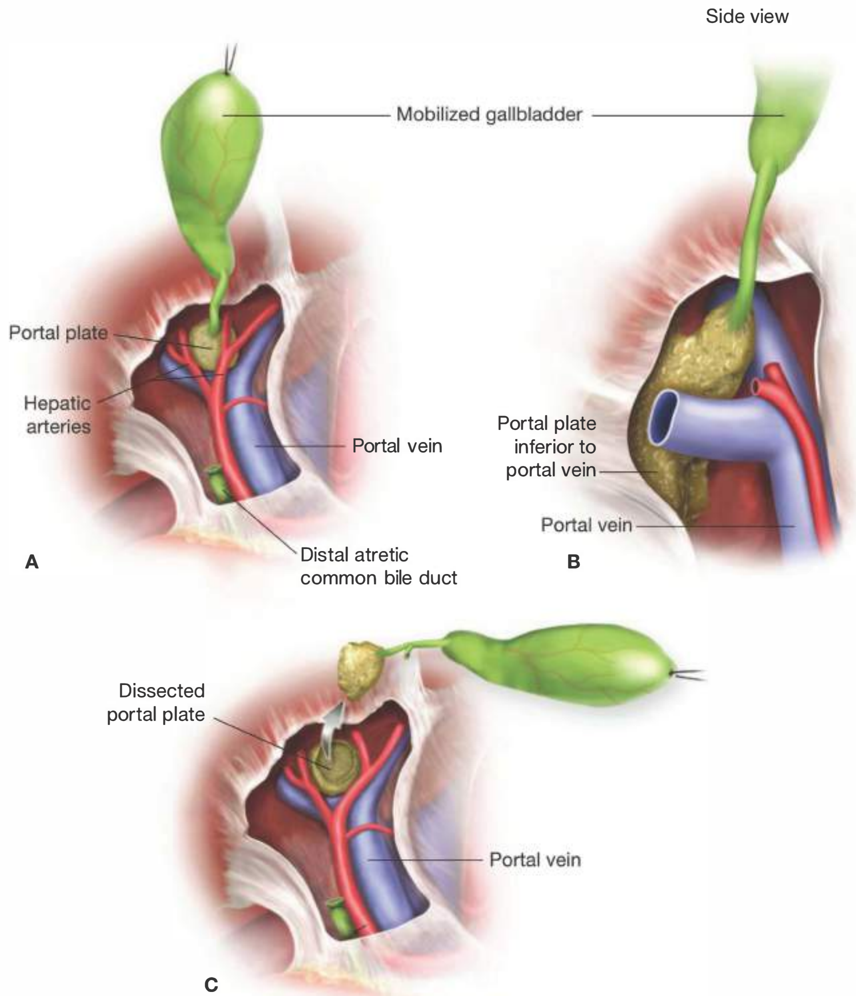

FIG 6 ● Portal dissection. The portal dissection commences once the vascular and ductal structures are identified. The CBD is divided and ligated distally, then dissected up until the tissue fans out into a conical configuration bordered by the PV inferiorly and laterally. **A.** The gallbladder is mobilized and used as traction to expose the cone of tissue at the porta. **B.** Lateral view of the dissection showing how the cone of the portal plate dips inferior to the PV confluence and why retraction down on the PV to place the posterior row of sutures is important. **C.** The dissected portal plate is transected just at the level of the liver capsule.

ROUX-EN-Y LIMB CREATION

- Retrocolic Roux-en-Y hepaticojejunostomy. The standard approach is to create a 40-cm Roux limb that originates 10 cm from the duodenojejunal junction. This is illustrated in the drawings in **FIG 7** and the initial anastomosis is shown in **FIG 8**. Numerous techniques are commonly used for the jejunojejunostomy. The authors prefer an end (proximal jejunum) to side (distal jejunum), single layer, hand-sewn anastomosis using interrupted 5-0 sutures. The end of the Roux limb is closed in two layers and then brought through a defect created in the transverse mesocolon to the right of the middle colic vessels.

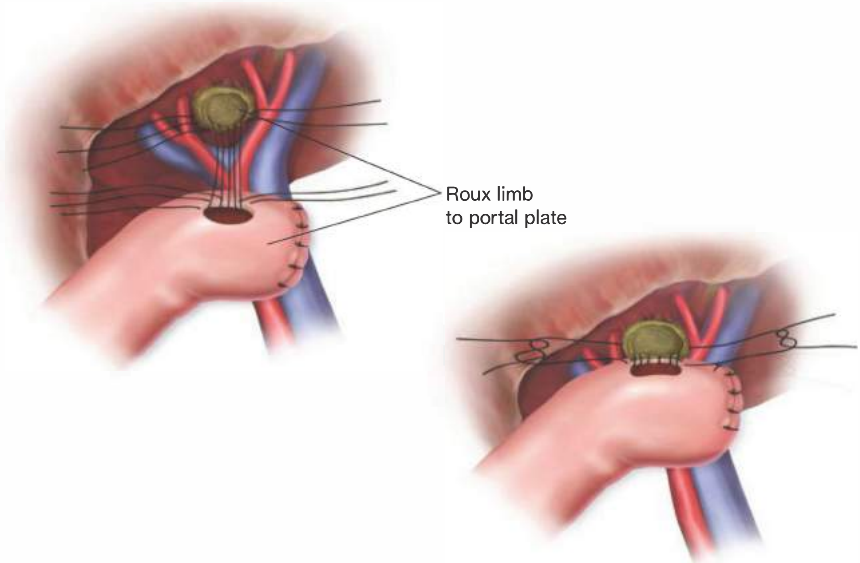

FIG 7 ● Portoenterostomy. The anastomosis is created using 5-0 absorbable monofilament sutures. The PV is retracted inferiorly and the sutures on the hepatic parenchyma/capsule are placed parallel to the PV. Knots can be inside or outside without affecting biliary drainage. The anterior row is placed with the same type of placement of suture on the hepatic parenchyma and knots on the outside.

FIG 8 ● Completed portoenterostomy. The intraoperative photograph shows a completed anastomosis at the level of the porta with a well-perfused Roux limb with a side anastomosis.

TECHNIQUES

PORTOENTEROSTOMY

- The antimesenteric border of the Roux limb is used for the anastomosis to the portal plate. Absorbable 5-0 monofilament sutures are used to create an interrupted, single-layer anastomosis (see **FIG 7**). First, the posterior row of sutures is placed in the liver capsule parallel to the porta border while inferiorly retracting the PV. This retraction maneuver minimizes the risk of occluding the plate with the edge of the anastomosis/jejunal border. The critical elements of the anastomosis are designed to capture the biliary drainage from the regions adjacent to the PV branches; these are lateral in the portal plate. To accomplish this, the hepatic capsular sutures should be oriented parallel to the PV, retracting the PV to get as far back from the site of drainage so as not to occlude these ductules with the subsequent anastomosis. The anterior suture line is then completed. **FIG 8** demonstrates a completed anastomosis. The limb is secured to the mesocolic defect with interrupted sutures, and the mesenteric defect of the jejunal anastomosis is closed as well.

PEARLS AND PITFALLS

Interpretation of cholangiogram	■ It is critical to occlude the distal CBD to ensure that potentially hypoplastic proximal ducts can fill. This avoids performing a Kasai for biliary hypoplasia.
Roux limb certainty	■ Always double check Roux limb anatomy such that distally divided jejunum is used for the limb; an error can be made by erroneously bringing proximal jejunum to the porta. Also, ensure that there is not a redundant segment that can kink as the normal anatomic position of the liver is reestablished.
Portal dissection/anastomosis	■ The critical dissection is to divide the porta just at the liver capsule to a translucent layer, behind which is the hepatic parenchyma. Do not cut into the liver as it only bleeds and increases scarring. ■ Ensure lateral dissection at the zone into which one can imagine the bile ducts exiting the liver normally. Do not allow hepatic sutures to occlude the sites of drainage; place these sutures parallel to the vessels as the PV is retracted.
Vascular injury	■ If the hepatic arteries are looped, do not allow them to stay on tension for any significant period of time; thrombosis has been reported.

POSTOPERATIVE CARE

- Standard—The postoperative care is routine. A nasogastric tube remains in place until the patient passes flatus (2 to 3 days). A small Jackson-Pratt drain can be left in Morrison's pouch, but this could easily be omitted without consequence. If present, the drain is removed once the patient is on a diet and there is no bile in the drain. Pain control is heavily augmented by an epidural catheter and allows minimization of narcotics. Avoid the use of acetaminophen or other hepatotoxic drugs.
- The most important prognostic sign is the transition of the color of the stool with a green diaper representing an excellent day for the patient and team; pigmented stools suggest successful bile flow.
- Antibiotic prophylaxis for cholangitis—Intravenous antibiotics against Gram-negative organisms are continued beyond the perioperative prophylaxis time period to minimize the risk of cholangitis. Once the patient has begun an oral diet (usually days 2 to 4), they can be transitioned to trimethoprim (TMP)-sulfamethoxazole at 2.5 mg/kg/day based on the TMP component.
- Nutritional supplementation—We routinely discharge patients with vitamins A, D, E, and K supplements.
- Steroids—The perioperative use of steroids is controversial. The rationale is that biliary atresia is a progressive inflammatory process and also has choleretic effects. Currently, approximately half of pediatric surgical centers use perioperative steroids. The Biliary Atresia Research Consortium is studying this issue; however, the results are not yet available. Davenport et al.[3] reported a hastening of jaundice resolution without an effect on transplant-free survival. Their regimen was 2 mg/kg/day of prednisolone from days 7 to 21 tapering to 1 mg/kg/day from days 22 to 28. We use a higher pulse dose and start earlier according to the schedule noted in Table 1.

Table 1: Post-Kasai Steroid Pulse-Taper Dosing Schedule

Dose	Days	Postoperative Day
10 mg/kg	1	1
8 mg/kg	1	2
6 mg/kg	1	3
4 mg/kg	1	4
2 mg/kg	1	5
1 mg/kg	7	6–12
0.5 mg/kg	7	13–19
0.3 mg/kg	7	20–26
0.2 mg/kg	7	27–33
0.1 mg/kg	7	34–40

OUTCOMES

- Early, successful biliary drainage is defined as a total serum bilirubin less than 2.0 mg/dL in the first 3 months post-Kasai. In multiple studies, the postoperative resolution of jaundice ranges from 40% to 60%. The 1-year transplant-free survival in those patients with successful drainage was approximately 50%, thus early successful bile drainage is a strong indicator of a durable operative result.[4,5]

COMPLICATIONS

- Cholangitis—This complication typically presents with fever, an acute rise in the bilirubin, and return of acholic stools. This occurs more frequently in the first 6 months post portoenterostomy, and we aggressively treat this with parenteral antibiotics against Gram negatives, a repeat steroid pulse/taper regimen, and occasionally, a brief course of phenobarbital as a choleretic. Repetitive bouts of cholangitis should be investigated with a hepatobiliary iminodiacetic acid (HIDA) scan to rule out an afferent limb obstruction as the etiology rather than failure of the portoenterostomy.
- Progressive hepatic failure/portal hypertension—Despite bile drainage, some patients develop progressive hepatic insufficiency with a normal bilirubin. Typically, this is first manifest by hepatosplenomegaly and platelet sequestration in the spleen. Ascites and growth failure typically ensue. Duplex imaging of the portal venous system should be performed to evaluate for thrombosis or hepatofugal flow in the PV. The complications of portal hypertension are usually long-term management issues (>10 years). Varices should be conventionally managed with sclerotherapy or banding as appropriate. Rarely is portosystemic shunting required, and this usually corresponds with the need for ultimate hepatic transplantation.
- Early cessation of bile flow—Portoenterostomy revision has traditionally been discouraged due to the successful results with hepatic transplantation and the assumption that reoperation would only increase the difficulty of ultimate transplantation. This issue has been recently challenged.[1] Candidates for revision of the portoenterostomy should be limited to those with initially satisfactory bile drainage, or those with recurrent cholangitis and jaundice. Revision in a select group of patients (i.e., good initial bile drainage, not primary failure of the portoenterostomy) converted these patients to similar long-term transplant-free survival as those patients with durable bile flow. It remains controversial but probably reasonable to revise the portoenterostomy in this select group of patients.

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Chapter 15 Surgical Anatomy of the Liver

Teviah Sachs Timothy M. Pawlik

SIZE AND POSITION

- The human liver is the largest internal organ in the body. It is estimated to weigh 0.2% to 0.3% of ideal body weight, or approximately 1400 to 2100 g in an otherwise healthy adult patient,[1] depending on age, sex, and various disease processes.
- The liver sits in the right upper quadrant of the abdomen, beneath the diaphragm, and is sheltered by the ribs.
- In broad terms, the liver extends from the right 5th intercostal space superiorly to the edge of the costal margin inferiorly. A liver palpable below the costal margin often is a sign of hepatomegaly.
- The left lobe of the liver extends beyond the midline and can reach as far left as midclavicular line.
- Its location relative to external landmarks is neither consistent nor static and can vary depending on patient position, individual anatomy, and respiratory cycle. This must be taken into account when performing percutaneous procedures; radiographic guidance is essential.
- Liver dimensions vary depending on age, gender, and disease states. Average dimensions are presented in Table 1.
- The right and left hemilivers are anatomically and spatially divided by Cantlie's line, which runs from the fundus of the gallbladder to the suprahepatic inferior vena cava (IVC). Within the substance of the liver, the middle hepatic vein courses along this same path and is the true division of the right and left hemilivers (**FIG 1**).

COUINAUD'S SEGMENTS

- In 1954, Couinaud[2] published his seminal work, *Le Foie: Études Anatomiques Et Chirurgicales*, in which he classified the liver into segments, each with their own inflow, outflow, and biliary drainage (**FIG 2**). He based his segments on the arborization of the portal vein within the liver. These segments begin with the caudate lobe (segment 1) and continue in a clockwise fashion from left to right.
- Couinaud[3] further divided the liver based on sectors, which are based on the arborization of the hepatic veins, each of which relies on a portal pedicle (**FIG 3**).

Table 1: Average Dimensions of the Adult Liver

Direction	Length (cm)
Anterior to posterior	10.0–12.5
Right to left	20.0–25.5
Caudad to cephalad	15.0–17.5

From Kennedy PA, Madding GF. Surgical anatomy of the liver. Surg Clin North Am. *1977;57:233–244.*

GOLDSMITH AND WOODBURNE CLASSIFICATION

- Goldsmith and Woodburne[4] divided the liver into the caudate lobe and four distinct segments:
  - Left lateral (Couinaud segments 2 and 3)
  - Left medial (Couinaud segment 4)
  - Right anterior (Couinaud segments 5 and 8)
  - Right posterior (Couinaud segments 6 and 7)

BISMUTH CLASSIFICATION

- Bismuth divided the liver based on fissures: three vertical lines corresponding to the divisions made by the three major hepatic veins.[5]
- The fourth fissure, named the transverse fissure, is based on the level of the portal vein bifurcation within the liver and divides the "upper" liver from the "lower" liver.
- Bismuth identified eight subsegments:
  - Caudate lobe (Couinaud segment 1)
  - Left superior subsegment (Couinaud segment 2)
  - Left inferior subsegment (Couinaud segment 3)
  - Left medial subsegment (Couinaud segment 4)
  - Right anterior inferior subsegment (Couinaud segment 5)
  - Right posterior subsegment (Couinaud segment 6)
  - Right posterior superior subsegment (Couinaud segment 7)
  - Right anterior superior subsegment (Couinaud segment 8)

THE BRISBANE TERMINOLOGY OF LIVER ANATOMY AND RESECTION

- Due to the confusion between various classifications, the International Hepato-Pancreato-Biliary Association (IHPBA) formed a committee in 1998 to delineate an accepted and

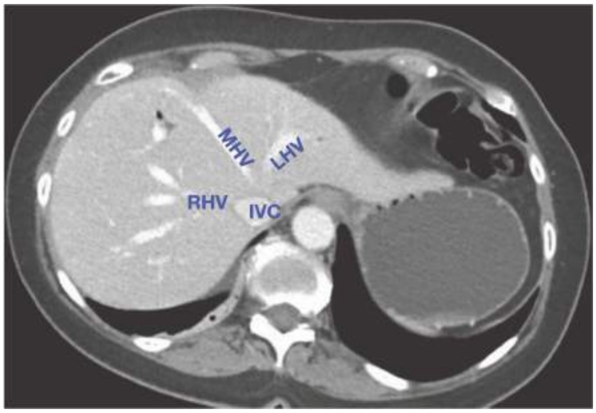

FIG 1 ● Axial CT image showing the *MHV*, which separates the right and left hemilivers. The *IVC*, left hepatic vein *(LHV)*, and the branching of the right hepatic vein *(RHV)* are also shown.

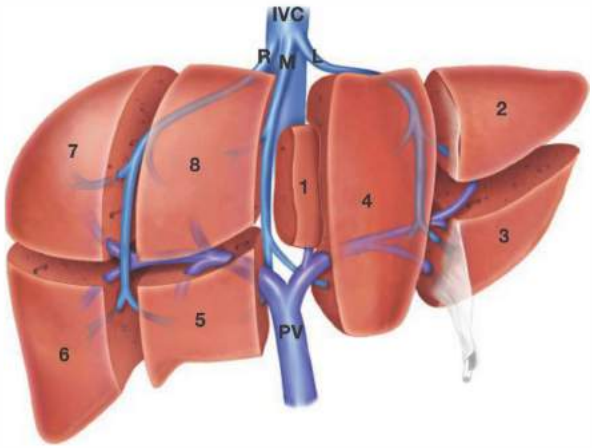

FIG 2 ● Diagram showing the segments (numbered *1* to *8*) of the liver as described by Couinaud. The *IVC* as well as the right *(R)*, middle *(M)*, and left *(L)* hepatic veins. The portal vein *(PV)* is also shown. (From Smadja C, Blumgart L. The biliary tract and the anatomy of biliary exposure. In: Blumgart L, ed. *Surgery of the Liver and Biliary Tract*. New York, NY: Churchill Livingstone; 1994:11–24.)

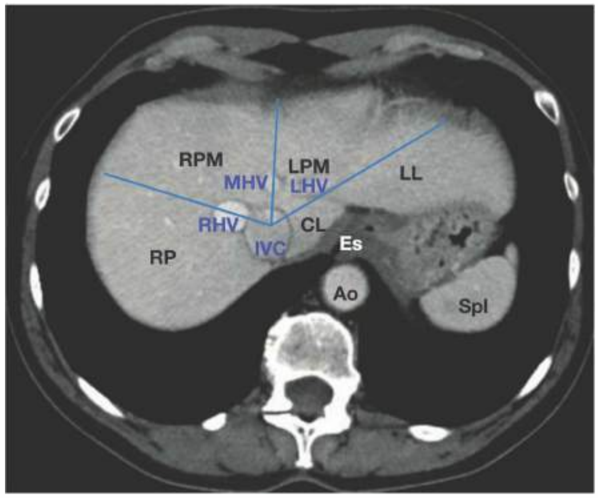

FIG 3 ● Axial CT image, venous phase, showing the right (RHV), middle (MHV), and left (LHV) as they enter the inferior vena cava (IVC). *Blue lines* show approximate direction of hepatic veins as they traverse the liver. Individual liver sectors are labeled (*RL*, right lateral; *RPM*, right paramedian; *LPM*, left paramedian; *LL*, left lateral). Also labeled are the caudate lobe *(CL)*, esophagus *(Es)*, aorta *(Ao)*, and spleen *(Spl)*.

universal terminology to describe hepatic anatomy and, more specifically, hepatic resections.[6] In 2000, their terminology was published. In it, a nomenclature for anatomic terminology and that of surgical resection were clearly delineated (Table 2).

CAUDATE LOBE

- The caudate lobe is distinct in many ways. Because of its distinct inflow, outflow, and drainage, it is sometimes termed "the third lobe of the liver."
- Embryologically, it is derived from the right lobe,[7] laying on the posterior surface of the right hemiliver, bordered on the left by the ligamentum venosus. It is bordered superiorly by the hepatic veins as they enter the IVC and posteriorly by the IVC itself. Inferiorly, it is bordered by the hilum of the liver and the bifurcation of the left and right portal veins.
- Anatomically, there are three portions to the caudate lobe (**FIG 4**), each based on the portal inflow:[8]
  - The Spiegelian lobe (or Spiegel's lobe)
  - The paracaval portion (or Couinaud's segment 9)
  - The caudate process

Table 2: The Brisbane 2000 Terminology of Liver Anatomy and Resections

Anatomical Term*	Couinaud Segments	Surgical Resection Term	Based Upon
Right Liver *Right Hemiliver*	5–8	*Right Hepatectomy* *Right Hemihepatectomy*	Midplane of liver
Left Liver *Left Hemiliver*	2–4	*Left Hepatectomy* *Left Hemihepatectomy*	
Right Anterior Section	5, 8	*Right Anterior Sectionectomy*	Hepatic artery and biliary duct divisions
Right Posterior Section	6, 7	*Right Posterior Sectionectomy*	
Left Medial Section	4	*Left Medial Sectionectomy*	
Left Lateral Section	2, 3	*Left Lateral Sectionectomy*	
Right Anterior Sector *Right Paramedian Sector*	5, 8	*Right Anterior Sectorectomy* *Right Paramedian Sectorectomy*	Portal vein divisions
Right Posterior Sector *Right Lateral Sector*	6, 7	*Right Posterior Sectorectomy* *Right Lateral Sectorectomy*	
Left Medial Sector *Left Paramedian Sector*	3, 4	*Left Medial Sectorectomy* *Left Paramedian Sectorectomy*	
Left Lateral Sector *Left Posterior Sector*	2	*Left Lateral Sectorectomy* *Left Posterior Sectorectomy*	

**Terms that include segment 1 should be stated as such (i.e., left hepatectomy extended to segment 1).*
Adapted from Strasberg SM. Terminology of liver anatomy and resections: the Brisbane 2000 terminology. In: Clavien PA, Sarr MG, Fong Y, eds. Atlas of Upper Gastro-intestinal and Hepato-Pancreato-Biliary Surgery. *Berlin: Springer; 2007:313–317.*

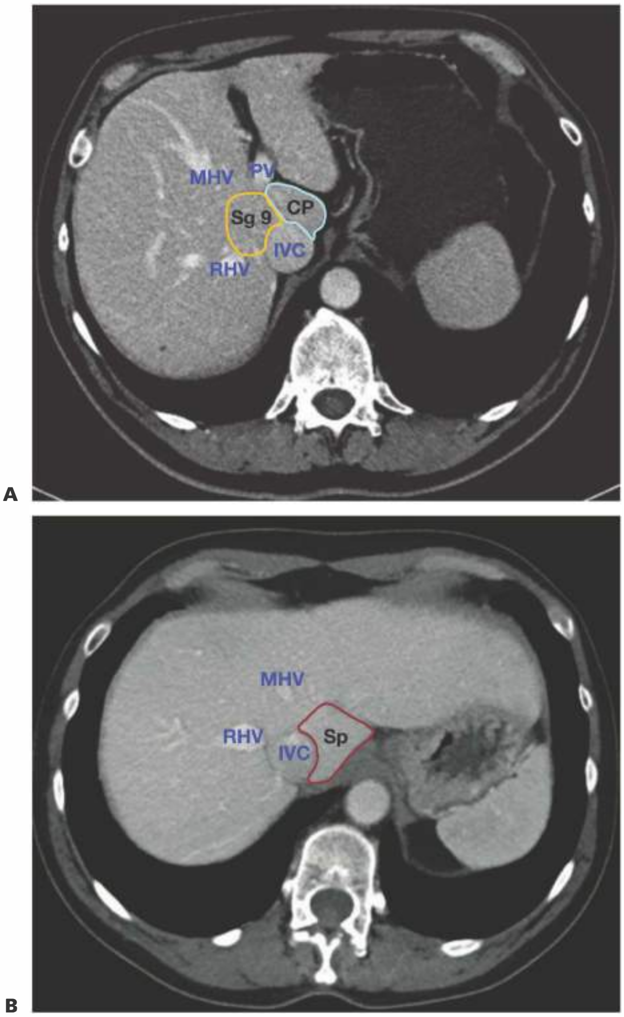

FIG 4 ● **A.** Axial CT image showing the caudate lobe. The caudate process *(CP)* is bounded by the anterolateral surface of the *IVC*, the left portion of liver hilum, and the left hepatic vein (not shown). Segment 9 *(Sg 9)* is known as the paracaval process and is bounded by the anterior surface of the *IVC*, the middle hepatic vein (*MHV*), and the right hepatic vein *(RHV)*. Also shown is the portal vein *(PV)*. **B.** Axial CT image (slightly more caudal than in **[A]**) showing Spiegel's lobe *(Sp)*—also known as segment 1—as it wraps around the medial aspect of the *IVC*.

- Surgically, the caudate can be divided in two: segment 1 (Spiegel's lobe) and so-called segment 9 (paracaval portion and caudate process) (**FIG 5**).
- The use of terminology related to Couinaud segment 9 is often dropped from the literature and this term is neither universally accepted nor used.
- The paracaval portion, which projects medially, can circumferentially wrap around the IVC.[9] This can be misinterpreted on computed tomography (CT) scan as an enlarged lymph node, and the surgeon should be aware of this to avoid inappropriate preoperative staging of a patient.
- The caudate derives its portal inflow from the left and right portal veins; venous drainage is directly into the IVC via multiple small caudate veins. Thus, in diseases of hepatic venous obstruction, such as Budd-Chiari syndrome, it will hypertrophy and provide alternate routes for obstructed hepatic venous flow.

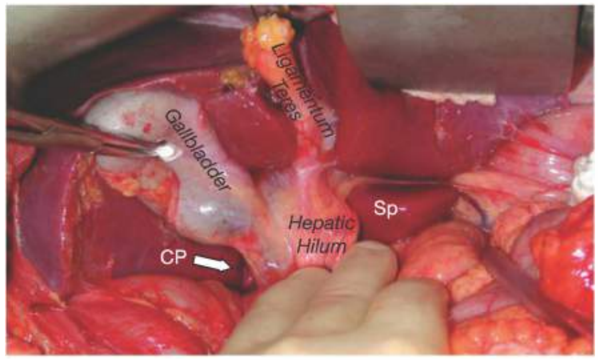

FIG 5 ● In situ photograph showing Spiegel's lobe *(Sp)* and the caudate process *(CP)* in relation to the hepatic hilum. Also shown are the gallbladder and the ligamentum teres.

SURFACE ANATOMY

- The liver is covered by a thin membrane called Glisson's capsule. This epithelial layer is contiguous with internal anatomy of the liver as sheaths around the portal veins, hepatic arteries, and bile ducts.[10]
- Despite its rounded, pyramidal shape, the liver can be described as having two surfaces: visceral and diaphragmatic.
  - The visceral surface is inferior.
  - The diaphragmatic surface can be divided into anterior, posterior, superior, and lateral aspects.
    - The anterior aspect opposes the diaphragm and the posterior abdominal wall. It is generally smooth and has few if any impressions.
    - The posterior aspect contains the bare area of the liver as well as the confluence of the hepatic veins prior to their entry into the IVC.
    - The lateral aspect opposes the right ribs 7 to 11, which often leave impressions on the liver surface.
    - The superior aspect is a continuation of the anterior surface and ends at the coronary ligament. It contains the cardiac impression and extends medially and laterally, sitting below the left and right lungs and pleura. This is clinically important as neoplasms of the dome of the liver can manifest by sympathetic effusions and diaphragmatic splinting.
- The majority of the surface of the liver is free of peritoneum, but there are several attachments and reflections of peritoneum—referred to as ligaments—that suspend the liver in its position.
  - Failing to properly understand these attachments can lead to injury to the associated visceral organs or the diaphragm.
- The falciform ligament is a bileafed peritoneal reflection, which envelops the ligamentum teres.
  - The ligamentum teres, or round ligament, is the remnant of the umbilical vein.
  - After enveloping the ligamentum teres, the peritoneum attaches anteriorly and superiorly to the posterior abdominal wall, tethering the liver slightly to the right of the midline.

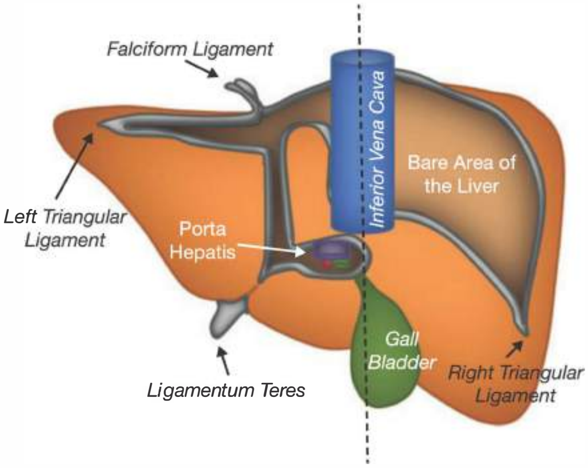

FIG 6 ● Posterior view, depicting the peritoneal reflections constituting the ligaments of the liver. Note the bare area at the caudal posterior surface of the liver. Also note the relative length of the left triangular ligament as compared to the right triangular ligament. The *dotted line* represents Cantlie's line, which divides the right and left hemilivers.

- Posteriorly and inferiorly, the ligamentum teres enters the liver between segments 3 and 4, whereas, in utero, the umbilical vein drains into the left portal vein.
- Although technically obliterated early in life, the umbilical vein recanalizes in cirrhotics and other patients with portal hypertension and must be carefully controlled when divided.

- The ligamentum venosus, also known as Arantius' ligament, in which the remnant of the ductus venosus lies, sits between the caudate lobe (segment 1) and the left lobe of the liver.
  - It forms a bridge between the left portal vein and the left hepatic vein, or sometimes to the junction of the left and middle hepatic veins. This can be very useful in locating the left hepatic vein during hepatic resection.
- The coronary ligament is the reflection of the visceral peritoneum as it attaches to the diaphragm. This creates a fibrous peritoneal ring or crown (Latin: *corona*) around the caudal posterior surface of the right hemiliver, encircling the bare area of the liver (**FIG 6**).
  - The bare area is so named because there is nothing between the liver and the diaphragm other than loose areolar tissue.
  - As the coronary ligament makes a sharp turn at the right posterior lateral edge of the liver, it creates an acute angle and is called the right triangular ligament.
  - On the left, the anterior and posterior edges similarly combine to form the left triangular ligament, which is longer and suspends the left lobe from the diaphragm.
- Visceral ligaments include the hepatorenal, gastrohepatic, and hepatoduodenal ligaments (**FIG 7**).
  - The hepatorenal ligament reflects off of the right coronary ligament posteriorly and inferiorly and then again off the right adrenal gland and superior pole of the right kidney.
  - The gastrohepatic ligament is a reflection off of the lesser curve of the stomach and the left coronary ligament inferiorly.
  - The gastrohepatic ligament is contiguous with the hepatoduodenal ligament, in which the porta hepatis runs, and together they form the lesser omentum.

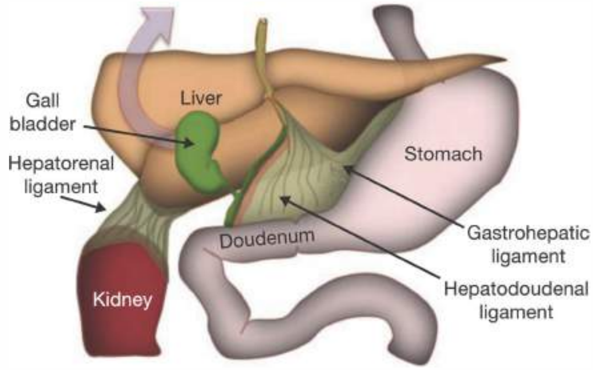

FIG 7 ● Diagram showing the attachments of the gastrohepatic, hepatoduodenal, and hepatorenal ligaments. The free edge of the liver is rotated superiorly as depicted by the *arrow*. The gastrohepatic and hepatoduodenal ligaments are contiguous.

BLOOD SUPPLY

- The liver has a dual blood supply, the hepatic artery and the portal vein, which equally provide the liver with oxygen.
- The portal vein supplies the liver with approximately 75% of its blood volume and the remainder is supplied by the hepatic artery.

Hepatic Arteries

- The common hepatic artery comes directly off the celiac trunk and gives rise to the right gastric and gastroduodenal arteries before becoming the proper hepatic artery (**FIG 8**).
- The proper hepatic artery travels within the hepatoduodenal ligament. It is spatially anterior to the portal vein and medial to the common bile duct. It divides into right and left hepatic arteries prior to entering the porta hepatis.
- The cystic artery most commonly comes off the right hepatic artery but can come off the proper hepatic artery or left hepatic artery, making misidentification of this structure a risk during cholecystectomy or other operations.

Right hepatic artery

- The right hepatic artery is generally longer than the left and follows a slightly more oblique angle, curving toward the

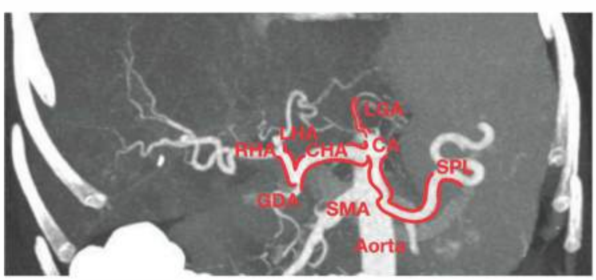

FIG 8 ● CT angiogram showing classic arterial anatomy. The common hepatic artery *(CHA)* and splenic artery *(SPL)* come off of the celiac axis *(CA)*. The CHA then gives off the gastroduodenal artery *(GDA)* and becomes the proper hepatic artery. This then divides into the right *(RHA)* and left *(LHA)* hepatic arteries. The *aorta* is also labeled, as is the left gastric artery *(LGA)* and the *SMA*.

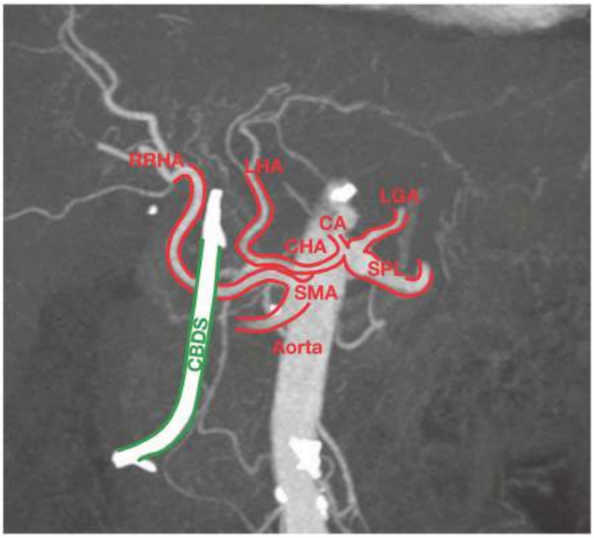

FIG 9 • A CT angiogram showing a replaced right hepatic artery *(RRHA)* coming off the *SMA*. A stent *(CBDS)* is seen in the common bile duct, which shows the anatomical relationship of the RRHA as it passes behind the common bile duct and portal vein (not shown).

neck of the gallbladder before arching again toward the posterior sector.[11] Due to its meandering course, it can be injured during cholecystectomy or misinterpreted as the cystic artery and ligated.

- After arching toward the gallbladder, it bifurcates intrahepatically into anterior (supplying segments 5 and 8) and posterior (supplying segments 6 and 7) sectoral branches. These, in turn, branch inferiorly and superiorly, to form the individual segmental branches.

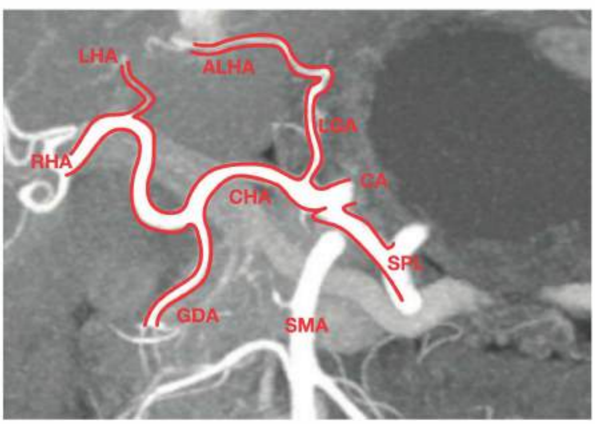

FIG 10 • CT angiogram showing an accessory left hepatic artery *(ALHA)* coming off of the left gastric artery *(LGA)*. The right hepatic artery *(RHA)* is seen coming off in normal anatomic position, from the common hepatic artery *(CHA)* just after it gives off the gastroduodenal artery *(GDA)*. The true left hepatic artery *(LHA)* is also seen, although it is far less pronounced than the RLHA which is the dominant arterial supply to the left hemiliver. Also shown are the following: *SMA*, celiac axis *(CA)*, and splenic artery *(SPL)*.

- In up to 20% of patients, the right hepatic artery has a variable anatomy.[12,13] The most common variant is the replaced or accessory right hepatic artery (**FIG 9**), which originates from the superior mesenteric artery (SMA), traveling posterior to the portal vein.
- The pancreatobiliary surgeon must always be cognizant of this aberrant anatomy.
- In approximately 10% of patients, the right hepatic artery will cross anterior to the common bile duct prior to entering the liver.

Left hepatic artery

- The left hepatic artery bifurcates early, into the medial (segment 4) and lateral (segments 2 and 3) sectoral branches. In some patients, the left hepatic artery does not exist, and the left medial sectoral branch arises from the right hepatic artery, crossing the midline passing posterior to the left lateral branch to supply segment 4.[14]
- The replaced or accessory left hepatic artery is less common, occurring in 10% to 15% of patients. When present, it arises from the left gastric artery, traveling instead in the gastrohepatic ligament (**FIG 10**).

Portal Veins

- The portal vein originates at the confluence of the splenic and superior mesenteric veins (**FIG 11**). It then runs superolaterally into the hilum of the liver, posterior and medial to the proper hepatic artery and common bile duct (**FIG 12**). The portal vein then divides early, most often while still in the hepatic hilum, into right and left portal veins.

Right portal vein

- The right portal vein follows a more linear path and branches early into anterior (segments 5 and 8) and posterior (segments 6 and 7) branches. These, in turn, give off the individual superior and inferior segmental branches.
- The right portal venous anatomy is often variable and preoperative as well as intraoperative; imaging is recommended prior to resection.

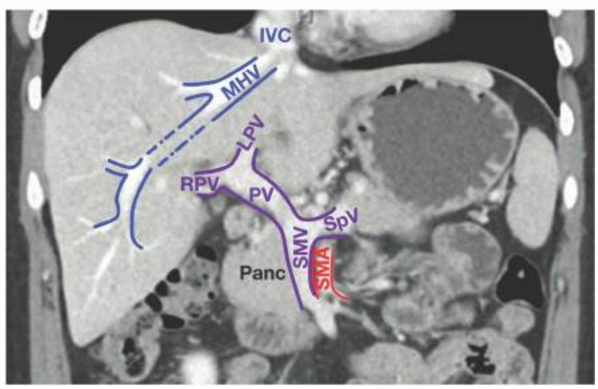

FIG 11 • Coronal CT demonstrating the confluence of the splenic vein *(SpV)* and the superior mesenteric vein *(SMV)* as they form the portal vein *(PV)*. The left portal vein *(LPV)* makes a sharp angle from the *PV*, whereas the right portal vein *(RPV)* is more direct. Note the proximity of the *SMV* and the *SMA* to the pancreatic head. Also shown are the *IVC* and middle hepatic vein *(MHV)*.

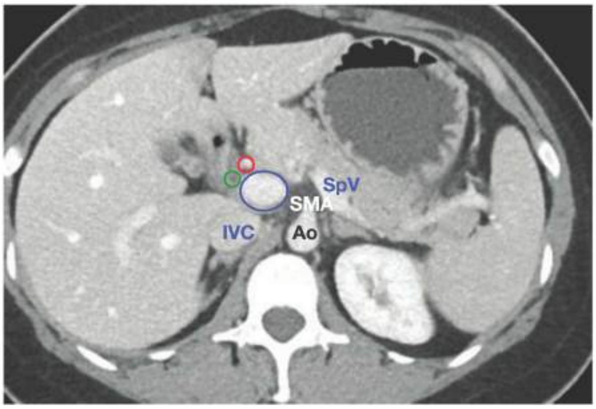

FIG 12 ● Axial CT demonstrating the normal anatomic relationship of the bile duct *(green circle)*, hepatic artery *(red circle)*, and portal vein *(blue circle)*. And they enter the hilum of the liver. Also labeled are the *IVC*, splenic vein *(SpV)*, aorta *(Ao)*, and *SMA*. This patient had a mass in the head of the pancreas.

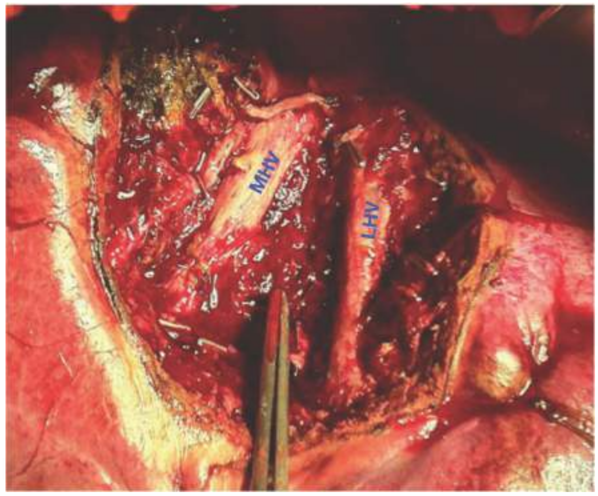

FIG 14 ● In vivo photograph showing the divided left hepatic vein *(LHV)* as it courses toward the divided *MHV*.

Left portal vein

- The left portal vein extends longer than the right. It makes an abrupt angle as it enters the liver from the hilum (**FIG 13**). The section of vein after the bifurcation and prior to the arborization of the left portal system is often referred to as the pars transversus.[13] This is important to identify when performing left hepatectomy.[15]
- The obliterated umbilical vein (ligamentum teres) and the obliterated ductus venosus (ligamentum venosus) join it as it enters the left lobe.
- The left portal vein most often gives off the dominant portal branch to the caudate lobe and usually does so prior to its segmental arborization.
- The left portal vein differs from the segmental anatomy of the hepatic artery and bile ducts, in that it does not give off a main branch to segments 2 and 3. Instead, it gives off branches to segments 3 and 4 and then continues as a single portal pedicle, sometimes referred to as the umbilical portion of the portal vein, before supplying segment 2.[16]

Hepatic Veins

- The hepatic veins divide the liver into its Couinaud sectors.
- The left and middle hepatic veins combine to form a common vein (truncus communis) prior to entering the IVC, although this occurs with some variety (**FIGS 14** and **15**).
- The caudate lobe has direct venous drainage to the IVC and is not drained by the three major hepatic veins.

Right hepatic vein

- The right hepatic vein separates segments 6 and 7 from segments 5 and 8.

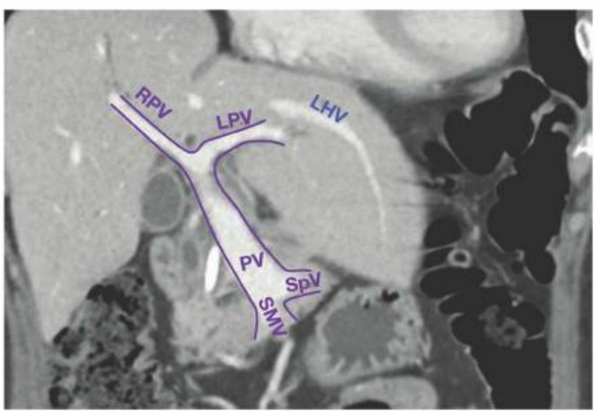

FIG 13 ● Coronal CT demonstrating the branching of the left *(LPV)* and right *(RPV)* portal veins off the main portal vein *(PV)*, which originates at the confluence of the superior mesenteric vein *(SMV)* and the splenic vein *(SpV)*. Note the acute angle made by the *LPV* as it enters the liver. Also shown is the left hepatic vein *(LHV)*.

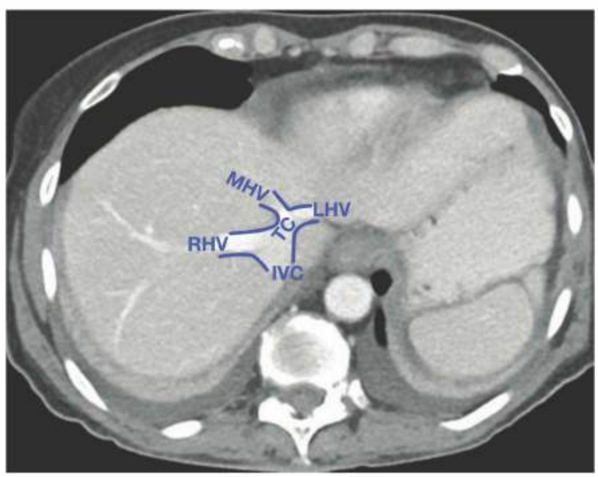

FIG 15 ● Axial CT scan showing the relationship of the hepatic veins as they converge to the *IVC*. The middle *(MHV)* and left *(LHV)* hepatic veins join to form the truncus communis *(TC)*, which empties into the *IVC*. The right hepatic vein *(RHV)* is also shown, similarly draining into the *IVC*.

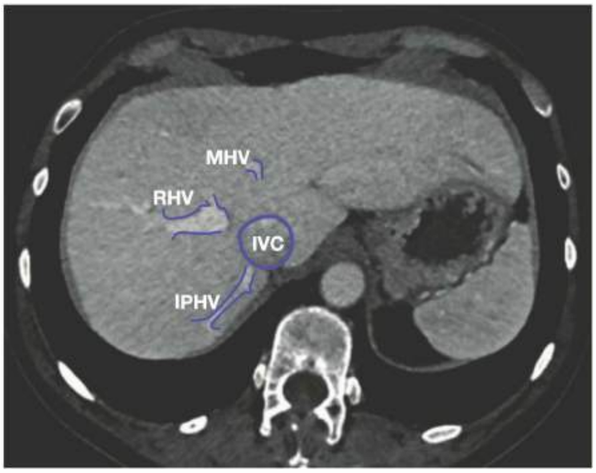

FIG 16 ● Axial CT showing an accessory hepatic vein. The inferior posterior right hepatic vein *(IPHV)* occurs in up to 25% of patients. Notice the position of the IPHV, far posterior on the liver. This is of utmost importance to characterize prior to operating on the liver. Also seen are the right hepatic vein *(RHV)*, *MHV*, and the *IVC*.

- It drains segments 6 and 7 as well as parts of segment 8.
- There can be accessory right hepatic veins, the most common of which is the inferior posterior right hepatic vein (**FIG 16**), which occurs in 20% to 24% of patients and can lie within the portocaval ligament. The surgeon must be aware of this possible anatomy prior to performing right hepatectomy.[17]

Middle hepatic vein

- The middle hepatic vein (MHV) follows Cantlie's line and is the line of division for right and left hepatectomy.
  - Right hepatectomy is performed just to the *right* of the MHV, preserving its length and ligating its rightward branches.
  - Left hepatectomy is conversely performed just the *left* of the MHV, preserving its length and ligating its leftward branches.
- It drains segments 4 and 5 and parts of segment 8.

Left hepatic vein

- The left hepatic vein drains segments 2 and 3 as well as parts of segment 4.
- Its arborization is variable, and careful identification of both the left and middle hepatic veins is paramount prior to performing left hepatic vein ligation for left hepatectomy.

BILIARY SYSTEM

- Bile is made by the hepatocytes and travels via an interlobular network of capillaries and ductules to the minor, then major biliary ductules, and eventually into the hepatic ducts.
- The right and left hepatic ducts come together to form the common hepatic duct (CHD), which accepts the cystic duct approximately 4 to 6 cm distal to the hepatic duct confluence. This then forms the common bile duct and travels another 4 to 8 cm before joining the pancreatic duct and emptying into the ampulla of Vater.
- There is considerable variation in biliary anatomy. The "typical anatomy" only occurs in 50% to 60% of patients[18,19] (**FIG 17**).
- The cystic duct is often tortuous and also often displays variable anatomy leading to misidentification and injury during cholecystectomy.
- The gallbladder sits in the gallbladder fossa between segments 4 and 5 and is attached to the liver surface. It is covered by peritoneum, and its fundus projects beyond the liver anteroinferiorly. Surgical considerations and anatomy of the gallbladder will be discussed further elsewhere in this book.

Right Hepatic Duct

- The right hepatic duct (RHD) is formed from the confluence of the right anterior hepatic duct (RaHD) and the right posterior hepatic duct (RpHD).
  - The RaHD drains the anterosuperior (segment 8) and anteroinferior (segment 5) ducts.
  - The RpHD drains the posterosuperior (segment 7) and posteroinferior (segment 6) ducts.
  - There exists considerable variation in the drainage pattern of the right system. The most common variant is Type C_1, where the RaHD drains directly into the CHD (**FIG 18**).
- The RHD is anterior and lateral while in the hilum of the liver; however, intrahepatically, it dives posterior to the portal vein in both RaHD and RpHD branches.

Left Hepatic Duct

- The left hepatic duct is longer than the right and can display similarly variable anatomy.[20]
- It drains the left lateral and medial hepatic ducts.
  - The left lateral hepatic duct drains the laterosuperior (segment 2) and lateroinferior (segment 3) branches.
  - The left medial hepatic duct drains the mediosuperior (segment 4A) and medioinferior (segment 4B) branches
- Unlike the right side, the left hepatic ductal system remains anterior to the portal vein throughout its intra- and extrahepatic course.

Biliary Drainage of the Caudate Lobe

- The caudate lobe drains directly into the left and right hepatic ducts, although this is variable.
- There is often a direct branch draining the caudate process into the RHD.

INNERVATION

- The liver has both sympathetic and parasympathetic innervations.
- The parasympathetic innervation is mostly via the left vagus nerve as it rotates anteriorly upon entering the abdomen. This is the anterior hepatic nerve plexus and travels mostly with the hepatic artery. There are also posterior hepatic fibers, which come from the right (posterior) vagus nerve, and travel mostly with the portal vein.
- Sympathetic innervation arrives via the splanchnic divisions of T7–T9, through the celiac ganglion, and runs mostly with the hepatic artery.
- Sensory fibers of the peritoneum of the liver run via the right phrenic nerve, and this leads to referred pain interpreted to be from the subscapular region with hepatic and diaphragmatic irritation from infection, tumor, or insufflation.

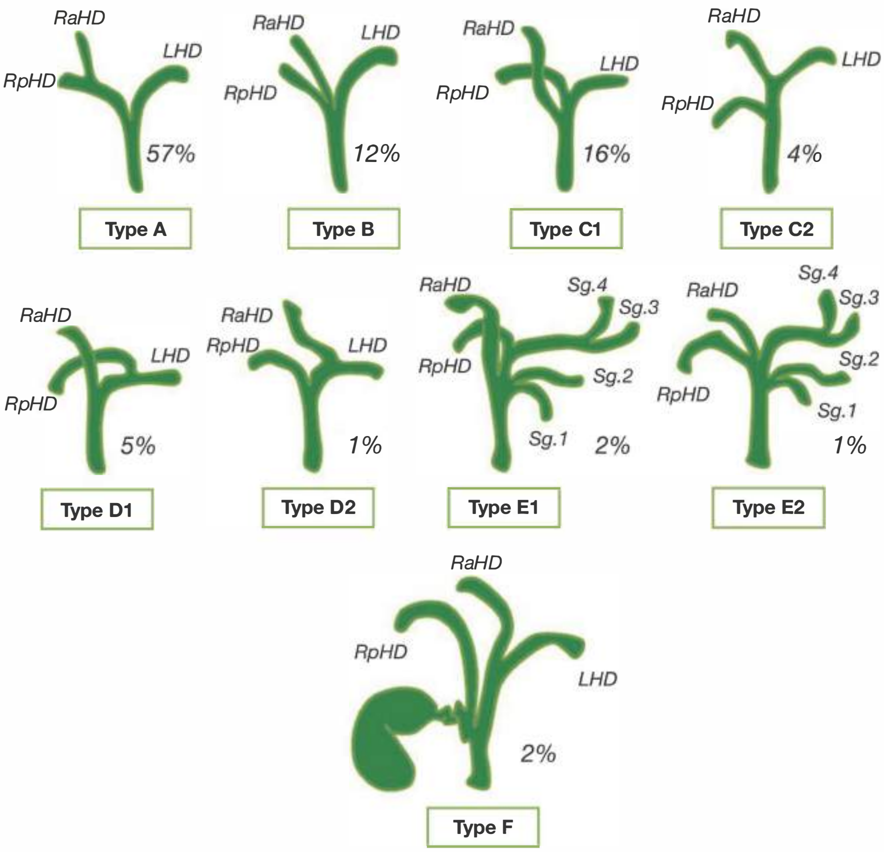

FIG 17 ● Typical and atypical variant anatomy, with percentages of frequency, of the hepatic ducts and biliary tree. Type A is typical anatomy. Type B shows the absence of a true RHD. Type C is a variation in which the one of the right hepatic branches drains into the CHD directly. Type D is a variation in which one of the right hepatic branches drains into the left ductal system. Type E is a variation in which there is an absence of a true confluence of right and left hepatic ducts. Type F shows a variant where the right posterior hepatic duct drains directly into the cystic duct. *RaHD,* right anterior hepatic duct; *RpHD,* right posterior hepatic duct; *LHD,* left hepatic duct; *Sg,* segmental branch with corresponding Couinaud segment number. (From Smadja C, Blumgart L. The biliary tract and the anatomy of biliary exposure. In: Blumgart L, ed. *Surgery of the Liver and Biliary Tract*. New York, NY: Churchill Livingstone; 1994:11–24.)

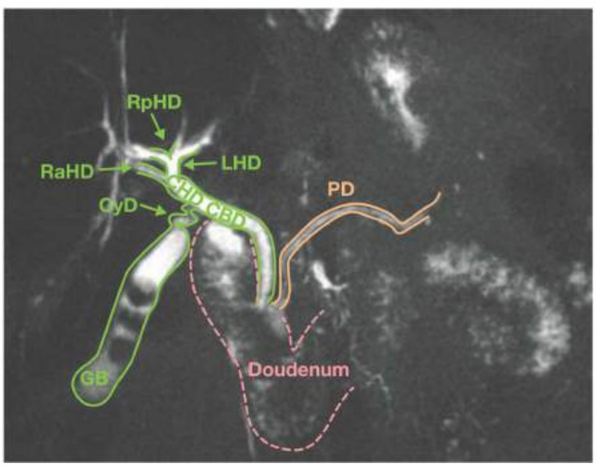

FIG 18 ● Magnetic resonance imaging (MRI) showing biliary anatomy. The right and left systems draining into the *CHD*. This is joined by the cystic duct *(CyD),* which is notably tortuous as it drains into the biliary tree. This confluence marks the beginning of the common bile duct *(CBD),* which joins the pancreatic duct *(PD)* to drain into the second portion of the duodenum. The gallbladder *(GB)* can also be seen, with three large stones present. This patient's anatomy reveals a common variant (Type C_1), with the right posterior hepatic duct *(RpHD)* joining the left hepatic duct *(LHD)* while the right anterior hepatic duct *(RaHD)* drains directly into the *CHD*.

LYMPHATICS

- The liver parenchyma drains lymph via empty spaces (space of Disse) between the endothelium and the hepatocytes themselves. This lymph is collected into larger spaces in the portal triad (space of Mall).[21] These are not actual lymphatics but rather nonendothelialized channels through which lymph passes. Lymph is eventually collected in true lymphatics within the portal triad and follows the path of these vessels.
- Lymphatics drain primarily into the lymph nodes of the porta hepatis followed by the celiac nodes. These lymph nodes should be evaluated for metastasis prior to resection when indicated (**FIG 19**).
- Secondary lymphatics follow the hepatic veins and drain into the phrenic lymph nodes.
- Superficially, beneath Glisson's capsule, lymph drainage from the liver follows one of five avenues:[22]
  - Anterior phrenic lymph nodes: drain anterosuperior surface
  - Lateral phrenic lymph nodes: drain posterosuperior surface
  - Left gastric lymph nodes: drain posterolateral surface
  - Celiac lymph nodes: drain posterior surface
  - Hepatic lymph nodes: drain visceral surface

CONCLUSIONS

- The anatomy of the liver is extremely complex and requires in-depth preoperative study prior to undertaking any liver operation.

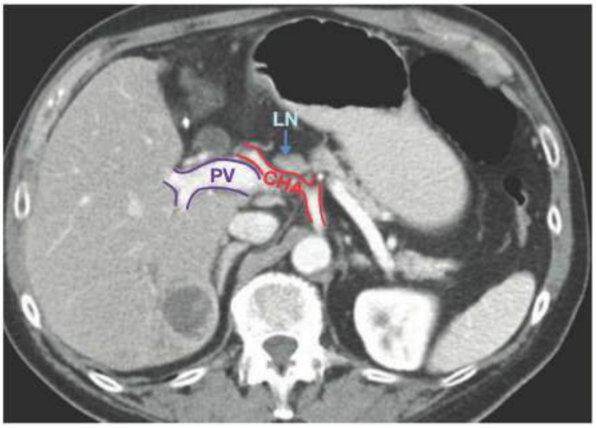

FIG 19 ● Axial CT showing an enlarged lymph node *(LN)* abutting the celiac bifurcation. A hepatocellular carcinoma can be seen in segment 6. Also labeled are the portal vein *(PV)* and the common hepatic artery *(CHA)*.

- The segmental anatomy as described by Couinaud is based on the portal venous anatomy. This knowledge has allowed surgeons of the modern era to perform increasingly specific and sparing resections, thus expanding the number of patients who can receive surgical therapy of liver disease and reducing the incidence of postoperative liver failure.
- The inflow and outflow of the caudate lobe are distinct from that of the rest of the liver.
- The liver has many variations of the biliary and vascular anatomy, and preoperative imaging is increasingly important in planning and executing successful liver operations.

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Chapter 16

Intraoperative Ultrasound of the Liver

Kristopher Croome KMarie Reid Lombardo

INTRODUCTION

- Intraoperative ultrasound (IOUS) of the liver involves the use of ultrasound imaging to provide real-time assessment during surgical procedures of the liver.[1–3]
- In 1981, Makuuchi et al.[4] described the use of IOUS (**FIG 1**) of the liver as an adjunct for hepatectomy; since then, the use of IOUS has expanded to include open percutaneous ablative techniques and various laparoscopic applications.
- During laparoscopic surgery, where tactile examination is less feasible, IOUS can be extremely valuable during the exploratory phase of the operation. The following chapter provides a review on the technical aspects of IOUS of the liver.

The Physics behind Ultrasonography

- Ultrasound measures the reflectivity of tissue to sound waves.
  - *Amplitude* is the maximum variation occurring in the sound wave (**FIG 2**).
  - *Wavelength* is the distance between the onset of peak compression or cycle to the next (**FIG 2**).
  - *Velocity* is the speed at which sound waves travel through a particular medium. Velocity is equal to the frequency × wavelength. Higher frequency will allow for greater penetration of the liver.
  - $V = f \times \lambda$

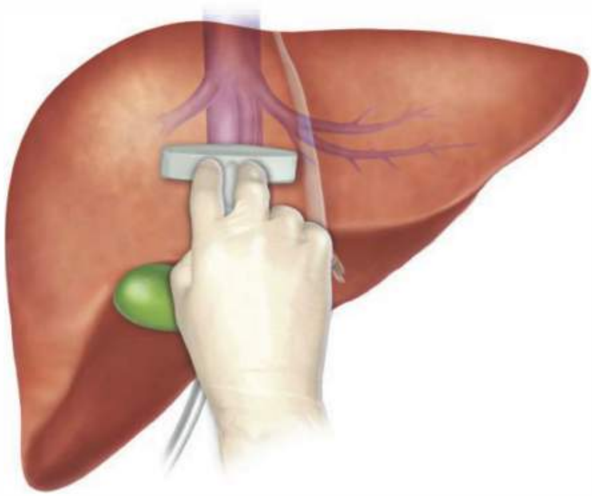


FIG 1 ● IOUS with T-probe.

Applications

- IOUS has numerous applications with the goal of improving surgical decision making, guiding the operation, and thereby improving outcomes. Here are common examples of its use:
  - **Evaluation of known hepatic lesions** to determine the extent of known disease and scrutinize the proximity of lesions relative to major structures such as hepatic and portal veins. For primary liver tumors, this can be helpful in staging.
  - **Detection of occult lesions** not detected on preoperative imaging. Subcentimeter metastatic lesions may not be detected by preoperative computed tomography (CT) or magnetic resonance imaging (MRI). Their number and locations may alter surgical plan. IOUS has a reported sensitivity of 90% for the detection of hepatic lesions with positive and negative predictive values of 90% and 78%, respectively.[2]
  - **Operative planning** as resection planes may not follow anatomic segments and as such, it is important to delineate the mass and relationship to hepatic or biliary pedicles to ensure adequate hepatic vein and biliary drainage. IOUS has been shown to alter the operative plan, when that plan was based on preoperative imaging, in 17% to 44% of cases in several reports.[2,5]
  - **Targeting** of lesions for biopsy. If an unsuspected lesion is identified during surgery, IOUS-guided biopsy will help to determine the next steps.
  - **Targeting** of lesions for therapeutic ablation, microwave, or cryotherapy. Metastatic disease such as colorectal liver metastases may require a multimodality approach to treatment in order to achieve optimal control of disease.

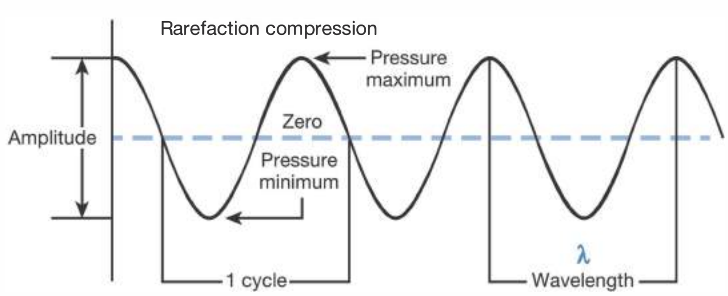


FIG 2 ● Wave properties such as amplitude and wavelength.

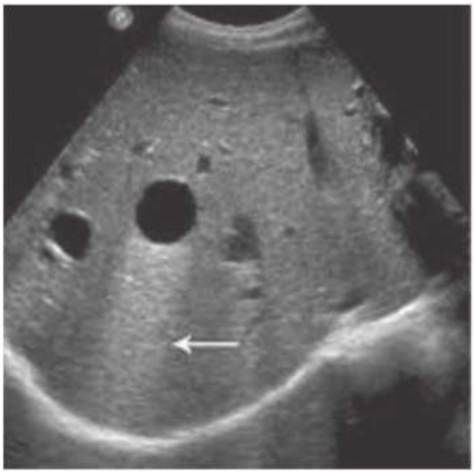


FIG 3 ● Simple hepatic cyst with posterior acoustic enhancement *(arrow)*.

Liver Parenchyma

- Normal liver parenchyma has a homogeneous echo pattern. Steatotic and cirrhotic livers have poor sound transmission and may appear diffusely hyperechoic.

Differential Diagnosis of Hepatic Lesions

- If a lesion is encountered, it should be examined in both transverse and longitudinal directions to determine its full extent. Its proximity and extension to neighboring vessels should be determined.
  - Benign lesions
    - Cyst—The ultrasound appearance is a well-defined lesion, with very thin, almost unapparent walls, without circulatory signal at Doppler investigation. The content is transonic suggesting fluid composition (**FIG 3**).
    - Hemangioma—Hemangiomas frequently appear as well-circumscribed hyperechoic lesions with sizes of 2 to 3 cm. Doppler exploration reveals no circulatory signal, because although the lesions are highly vascular, the blood flow through them is relatively slow (**FIG 4**).
    - Adenoma—Adenomas can be very difficult to distinguish from other benign lesions such as focal nodular hyperplasia (FNH). The appearance of adenomas can range from hyper- to hypoechoic; however, they are most frequently hypoechoic (**FIG 5**).

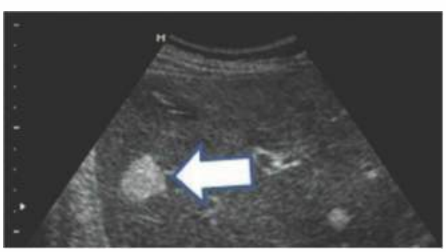


FIG 4 ● Hemangioma *(arrow)*.

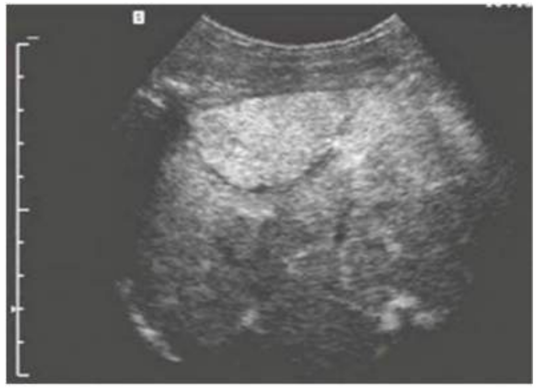


FIG 5 ● Adenoma.

  - Neoplastic lesions
    - Hepatocellular carcinoma (HCC)—HCC appearance on 2-D ultrasound is that of an isoechoic or hypoechoic solid tumor, with imprecise delineation, with heterogeneous structure, uni- or multilocular (encephaloid form). HCC may also frequently invade portal and hepatic veins and so these should be examined particularly in larger tumors (**FIG 6**).
    - Colorectal liver metastases (CRLM)—CRLM usually appear hypoechoic. They may take on a "target" or "bull's-eye" appearance due to alternating layers of hyper- and hypoechoic tissue. This pattern is highly suggestive of malignancy (**FIG 7**).
    - Neuroendocrine tumors (NETs)—Because NETs are hypervascular, they often appear as a hyperechoic lesion (**FIG 8**).

Required Equipment for Ultrasound

- Liver IOUS is best performed using a real-time B-mode scanner system with a 5-MHz or 10-MHz side fire T-shaped linear array probe. Saline or conductive gel can be applied to the liver surface to augment wave transduction. Required components for IOUS include the following:
  - Transducer—Transducers help to transmit ultrasound waves through the hepatic parenchyma. There are a

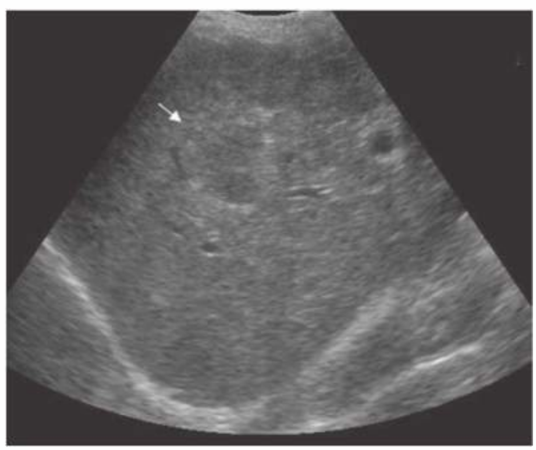


FIG 6 ● HCC *(arrow)*.

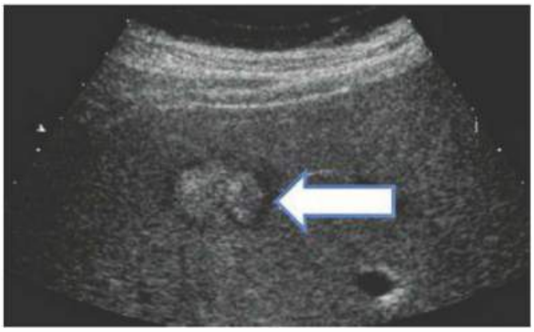


FIG 7 ● CRLM showing peripheral rim or bull's-eye appearance *(arrow)*.

variety of probes that are currently available and selection is based on the goal for the examination, body habitus and quality/character of hepatic parenchyma, and user preference. High-frequency probes allow for more adept superficial imaging, whereas lower frequency probes allow for deeper evaluation of the parenchyma. The most commonly used probe in open surgery is a T-probe. Probes can either be chemically sterilized or used with a sterile cover. Our group uses chemically sterilized probes (**FIG 9**).

- Processing unit: A variety of processing units are commercially available, most will include preset controls to adjust frequency, gain, depth, focus, freeze screens, and calipers to acquire measurements. We recommend familiarizing yourself with the processing unit available in your institution.
- Common controls:
  - Frequency: Determines how much tissue penetration will occur with scanning (higher frequency allows for better resolution).
  - Gain: Gain amplifies the echography, which manifests as contrast. This determines how the brightness of the image is depicted. To reduce the brightness of an image one would lower the gain.
  - Depth: The depth from which the returning ultrasound signals will be displayed. The scale on the image represents the depth. The maximum amount of depth will depend on the probe frequency. Higher frequencies will allow for improved depth penetration and potentially improved resolution.
  - Measurements: By freezing the image, calipers can then measure areas of interest.
- Display: Units are usually depicted as black and white with color available in Doppler mode.

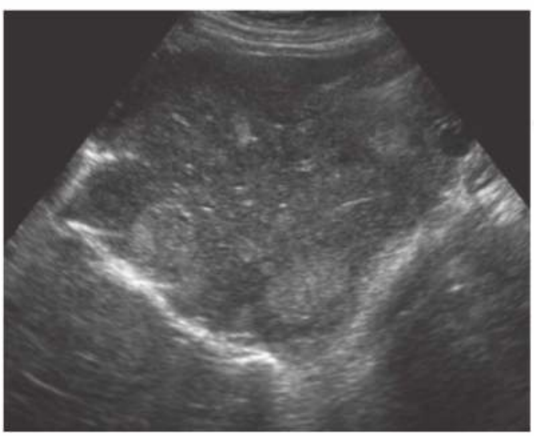


FIG 8 ● NET.

FIG 9 ● Example of some transducer probes available.

Three Modes Commonly Used for Intraoperative Ultrasound of the Liver

- B-mode or 2-D mode: In B-mode (brightness modulation) ultrasound, a linear array of transducers simultaneously scans a plane through the liver that can be viewed as a two-dimensional image on screen (**FIG 10**).

FIG 10 ● B-mode of the liver.

- Doppler mode: Information is sampled along a line through the body, and all velocities detected at each time point are presented (on a time line). When sound is reflected from a moving object, the frequency of the reflected echo changes in proportion to the velocity of the object (**FIG 11**).
- Duplex mode: The simultaneous presentation of 2-D (B-mode) and (usually) pulsed wave (PW) Doppler information. (Using modern ultrasound machines, color Doppler is almost always also used; hence the alternative name Triplex.) (**FIG 12**).

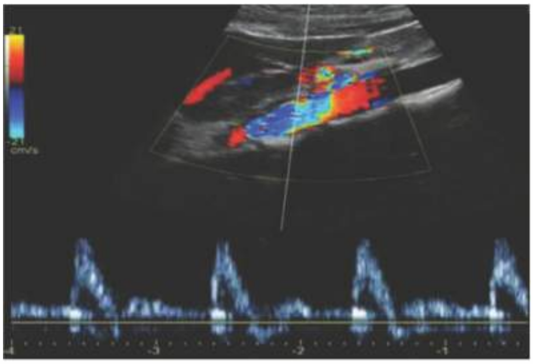


FIG 11 ● Doppler mode.

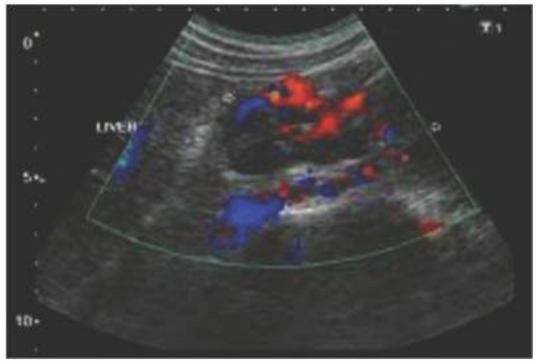


FIG 12 ● Duplex mode of the liver.

PRESCAN PREPARATION

First Step

- The lights of the operating room should be dimmed to improve visualization of the screen.

Second Step

- No coupling gel is generally required except if the transducer is placed in a sterile bag. If a sterile bag is used, then care should be taken to ensure no air bubbles are present at the contact surface.

Third Step

- Instill saline into the abdomen to aid in the transduction of sound waves.

Fourth Step

- The operator should be in good position to adequately visualize the console monitor (**FIG 13**).

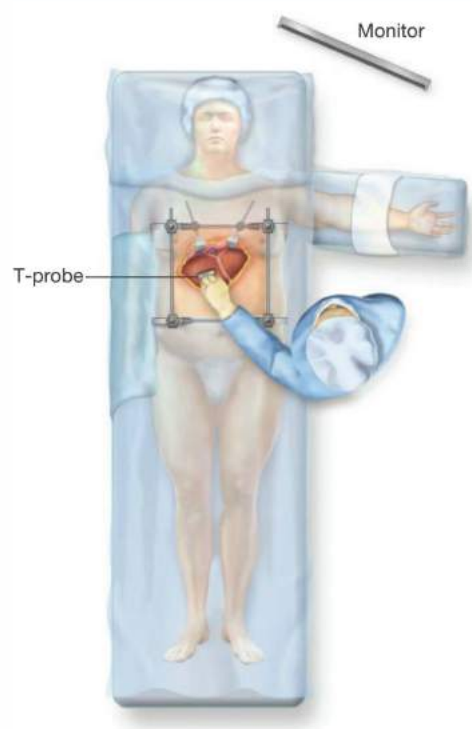


FIG 13 ● Operating positioning for adequate visualization of the monitor.

SCANNING

- Having a systemic technique to hepatic ultrasound is of utmost importance. There are many approaches that have been described. You will need to use two methods for ultrasound placement in open and laparoscopic cases.

Contact Scanning

- For contact scanning, the probe should be in direct contact with the liver surface.
- This technique is used for surveying the liver in most situations, with a systematic approach across the liver surface (Figure 14).

Stand-off Scanning

- In stand-off scanning, water is applied to the surface of the liver for coupling in order to adequately visualize the right posterior segments (segments 6 and 7). The probe is then held off of the liver surface immersed within the water. This technique can be particularly useful for superficial lesions and to detect lesions in the posterior segments of the liver.

Systematic Approach

- Identify the confluence of the hepatic veins with the inferior vena cava (IVC). This can be used as a rough indicator of the patient's central venous pressure (CVP) or volume status based on IVC distention. Follow the left, middle, and right hepatic veins, respectively.
- Identify the portal vein bifurcation. Follow the left portal vein to identify segment 4 and the bifurcation of segments 2 and 3.
- Again, identify the portal vein bifurcation and follow the right branch to its bifurcation and identify the right anterior and right posterior pedicles.
- If there are known lesions, identify these ultrasonographically in order to determine the echogenic profile that will aid in identifying occult lesions of the same pathology.
- Next, survey the entire liver for any additional disease. The two most commonly used survey methods are the lawn-mower method and the pedicle tracking method.

METHODS

Lawn-Mower Method

- The liver is scanned with overlapping fields from the dome to the caudal edge, proceeding from left to right through the entire organ in a sequential manner (FIG 14).

Pedicle Tracking Method

- To scan the liver, the pedicle tracking method can be used instead of the lawn-mower method. Using this technique, the liver is scanned segment by segment by following the vascular inflow and outflow. The hepatic ultrasonographer should be well versed in hepatic segmental anatomy following Couinaud nomenclature (The Brisbane 2000 terminology of hepatic anatomy and resections).[5]

In-Plane and Out-of-Plane

- It is important to understand the concepts of in-plane and out-of-plane when visualizing structure. In-plane refers to the visualization of structures in their long axis. Out-of-plane refers to visualizing structures at a 90-degree angle (FIG 15).

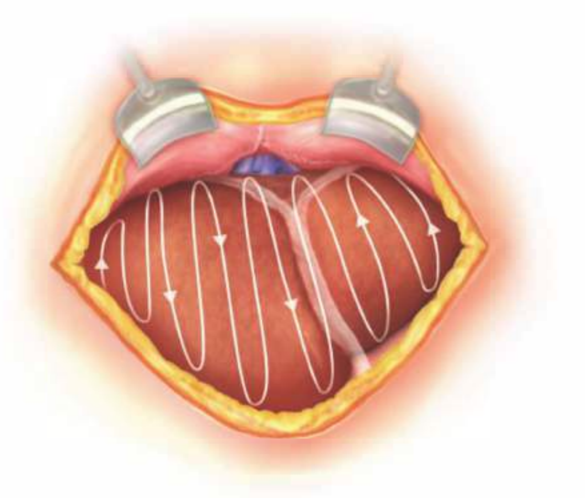


FIG 14 ● The pattern for scanning with the lawn-mower method.

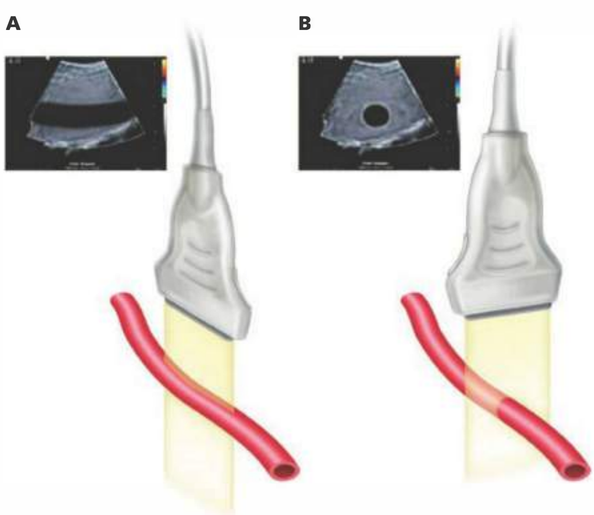


FIG 15 ● **A.** An ultrasound probe in plane with structure (vessel in this case). **B.** The ultrasound probe at 90 degrees with structure.

IMAGING EXAMPLES

Hepatic Vein Confluence into Inferior Vena Cava (FIG 16)

- The three hepatic veins can be identified entering into the IVC.
- The middle and left veins can usually be seen forming a common confluence before going into the IVC.
- The hepatic veins are anechoic vessels, frequently lacking a visible wall structure.

Portal Vein Bifurcation (FIGS 17 and 18)

- The portal vein can be identified branching into its main right and left branches.
- The portal veins can be differentiated from the hepatic by their white outline, a result of invested Glisson's capsule.
- The hepatic hilum can be located at the base of segments 4 and 5.
- The right and left portal veins then ramify into their section branches (anterior and posterior on right and medial and lateral on the left).
- The arteries and bile ducts run parallel to the portal veins from the liver, branching out into the liver from the hilum.
- The arteriole and biliary branches lie anterior to the portal veins.
- Duplex color imaging is useful in differentiating the hepatic arteries from the bile ducts.

Left Portal Vein Bifurcation into Segments 2, 3, and 4 (FIG 19)

- The left portal vein branch is longer than its right counterpart. It turns anteriorly (toward the probe) as it ascends into the umbilical fissure.

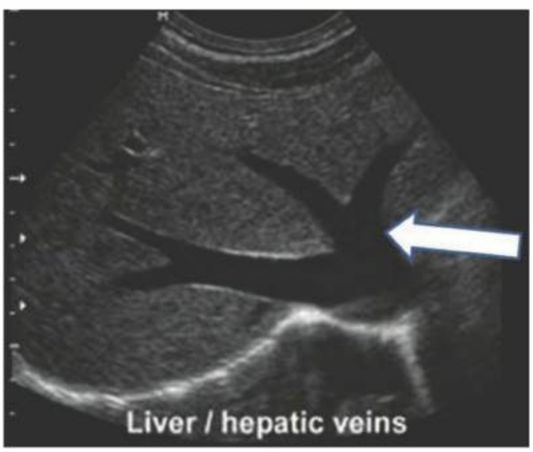


FIG 16 ● The hepatic vein confluence with the IVC. Note that the left and middle hepatic veins often share a common trunk *(arrow)*.

FIG 17 ● Portal vein bifurcation into its main right and left branches.

Right Portal Vein Bifurcation into Anterior and Posterior Pedicle (FIG 20)

- If one follows the right portal vein from its origin, one can identify the bifurcation into the right anterior (supplying segments 5 and 7) and the right posterior (supplying segments 6 and 7) branches.

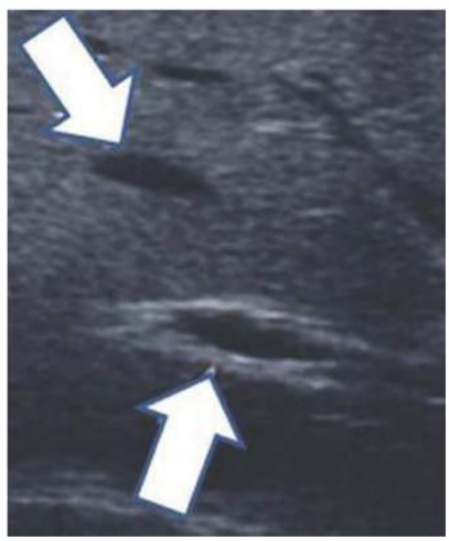


FIG 18 ● Differentiating portal branches from hepatic vein *(top arrow)* branches can be done by looking for the white outline in portal vein *(bottom arrow)* branches as a result of invested Glisson's capsule.

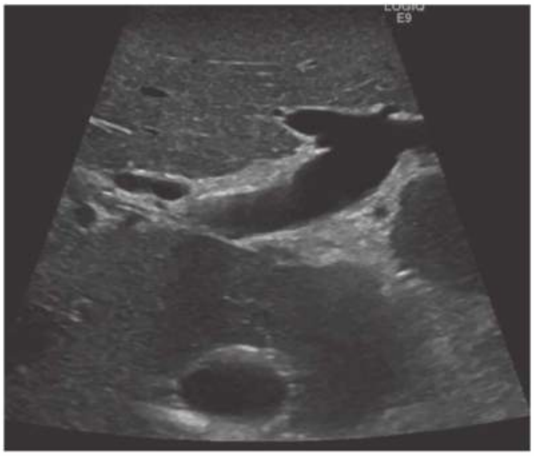


FIG 19 ● Left portal vein bifurcation into segments 2, 3, and 4.

FIG 20 ● Right portal vein bifurcation into anterior and posterior pedicle.

TARGETING OF LESIONS

- Multiple different methods of IOUS-assisted targeting ablation technologies.
    - The ablation probe and the ultrasound should be "in plane" so that the approach to the targeting lesion can be visualized (**FIG 21**). Once the probe has reached its intended target, the ultrasound probe can be turned 90 degrees to ensure that it is in the center of the intended target.
- Following ablation, a significant artifact will be generated, limiting ability to target further lesions in that field. As such, deeper lesions should be targeted first if multiple lesions are being targeted in one area.
- Pre- and postablation images should be captured for the medical record.

FIG 21 ● Imaging in-plane targeting of lesion.

LAPAROSCOPIC ULTRASOUND

- Laparoscopy has obvious shortcomings in evaluating the liver because it eliminates the surgeon's ability to palpate the hepatic parenchyma to detect lesions. IOUS attempts to restore some of the loss of tactile feedback while providing important information as seen in open procedures (FIG 22). The main goals of laparoscopic IOUS are the same of ones presented earlier in this chapter in open liver surgery. Laparoscopic IOUS has a few theoretical drawbacks if compared to traditional IOUS, including the difficulty in the ultrasound study of the superior and posterior segments. Some of this is dependent on probe type, as probes with varying degrees of freedom are available.

FIG 22 ● Laparoscopic IOUS. Typically, start high on the patient, to the right of the falciform.

CHECKING FOR BILIARY LEAK BY USE OF AIR CHOLANGIOGRAM

- This technique has been shown to result in a lower rate of postoperative bile (1.9% vs. 10.8%)[6] (FIGS 23 and 24).
  - A cholangiography catheter is inserted into the cystic duct and secured with a silk tie.
  - A syringe of air is then injected to fill the biliary tree while occluding the distal common bile duct by finger compression.
  - IOUS is then used to look at all liver segments to ensure bile duct patency. If there is an excluded segment, it will have an absence of pneumobilia.
  - Nonvisualization of pneumobilia suggests that there is a bile duct obstruction, a massive air leak via a large open bile duct, or incomplete manual occlusion of the distal common bile duct.

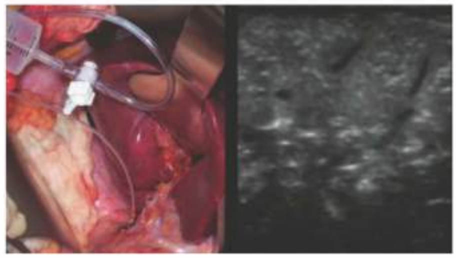
A  B

FIG 23 ● **A.** Injection of air into cystic duct following resection. **B.** Appearance of the liver following injection on air. The appearance is that of "Christmas tree lights" in liver segments that are in continuity.

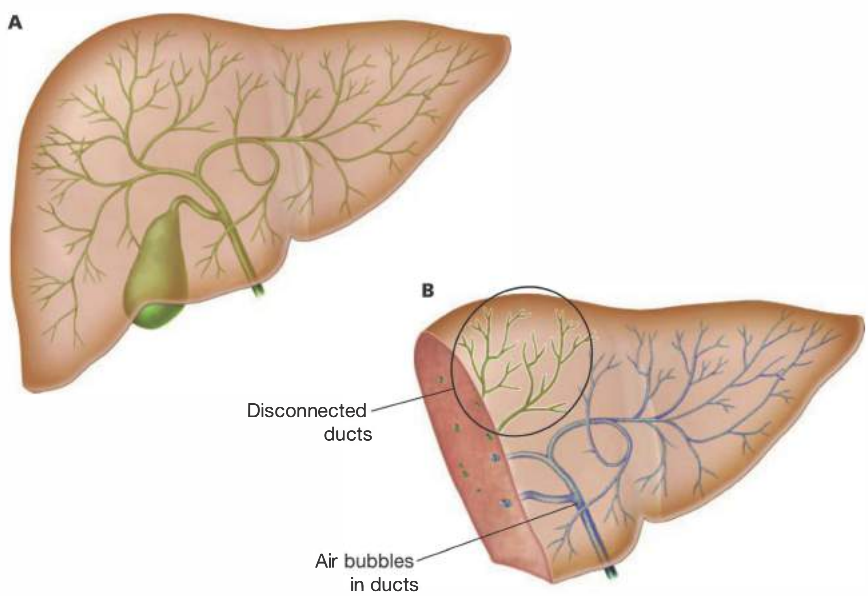


FIG 24 ● **A.** The liver, prior to resection, showing the biliary system. **B.** The liver following resection, showing air within segments in continuity and no air in excluded segments.

IDENTIFYING STRUCTURES IN THE HEPATIC HILUM

- Ultrasound of the hepatic hilar structures can be performed by placing the probe directly on the hepatic hilum (**FIG 25**). The classic appearance of the hepatic hilum on IOUS has been described as "Micky Mouse ears" consisting of the bile duct to the right, the hepatic artery to the left, and the portal vein posteriorly.
- The use of IOUS in the hilum can be useful for identifying the level of the hepatic artery bifurcation as well as any other anamolous anatomy such as a replaced right hepatic artery.

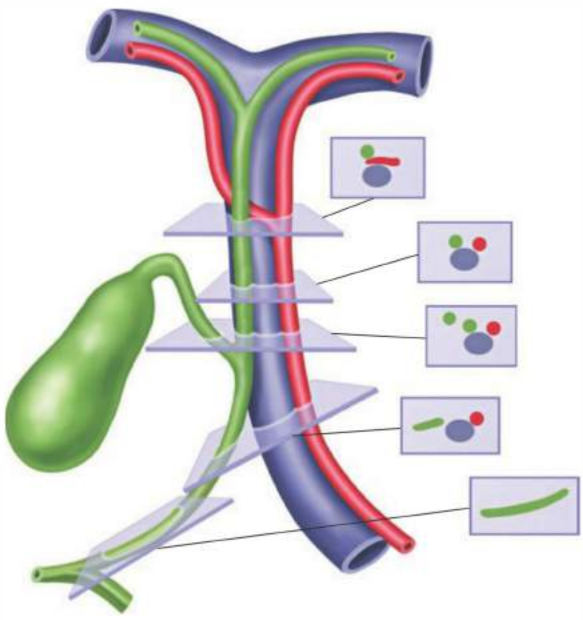


FIG 25 ● Relationship of structures of the hilum.

PEARLS AND PITFALLS

Indications	■ Ultrasound (US) is an essential adjunct during laparoscopic procedures.
Prescan preparation	■ Be familiar with your institution's US transducers and processor. ■ Immerse the liver in saline to optimize resolution.
Scanning	■ Scan a known lesion first to identify the US imaging characteristics of the pathology of interest. ■ Use a system to assure the entire liver is assessed. ■ Use "stand-off" scanning to avoid missing superficial lesions.
Targeting	■ Obtain permanent images for the medical record before and after ablation.

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Chapter **17**

Fenestration or Enucleation of Hepatic Cystic Disease

Purvi Y. Parikh

DEFINITION

- Fenestration is defined as the removal of the free wall of a hepatic cystic lesion with the intent of forming a permanent communication between the residual cyst cavity and the peritoneal cavity. Thus, the procedure allows for any secreted fluid subsequently produced by the cyst lining to be absorbed by the peritoneum.
- Enucleation involves removal of the cyst in toto without spillage of contents; the intent is to use the capsule of the cyst as a resection plane to preserve hepatic parenchyma.

DIFFERENTIAL DIAGNOSIS

- Common cystic lesions range from the single, simple, small liver cyst to polycystic liver disease.
- More uncommon lesions are mesenchymal hamartomas, biliary hamartomas, and ciliated foregut hepatic cysts.
- Parasitic infection of the hepatic cyst must be ruled out prior to proceeding with surgery. Serology and characteristic imaging features make this determination straightforward.
- Biliary cystadenomas/cystadenocarcinomas that have malignant potential require enucleation rather than fenestration. The identification of bile in the cyst is the most important factor in identifying cysts with malignant potential that warrant the increased morbidity of enucleation.

PATIENT HISTORY AND PHYSICAL FINDINGS

- Most simple hepatic cysts are asymptomatic and detected as an incidental finding during imaging of the abdomen.
- Simple hepatic cysts are congenital lesions, which are progressive dilatations of biliary microhamartomas known as von Meyenburg's complexes. Such cysts are lined by flattened biliary epithelium without a separation from adjacent hepatic parenchyma. They do not communicate with the biliary tree. These cysts contain serous fluid, which is continuously excreted by thin lining of epithelial cells.
- The prevalence of hepatic cysts is 16% to 18%. Females are affected more frequently than males.
- The frequency increases with age, with the peak incidence between ages 50 and 60 years.
- Large cysts may exert a mass effect and cause upper abdominal discomfort and early satiety (**FIG 1**).
- Symptoms are more common with right-sided cysts.
- Ultrasound-guided percutaneous cyst aspiration has minimal role in treatment of symptomatic cysts, as the recurrence rate is high and as rapid as 2 weeks.
- If symptoms persist after needle aspiration, the cyst is not the likely cause and other diagnoses should be investigated.
- Alternatively, if symptoms resolve after aspiration and return with recurrence of the cyst, definitive treatment of the cyst is indicated.
- Indications for intervention include pain, jaundice, infection, and hemorrhage. Occasionally, compression results in portal hypertension and indicates resection is appropriate.
- Most cysts that are incidentally identified do not warrant resection, provided the cyst lacks features of malignant potential. These features include septations; heterogenous attenuation; and a thickened, enhancing cyst wall.
- Complications are rare but include intracystic hemorrhage, biliary obstruction due to compression, cyst rupture, and cyst torsion. Bacterial infection leading to symptoms is occasionally observed.

A

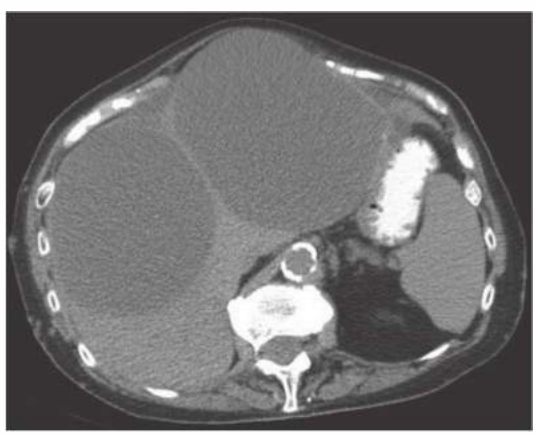

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FIG 1 ● **A.** Large, simple bilobar liver cyst. **B.** Large, simple bilobar liver cyst (axial).

IMAGING AND OTHER DIAGNOSTIC STUDIES

- Because most hepatic cysts are asymptomatic, they are most frequently detected on imaging of the abdomen obtained for other indications.
- Laboratory tests of liver enzymes (aspartate aminotransferase [AST], alanine aminotransferase [ALT], bilirubin, alkaline phosphatase) and tumor markers (carcinoembryonic antigen [CEA], carbohydrate antigen 19-9 [CA 19-9]) and serologies (hydatid)
- Ultrasound scanning demonstrates a rounded, anechoic intrahepatic mass with good thorough transmission and an imperceptible wall.
- Computed tomography shows a benign hepatic cyst as a homogenous lesion of low attenuation with no enhancement of the wall or content following administration of contrast.
- Magnetic resonance scanning diagnostic criteria are a homogenous lesion with low attenuation in T1 weighted images and a very high–signal intensity on T2 weighted images.
- Importantly, neuroendocrine and sarcoma hepatic metastases occasionally appear cystic.

FENESTRATION

Preoperative Planning

- Prior to operation, the patient should be counseled regarding the pros and cons of laparoscopic versus open surgery.
- Although the risk of infection after liver surgery is low, antibiotic prophylaxis significantly reduces the risk of postoperative infection.

Laparoscopic Fenestration

- Laparoscopic cyst fenestration has evolved to be the first-line surgical approach for symptomatic cysts.
- **Port placement**. A three-port laparoscopic technique is used (**FIG 2**): camera (30 or 45 degree), grasper for the cyst wall, and cutting instrument (cautery, Harmonic scalpel, or scissors). One of the ports should be 10 mm for clip application.
- **Grasping of cyst**. The cyst can be elevated with a grasper once it has been punctured through the exposed wall immediately adjacent to the liver parenchyma by insertion of a cutting instrument. The contents are drained and sent for analysis (**FIG 3**).

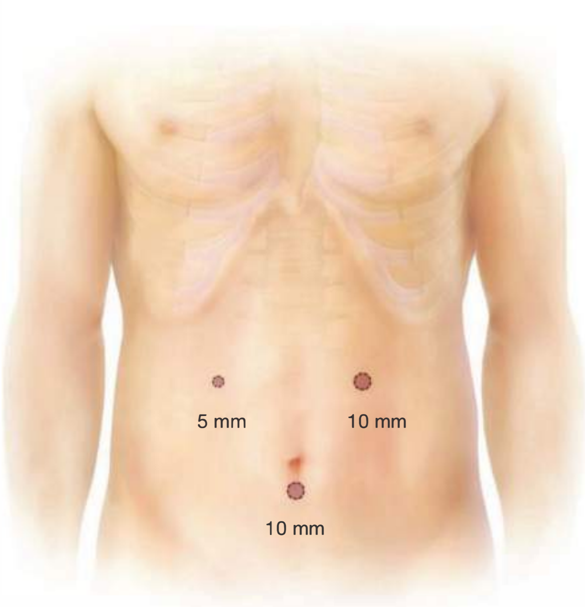
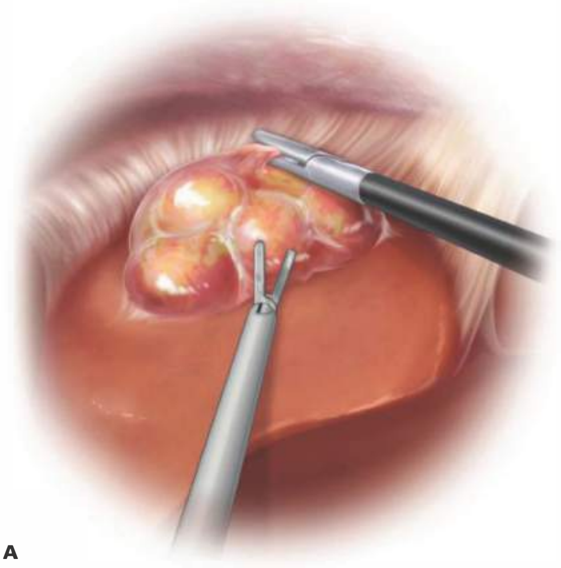


FIG 2 ● Trocar placement.



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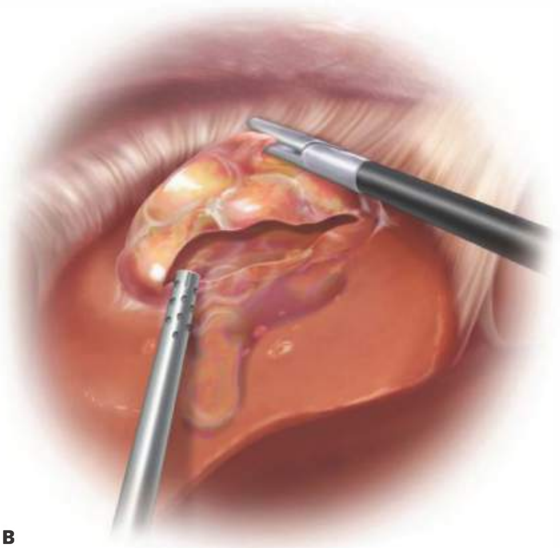

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FIG 3 ● **A.** Grasping of the liver cyst wall. **B.** Grasping and elevating the liver cyst.

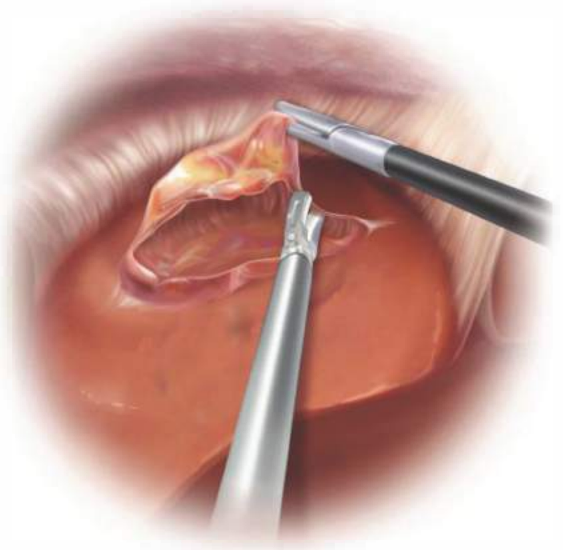

FIG 4 ● Resection of liver cyst wall.

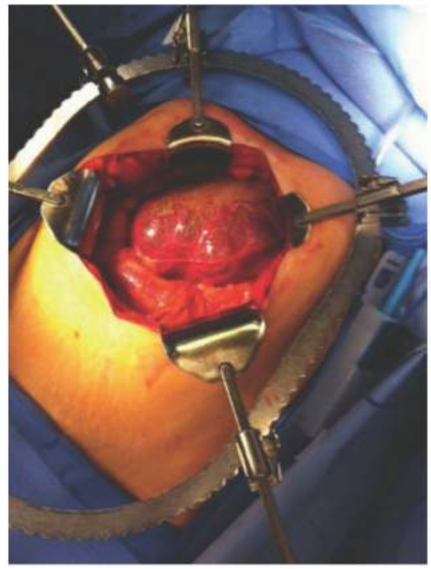

FIG 5 ● Open biliary cystadenoma resection.

- **Resection of cyst wall**. A wide excision of the cyst wall is performed using bipolar electrocautery or Harmonic shears. The intent is to excise the entire free wall and not to venture into the hepatic parenchyma (**FIG 4**).
- **Removal of resected cyst**. The resected cyst wall is removed in an endoscopic retrieval bag and the remnant cyst epithelium inspected.
- **Obliteration of remnant cyst epithelium**. Obliteration of the remnant cyst wall against the hepatic parenchyma should be treated with electrocautery, argon beam coagulation, or topical sclerosant.
- **Omentoplasty**. To minimize the risk of the resultant space-occupying defect evolving into a fluid collection, an omentoplasty is advised. A pedicle of omentum is mobilized from the transverse colon and advanced into the cyst cavity. It can be sewed in place with sutures or held in place with laparoscopic clips.
  - If omentoplasty is not possible, it is important to resect the maximal amount of the wall of the cyst to enhance retraction of the remnant edge of the cyst, thus preventing reapproximation of the rim by contraction with subsequent recurrence.
- After removal, the cyst wall is assessed histologically.

Open Fenestration

- Open cyst fenestration is reserved for recurrent disease or patients with extensive abdominal adhesions from prior surgical procedures.
- **Incision**. A right subcostal or midline incision; triangular and coronary ligaments are divided to rotate the liver (**FIG 5**).
  - Using the nondominant hand, the surgeon pulls the liver toward the midline to complete the exposure of the cyst. The cyst is unroofed to the level of the parenchyma.

ENUCLEATION

Laparoscopic Enucleation

- Laparoscopic enucleation can be effectively employed in the management of peripheral cysts, especially those located in the left lateral lobe or in the anterior segments.
- The epithelial wall and associated pseudocapsule easily lacerate, and cystic lesions often compress adjacent vasculature; thus, laparoscopic enucleation of hepatic cysts is often perceived as a straightforward option that can rapidly deteriorate into a loss of the surgical plane, significant hemorrhage, and carbon dioxide gas venous embolism.
- A minimum of three ports are necessary. Additional trocars can facilitate this approach.
- The most common instruments used to establish a hemostatic plane between the pseudocapsule of the cyst and the hepatic parenchyma are ultrasonic shears, bipolar electrocautery, and surgical staplers (**FIG 6A,B**).
- Additional ports should be placed to provide optimal positioning of the instrument to achieve complete cyst resection with the intent of sparing of healthy parenchyma. The development of a dissection plane is most efficiently and safely achieved with the shaft, rather than the tip, of the instrument.
- Once the dissection is completed circumferentially and the cystadenoma is enucleated, the specimen should be sent for immediate gross inspection and histologic analysis, as indicated, to exclude occult cystadenocarcinoma.

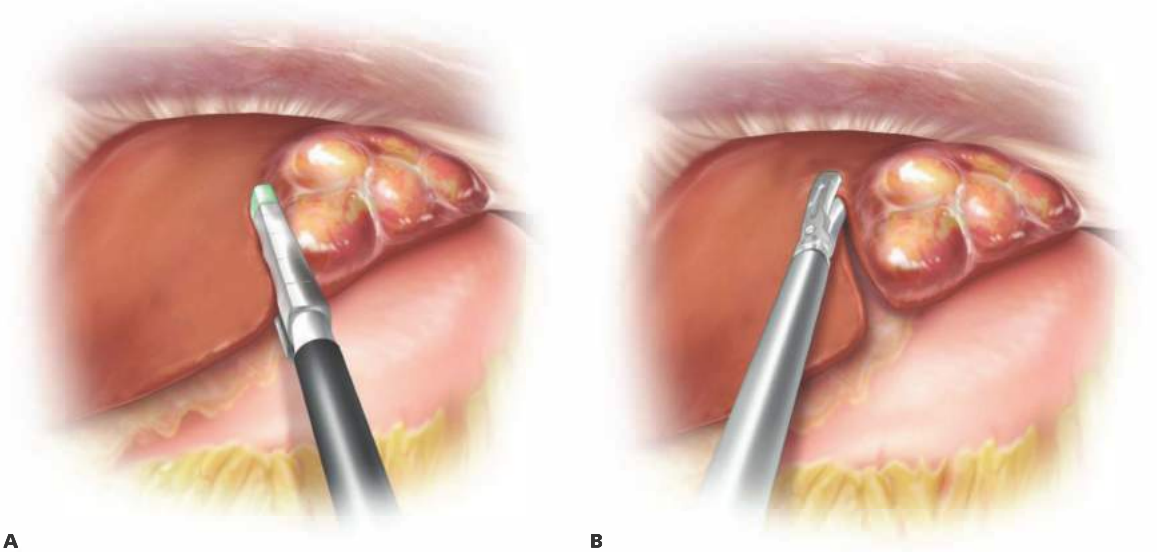

FIG 6 ● **A,B.** Techniques to resect a liver cyst.

- After dissection of the cyst from the hepatic parenchyma is completed, hemostasis is achieved and confirmed by electrocautery and direct inspection.
- If a bleeding vessel is identified, hemostasis is secured by electrocautery, surgical clips, and hemostatic agents or devices.

Open Enucleation

- Small cysts and biliary cystadenomas concerned for malignancy require enucleation of the cyst en toto.
- **Mobilization of the liver**. The affected lobe should be fully mobilized prior to enucleation. After mobilization of the liver, countertraction is maintained by the non-dominant hand of the surgeon.
- **Identification of interface**. The interface between the cyst pseudocapsule and the hepatic parenchyma is identified and developed (**FIG 7A,B**). Electrocautery is typically employed to initially enter the dissection plane between the cyst wall and the parenchyma. Blunt dissection should be adopted shortly thereafter, as this approach will facilitate deviation from the surgical plane and external identification of major vascular structures that have been compressed by cyst expansion.

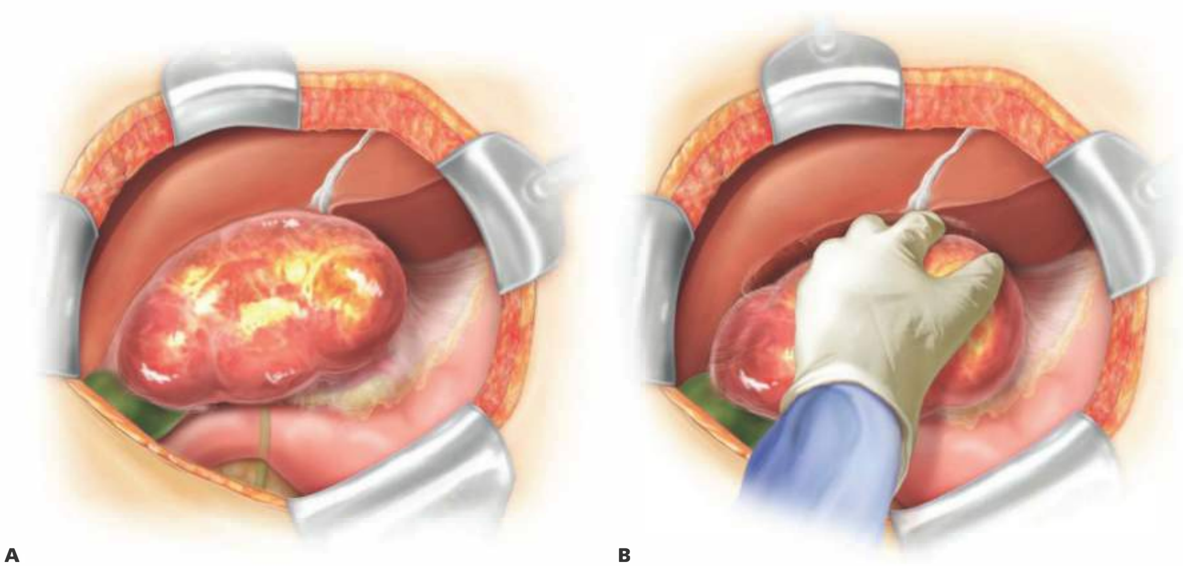

FIG 7 ● **A.** Mobilization of the liver. **B.** Identification of the interface.

- **Dissection and enucleation**. The dissection should proceed anterior to posterior, maintaining a broad plane; avoid the development of narrow, deep dissection planes. Once the dissection is completed circumferentially and the cystadenoma is enucleated, the specimen should be sent for immediate gross inspection and histologic analysis, as indicated, to exclude occult cystadenocarcinoma (**FIG 8**).
- Injury to the adjacent, compressed bile ducts can be intrinsic to this procedure. A fine (4-0 or 5-0 absorbable) monofilament suture is used for repair. Abdominal drainage in this setting is optional, but the author routinely places a closed suction drain in this clinical setting (**FIG 9**).
- Complete excision of the cystadenoma eliminates risk of recurrence.

FIG 8 ● Enucleation of entire cyst.

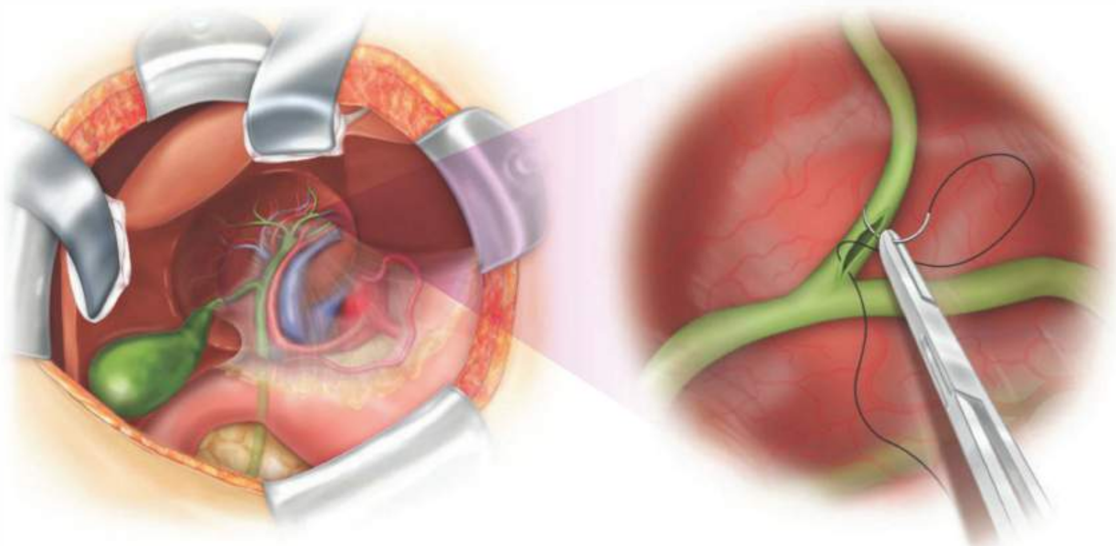

FIG 9 ● Repair of inadvertent injury.

PEARLS AND PITFALLS

Differential diagnosis	▪ Fenestration is straightforward; enucleation is considerably more morbid. Concern for malignant potential must be present to justify enucleation. ▪ Bile in the cyst warrants enucleation. The site of communication with the biliary tree is often not obvious. A cholangiogram via the cystic duct with methylene blue can facilitate identification of this site of communication.
Surgical technique	▪ Make certain the portal triad is accessible for a Pringle maneuver. ▪ During laparoscopic resection of hepatic cysts, be aware that major pedicles may not be amenable to sealing devices. Surgical staplers are the best option to laparoscopically control and divide these structures. ▪ When encountering significant hemorrhage during laparoscopic procedures, delay from hesitation to convert to an open procedure often leads to unnecessary transfusion or carbon dioxide embolism that can be life threatening. ▪ In an emergent conversion, use a midline incision. ▪ Look for small biliary radicals after enucleation. Drainage is not a good alternative for repair or ligation.

POSTOPERATIVE CARE

- If a drain has been placed, it can be removed on the first postoperative day, provided there is no bilious effluent.
- After a liver cyst fenestration, most patients should have routine postoperative surveillance.
- Consider intermediate or intensive care units for complicated cases of polycystic disease or for resections resulting in significant blood loss (>1,000 mL).

OUTCOMES

- The results of laparoscopic cyst fenestration are excellent. Three studies have reported outcomes in patients treated with laparoscopic cyst fenestration with a near follow-up of more than 4 years. There is no reported mortality with asymptomatic recurrence seen in up to 50% but symptomatic recurrence noted in only 4.5%.

COMPLICATIONS

- Intraabdominal bleeding
- Bile leak
- Subphrenic abscess
- Biloma
- Wound infection

SUGGESTED READINGS

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Chapter **18**

Surgical Management of Hepatic Trauma

Walter L. Biffl Carlton C. Barnett, Jr.

DEFINITION

- Hepatic trauma is defined as injury to the liver. It may be associated with hemorrhage, bile leak, or devitalized tissue. There is a spectrum of severity of liver trauma (Table 1),[1] and a broad range of techniques may be employed to manage various injuries.[2–4]

DIFFERENTIAL DIAGNOSIS

- Abdominal trauma can be associated with injuries to any abdominal organ. Major sources of hemorrhage include solid organs (e.g., liver, spleen, kidneys) and major vessels in the retroperitoneum (e.g., aorta, inferior vena cava [IVC], renal vessels) or mesentery. Peritonitis may result from bile leak or from any injury to a hollow viscus (e.g., bowel, biliary tree, pancreas).

PATIENT HISTORY AND PHYSICAL FINDINGS

- Liver injuries may occur following either blunt (e.g., motor vehicle crash, fall) or penetrating (e.g., gunshot or stab wound) trauma to the abdomen.
- The liver is one of the most commonly injured organs following blunt trauma. Impact to the lower right chest or the abdomen puts the patient at risk of liver injury. Any high-energy mechanism should raise concern of intraabdominal injury.
- The liver, due to its large surface area, is frequently injured in penetrating abdominal or lower thoracic trauma. The path of gunshot wounds to the torso cannot be determined based on physical examination alone.

Table 1: Grading of Liver Injuries

Grade		Injury Description
I	Hematoma	Subcapsular, <10% surface area
	Laceration	<1 cm parenchymal depth
II	Hematoma	Subcapsular, 10%–50% surface area; intraparenchymal, <10 cm diameter
	Laceration	1–3 cm parenchymal depth, <10 cm length
III	Hematoma	Subcapsular, >50% surface area or expanding; intraparenchymal, >10 cm diameter or expanding, or ruptured
	Laceration	>3 cm parenchymal depth
IV	Laceration	Parenchymal disruption involving 25%–75% of hepatic lobe or 1–3 Couinaud's segments in a single lobe
V	Laceration	Parenchymal disruption involving >75% of hepatic lobe or >3 Couinaud's segments in a single lobe
	Vascular	Juxtahepatic venous injuries
VI	Vascular	Hepatic avulsion

Advance one grade for multiple injuries up to grade III.

From Moore EE, Cogbill TH, Jurkovich GJ, et al. Organ injury scaling: spleen and liver (1994 Revision). J Trauma. *1995;38:323–324.*

- Abdominal pain or tenderness on examination raise concern for abdominal injury; however, patients may have severe liver injuries in the absence of pain or tenderness. Vital signs are a critical component of the assessment of trauma patients, as the decision to proceed with surgical (versus nonoperative) management is primarily based on physiologic condition of the patient. The vast majority of liver injuries are managed nonoperatively.

IMAGING AND OTHER DIAGNOSTIC STUDIES

- Ultrasound—in particular, the focused abdominal sonographic examination for trauma (FAST)—is increasingly used as an initial triage tool in trauma patients. Following blunt trauma, the finding of free fluid in the abdomen in the presence of shock is an indication to proceed to exploratory laparotomy (LAP) without delay. The finding of hemoperitoneum on FAST exam in the absence of hemodynamic instability is not an indication for LAP; injuries to abdominal wall, omentum, or liver often stop bleeding spontaneously and do not require any interventions.
- The FAST exam is less useful in penetrating trauma victims. Those with gunshot wounds should undergo immediate LAP. Those with stab wounds should undergo LAP if they exhibit shock, evisceration, or peritonitis. Otherwise, they should be admitted for serial clinical assessments to detect ongoing hemorrhage or hollow viscus injury.
- Most liver injuries due to blunt trauma are diagnosed by computed tomography (CT) (**FIG 1**). CT is indicated in any patient with major abdominal blunt trauma mechanism, abdominal pain or tenderness, hemoperitoneum on FAST exam in a stable patient, pelvic fractures, or the inability to clinically assess the abdominal exam and the potential

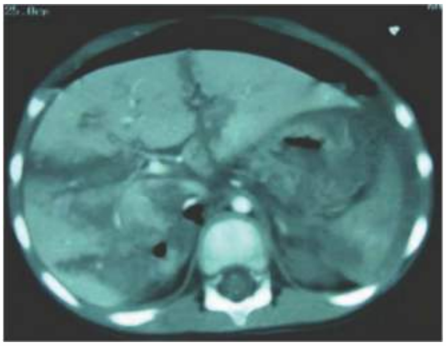


FIG 1 ● CT scan image of a grade IV liver injury. Despite the extensive injury to the liver, note the relative paucity of blood surrounding the liver. This is a pitfall of FAST ultrasonography, as it detects primarily free fluid. It also speaks to the lack of sensitivity of FAST for individual organ injuries. It detects blood but not the source of the bleeding.

for abdominal trauma (e.g., a patient with severe traumatic brain injury following motor vehicle crash). Specific to liver laceration, the identification of intravenous contrast extravasation warrants treatment rather than observation.
- Arteriography with embolization can be selectively employed as a primary treatment or as an adjunct to surgical management of liver lacerations with arterial hemorrhage. This may be employed more frequently in centers with hybrid operating room (OR)/interventional radiology (IR) suites.
- Cholangiography is sometimes useful to determine whether there is biliary injury and ongoing bile leak. This is generally performed later in the postinjury course. The presence of a biliary injury and bile leak generally calls for intervention either surgical or endoscopic.
- Magnetic resonance imaging has little role in the management of liver trauma.

SURGICAL MANAGEMENT

- Severe abdominal pain or tenderness, peritonitis, evisceration, or shock with a presumed abdominal injury warrant LAP.
- Following stab wounds, the presence of shock, evisceration, or peritonitis is a clear indication for LAP. Gunshot wound to the abdomen, given its high association with significant injury, is an indication for LAP regardless of the initial physical findings.

Preoperative Planning

- Prior to taking the patient to the OR, the surgeon should communicate with the OR team regarding the suspected diagnoses and planned interventions, anticipated blood loss and transfusion requirements, positioning and incisions, extent of skin preparation, the need for imaging, and any special equipment needs.

Positioning

- The patient should be positioned supine. There is no advantage to tucking the arms. In the setting of trauma, it is best to leave both arms out to allow the anesthesiologist's access for venous and arterial catheterization and sampling.

TECHNIQUES

SKIN INCISION

- Exploratory LAP for trauma should be performed through a generous midline abdominal incision. Although it may not initially extend from the xiphoid to pubis, as is classically suggested, once a major liver injury is identified, extension up to the xiphoid process is recommended to afford optimal exposure. Some elective liver surgery is performed through right or bilateral subcostal incisions, with or without cephalad extension in the midline. This may be chosen if the operation is performed later in the patient's clinical course for complications of liver injury, typically bile leak. However, this may limit access to the lower abdomen in the event there are multiple injuries. If a midline incision has been made, the surgeon should not hesitate to extend the incision to the right if necessary. Adequate exposure is critical to repairing major hepatic injuries.

ABDOMINAL EXPLORATION

- The initial objective of trauma LAP is to determine if there is exsanguinating hemorrhage and from where it emanates. Blood must be evacuated and the source identified. Primary culprits are solid organs, retroperitoneal vessels, and mesentery. The surgeon should be able to rapidly assess the liver for major lacerations, by inspecting it and palpating its surface.

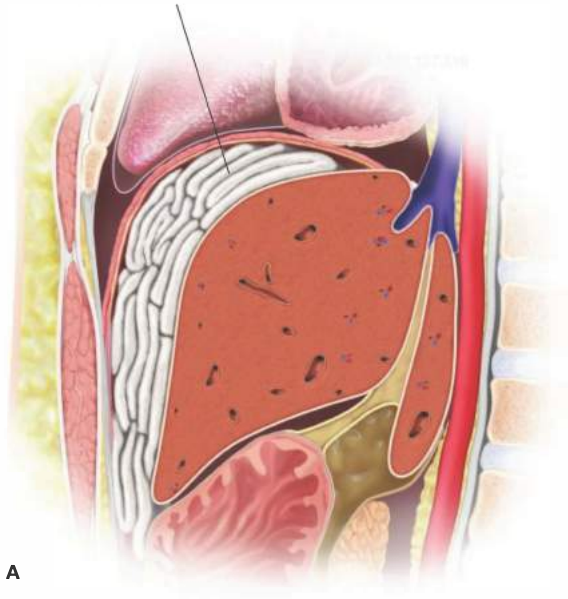
MANUAL COMPRESSION

- The first step in hepatic hemorrhage control is manual compression (**FIG 2**). This should be able to control the vast majority of liver bleeding. The importance of simultaneous aggressive resuscitation cannot be overemphasized. Restoration of blood volume and maintenance of tissue perfusion, correction of coagulopathy, and active warming of the patient are critical to avoid the "bloody vicious cycle" that can lead to early mortality.

FIG 2 ● Manual compression of the liver is performed to restore the normal anatomic contour of the liver and tamponade bleeding. This maneuver can control hemorrhage while planning packing or definitive interventions.

PERIHEPATIC PACKING

- Perihepatic packing should be performed in such a manner to maintain hemostatic compression on the liver (**FIG 3**). The supporting ligaments of the liver are left intact at this stage, as they may provide tamponade of venous bleeding. However, should the patient have stellate lacerations or extensive subcapsular injury, one should not hesitate to mobilize the suspensory ligament of the falciform or the right and left triangular ligaments to allow better exposure. Packing should be performed in a systematic fashion, placing packs between the liver and the abdominal wall, diaphragm, and retroperitoneum.



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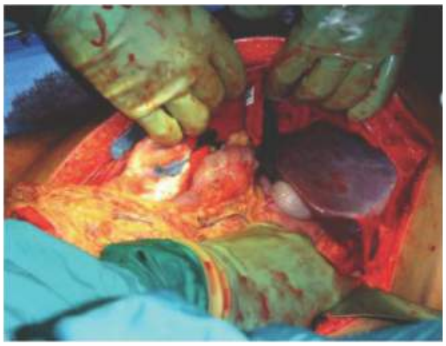

B

FIG 3 ● The liver is packed with LAP pads to provide compression against the abdominal wall, diaphragm, and retroperitoneum. **A.** In the sagittal view, packs are present between the liver and the diaphragm and abdominal wall. **B.** In the photograph, the right lobe is compressed by packs.

TOPICAL HEMOSTASIS

- Grades I and II lacerations (see Table 1) may stop bleeding spontaneously or after a short period of packing (**FIG 4**). Ongoing hemorrhage can usually be controlled with electrocautery or argon beam coagulation, with or without application of topical hemostatic agents such as microcrystalline collagen, fibrin glue, or other agents (**FIG 5**).

FIG 4 ● Low-grade lacerations *(arrow)* may often stop bleeding spontaneously or following a brief period of compression or packing.

A 

B 

FIG 5 ● Low-grade injuries with persistent bleeding may be treated by topical hemostatic techniques such as argon beam coagulation **(A)** or microcrystalline collagen application **(B)**.

DAMAGE CONTROL

- In the physiologically compromised patient, the decision to pursue damage control must be made early in order to optimize the patient's chance of survival. Time-consuming efforts to stop relatively minor bleeding should not distract the surgeon from the primary objective. The liver should be packed quickly and other damage control maneuvers completed prior to a temporary abdominal closure. In order to facilitate later pack removal without disrupting clot, a nonadherent plastic drape may be spread over the liver surface, with the packs placed on top of the plastic.

DEEP PARENCHYMAL HEMORRHAGE CONTROL

- If the patient's condition allows, the liver should be examined to determine the extent of the injury. Grades II and III lacerations should be inspected to determine whether a discrete vessel may be ligated (FIG 6). Bleeding can generally be controlled by packing the wound with an omental pedicle or a plug of topical hemostatic agents such as absorbable gelatin sponge wrapped in oxidized regenerated cellulose (FIG 7). Suture hepatorrhaphy is an option, but one must avoid leaving a large dead space and avoid devitalizing tissue or lacerating vessels or bile ducts. Extensive lacerations may need to be explored to control major vessels. The finger fracture technique allows one to reach major vessels for ligation (FIG 8). Stapling devices can also be useful in dividing the hepatic parenchyma to reach deep vessels (FIG 9).

FIG 6 ● The laceration should be explored to identify discrete vessels to ligate.

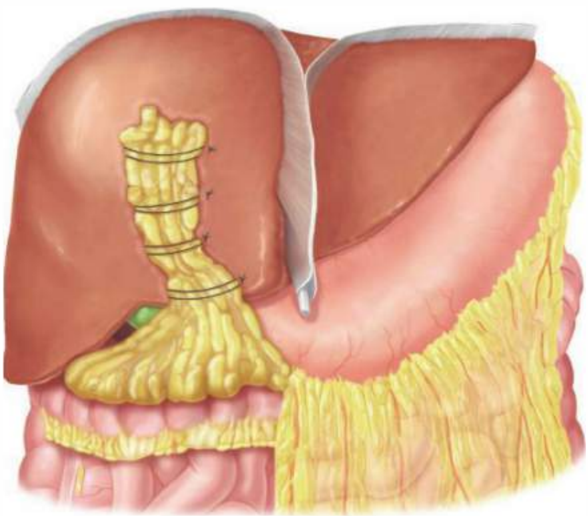

FIG 7 ● Omental pedicle packing may provide hemostasis for deeper injuries.

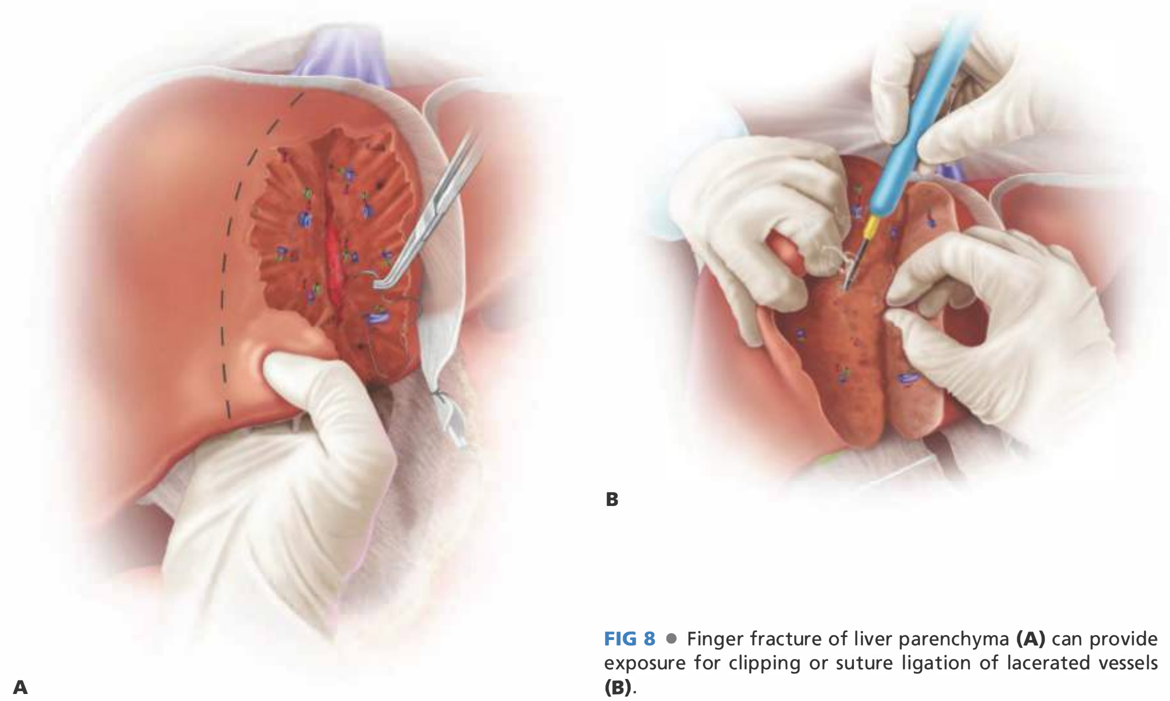

FIG 8 ● Finger fracture of liver parenchyma **(A)** can provide exposure for clipping or suture ligation of lacerated vessels **(B)**.

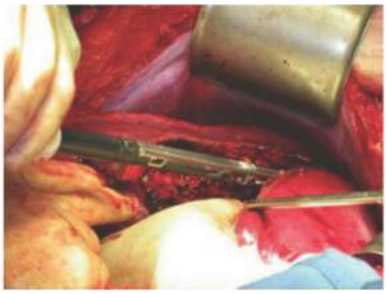

FIG 9 ● Surgical staplers may be used to divide liver parenchyma to reach bleeding vessels.

BALLOON TAMPONADE

- Transhepatic penetrating wounds may leave a long intracavitary defect that is difficult to access for vascular control. Balloon tamponade may be accomplished by a device originally described by Poggetti and colleagues.[5] This may be fashioned by ligating a 1-in Penrose drain at one end. A red rubber catheter is inserted into the open end and secured with a second ligature. The Penrose drain is pulled through the wound, with the red rubber catheter and drain exiting the abdominal wall. The balloon is inflated with saline to achieve tamponade (**FIG 10**).

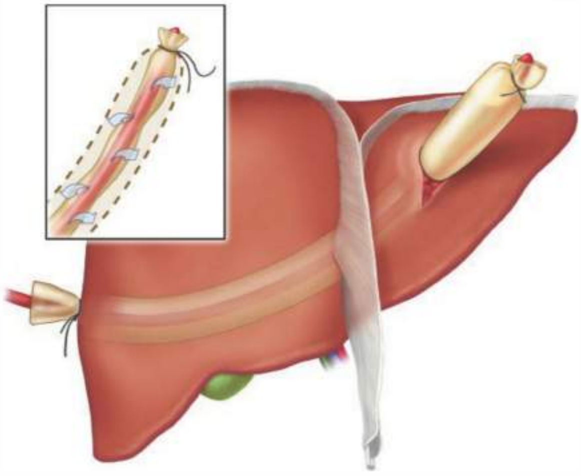

FIG 10 ● Balloon tamponade is an effective means of hemorrhage control for penetrating wounds through the middle of the liver.

PRINGLE MANEUVER

- Bleeding that persists despite packing may be arterial in origin. The Pringle maneuver—that is, control of the hepatoduodenal ligament with a Rumel tourniquet or vascular clamp—should be employed (**FIG 11**). If this controls hemorrhage, it is likely that the bleeding is from either a hepatic arterial branch or major branch of the portal vein. This cannot be left in place for a prolonged period. Intermittent unclamping decreases the degree of ischemia/reperfusion injury. Definitive maneuvers must be undertaken and the clamp should be released within 60 minutes if possible. Ligation of the right or left hepatic artery may control the bleeding. Alternatively, in the appropriate setting, the patient may undergo arterioembolization.

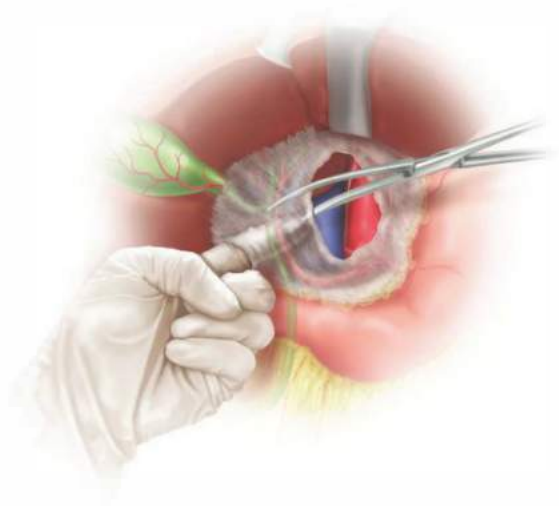

FIG 11 ● The Pringle maneuver. A vascular clamp is applied to the hepatoduodenal ligament, passing the posterior blade through the foramen of Winslow, guided by the index finger.

HEPATIC RESECTION

- Resection of devitalized tissue may be performed at the initial operation; in the damage control setting, however, this is reserved for subsequent LAP. The extent of devitalized tissue is generally readily apparent (**FIG 12**). Resection may be necessary to control major vascular or biliary structures. Again, in the patient who is severely compromised physiologically, this is best done after resuscitation.

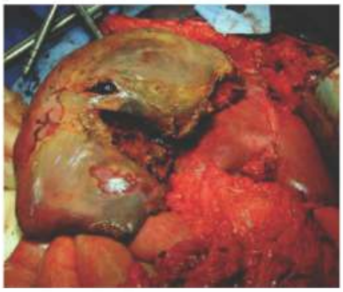

FIG 12 ● Hepatic necrosis may result from major injury or vascular ligation to control bleeding.

HEPATIC VASCULAR ISOLATION

- Bleeding that persists despite the Pringle maneuver is likely from the hepatic veins. Hepatic vascular isolation with or without venovenous bypass should be considered (**FIG 13**).[6] This entails control of the suprarenal IVC, the suprahepatic IVC, and a Pringle maneuver. If the interruption of venous return results in cardiovascular collapse, the aorta may need to be cross-clamped while venovenous bypass is established. The suprahepatic clamp may be placed below the diaphragm, but this is not ideal. The clamp optimally should be placed within the pericardium. This can be accomplished from within the abdomen, but the exposure is markedly improved by median sternotomy (**FIG 14**).

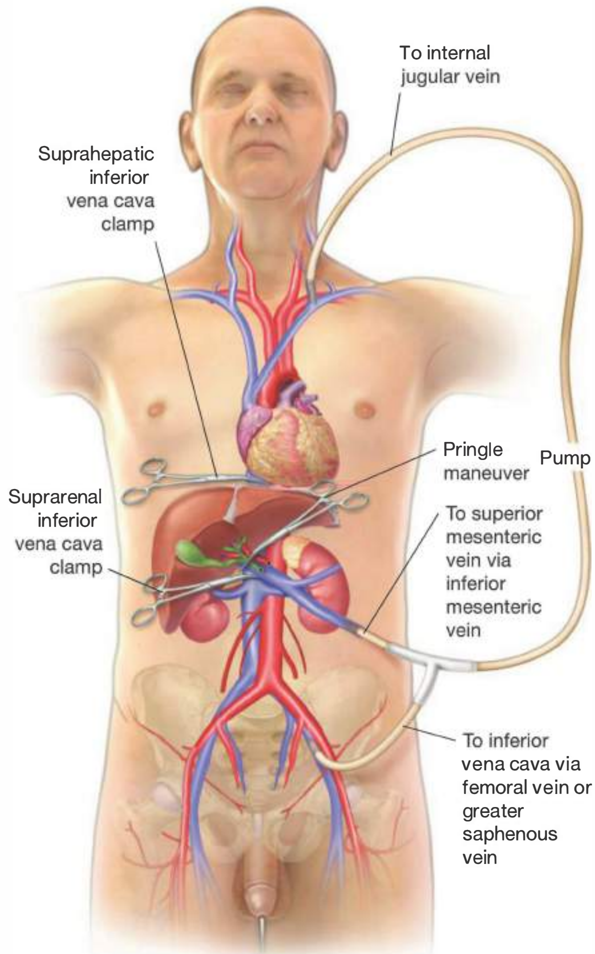

FIG 13 ● Hepatic vascular isolation and venovenous bypass is performed by clamping the suprarenal IVC, the suprahepatic IVC, and a Pringle maneuver. Venous cannulae are positioned in the femoral vein and superior mesenteric vein, and blood is shunted into the internal jugular vein.

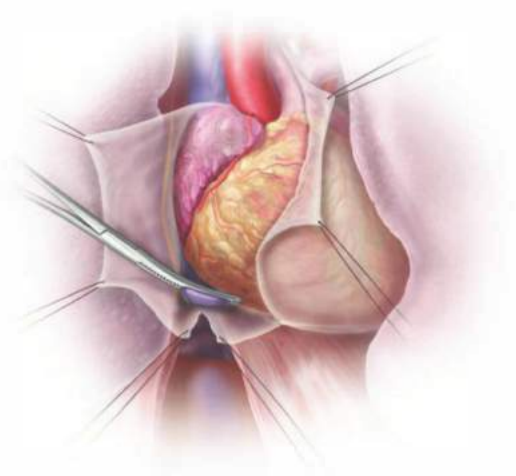

FIG 14 ● Combining a median sternotomy with a midline LAP incision provides exposure to the hepatic veins and retrohepatic vena cava while avoiding injury to the phrenic nerves. The pericardium and diaphragm can be divided down the center toward the IVC.

CLOSURE

- If the liver is to remain packed, a temporary abdominal closure should be performed. Goals are rapid closure, containment of abdominal viscera, prevent bowel from adhering to fascial edges, allow room for swelling of abdominal viscera, provide a means for egress of ascites, maintain sterility of the abdominal cavity, avoid damage to fascia and skin edges, and minimize cost. The "Vac-Pack" dressing satisfies all of these requirements (**FIG 15**). A plastic sheet is draped over the bowel and extended to the paracolic gutters to keep the bowel from adhering to wound edges. Slits are cut in the sheet to allow egress of ascites. A towel is placed over the sheet to prevent suction drains from adhering to bowel through the slits. Drains are placed on top of the towel. An adhesive drape is placed over the entire wound. Definitive closure may be achieved by simple running fascial suture (e.g., no. 2 nylon) and skin staples.

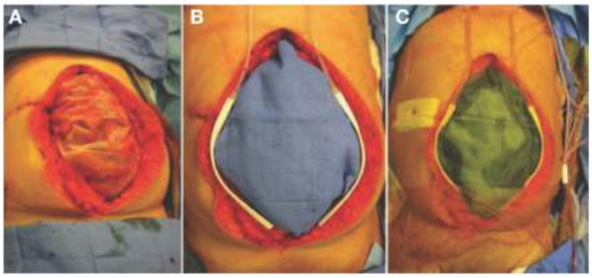

FIG 15 ● Temporary closure of the abdomen entails covering the bowel with a fenestrated plastic drape **(A)**, placement of closed suction drains and a blue towel **(B)**, followed by an adhesive occlusive dressing **(C)**.

PEARLS AND PITFALLS

Indication for LAP	■ Unstable patients should go to the OR promptly. Pursuing angioembolization in an unstable patient is not advisable and may prove disastrous.
Incision	■ A midline incision is the best choice in an unstable trauma patient. The surgeon should not hesitate to extend the incision rightward or into the chest in order to gain exposure and control. Median sternotomy markedly improves exposure for retrohepatic venous repairs.
Damage control	■ The decision to pack the liver should be made very quickly, as should the decision to adopt a "damage control" strategy.
Resuscitation	■ Ongoing resuscitation is critical during the operative phase.
Definitive procedures	■ Avoid major definitive procedures at the first operation, if the patient's condition warrants damage control.

POSTOPERATIVE CARE

- Trauma patients should be monitored for response to resuscitation. Once resuscitated, postoperative care is routine for abdominal surgery, with provision of diet as tolerated and early ambulation.

OUTCOMES

- Severe liver injuries may be associated with high morbidity and mortality rates. However, patients who survive without significant complications should be expected to have normal life span and functional status vis-à-vis the liver injury.

COMPLICATIONS

Hemorrhage

- Postoperative bleeding is not common outside of the damage control setting. Bleeding may continue despite liver packing. In this case, depending on the patient's condition, angioembolization may be reasonable to control arterial hemorrhage. On the other hand, if the patient is physiologically compromised, it is prudent to return to the OR to control surgical hemorrhage while resuscitating the patient.

Abdominal Compartment Syndrome

- The abdominal compartment syndrome refers to intraabdominal hypertension that is associated with organ dysfunction (see Part 3, Chapter 26). It is often seen in association with damage control surgery in the presence of liver packing. The accumulation of ascites and retroperitoneal edema, coupled with bowel swelling, lead to a progressive rise in abdominal pressure. Patients may develop the abdominal compartment syndrome in spite of an open abdomen, so the intraabdominal pressure and organ function should be monitored.

Bile Leak

- This is the most common major complication of liver injury. Leaks may come from any biliary repair or anastomosis. They may also originate from peripheral biliary radicals. If a bile duct repair has leaked, it may be managed via endoscopic means (e.g., stenting). Peripheral leaks usually spontaneously seal, but occasionally, leakage persists. This may be managed by endoscopic stenting. Bile collections should be drained.

Hemobilia

- Generally caused by injuries to an adjacent hepatic artery and bile duct, hemobilia is heralded by right upper quadrant pain, jaundice, and falling hemoglobin level. A more dramatic presentation may be upper gastrointestinal hemorrhage, as blood enters the duodenum via the common bile duct. Endoscopy can make the diagnosis, as blood is seen exiting from the ampulla of Vater. Angioembolization of the involved artery may be definitive treatment, but occasionally, drainage and/or debridement of a large hematoma/biloma cavity is needed.

Bilhemia

- Bilhemia results from a biliovenous fistula. Bilirubin levels can rise dramatically. Endoscopic biliary stenting may facilitate resolution, but hepatic resection may be required.

Hepatic Necrosis

- Although this may result from the initial injury, ligation or embolization of major vascular branches may also result in hepatic necrosis. This generally requires operative debridement or resection.

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Chapter **19**

Hepatic Neoplasm Ablation and Related Technology

Ido Nachmany Ravit Geva

DEFINITION

- Hepatic ablation represents the use of chemical or physical means to destroy a neoplastic lesion and surrounding normal tissues as an alternative to resection.

INTRODUCTION

- The liver is one of the most common sites for development of malignancy—either primary or metastatic disease.
- As a general concept, the main curative option for liver tumors is surgical resection via partial hepatectomy or whole liver replacement. A variety of clinical situations preclude this approach; ablation is an attractive and viable option in some of these clinical situations.
- The most common indications for liver resection are colorectal cancer liver metastases (CLM), primary liver cancer (mainly HCC and CCA).
- In the case of CLM, about 50% of patients will ultimately develop liver metastases. Only about 15% to 20% are resectable at presentation.[1]
- Oncologic benefit of liver resection has been shown only when complete clearance of metastatic disease is achieved.
- Factors limiting resection include extent of tumor involvement, volume of the postresection liver remnant, anatomic proximity to essential intrahepatic structures, underlying liver disease, and comorbidities.
- HCC is the only universally accepted oncologic indication for liver transplantation (OLT). Only a small subset of patients is suitable for OLT, mainly due to stringent criteria influenced by the limited organ availability and inferior long-term survival in patients with locally advanced disease.
- For patients with unresectable liver tumors or those beyond criteria for OLT, life prolongation and control of symptoms are the major goals. This can be achieved by systemic therapy or by different locoregional modalities, grouped under two major categories: tumor ablation and transarterial treatment (chemotherapy infusion, embolization, combination of the two and irradiation).
- Ablation can be achieved by direct application of thermal energy (by cooling: cryoablation; heating: radiofrequency ablation [RFA] or microwave ablation [MWA]), chemical ablation: percutaneous acetic acid (PAI) or percutaneous ethanol injection (PEI), or newer techniques: irreversible electroporation (IRE).
- The most commonly applied modality is thermal ablation using RFA technique. In recent years, MWA has also been rapidly gaining acceptance.
- Based on accumulating data supporting the clinical benefit of ablation techniques, there had been an expansion of the indications. Ablation is now introduced in combination with liver resection and, in limited cases, as a replacement of resection with curative intent.
- Ablation can be performed percutaneously, laparoscopically, or via laparotomy.
- The main advantage of a percutaneous approach is the minimal invasiveness of the procedure.
- The advantages of using ablative modalities in surgery are the ability to reach any territory of the liver, the ability to combine ablation with resection, and the control of inflow and outflow. This may counteract the cooling effect of blood flow in major vessels (referred to as the "heat sink" effect). Laparoscopic ablation may combine the benefits of surgery with those of minimally invasive treatment.
- Studying the long-term effectiveness of ablative modalities has been challenging; in part, this is due to the rapid evolution of ablative tools (probes and energy sources), thus the field is in constant development. Also, the results of most studies are limited by sample size, methodology, and follow-up time.

INDICATIONS

- HCC
  - The vast majority of patients with HCC have background chronic liver disease. The management of these patients takes into account the primary liver disease (synthetic dysfunction and portal hypertension) as well as the extent of the tumor.
  - The most commonly used algorithm outside of the United States for HCC management is the Barcelona Clinic for Liver Cancer (BCLC) staging and treatment strategy.[2] Other criteria (Milan and University of California, San Francisco [UCSF]) have also been forwarded.
  - Based on the BCLC algorithm, patients suitable for curative treatment are those with very early and early stages (stages 0 and A).
  - Curative options include resection, liver transplantation, and, in some cases, ablation. The choice between the different options is based on the extent of liver disease, tumor stage, tumor location, and patient comorbidities.
  - There are three subsets of patients specifically suitable for ablation:
    - Patients with unresectable HCC beyond transplant criteria. Tumor ablation is usually combined with other treatment modalities, such as transarterial chemoembolization (TACE). These patients are not considered curable.
    - Patients with very early stage HCC (stage 0—single, up to 2 cm tumor with Child A cirrhosis, and in good performance status) are usually considered resection candidates. Recent data suggest that they can also be managed by ablative modalities. The main potential benefit of resection over ablation is the availability of

the pathologic specimen. The presence of microvascular invasion or microsatellites in the specimen, which are major risk factors for recurrence, is considered by some an indication for "salvage OLT."[3] Therefore, if the patient is a transplant candidate, resection is preferred over ablation. On the other hand, ablation offers a less invasive procedure and may be attractive alternative to patients.
    - Patients with early stage HCC (stage A—up to 3 lesions, largest ≤3 cm, with Child A–B cirrhosis, and in good performance status) are best treated by OLT unless they have significant comorbidities. In such cases, ablation may be an alternative.
- Colorectal liver metastases
    - The only curative option for patients with CLM is resection, but unfortunately, this is possible in only about 15% to 20% of cases. Some patients may become resectable with neoadjuvant chemotherapy or with anticipated liver remnant volume manipulation such as portal vein embolization.[4]
    - The advantages of RFA include low complication rates, fast recovery, and good safety profile in patients with marginal liver reserve. The main disadvantages are the higher local recurrence rates and limitations in treating large or multiple lesions.
    - Tumor ablation is a valid option for
        - Patients with limited disease that cannot achieve R0 resection with surgery
        - Patients who are not surgical candidates due to systemic conditions or because of multiple previous operations on the liver
        - Some authors consider ablation an alternative in patients with resectable metastases. There are currently no studies to support this approach.[5] In the future, with improving devices and technique, the equivalence of ablation and resection may eventually be demonstrated.
        - Ablation can also be used in combination with resection of other metastases. This is usually done for relatively small and deeply seated lesions for which resection would dramatically increase the morbidity of the procedure.

CONTRAINDICATIONS

- There are very few contraindications for ablative therapy.
- An absolute contraindication for thermal ablation is abutment of hilar structures, mainly the bile ducts and gallbladder, due to the high risk of thermal injury. This may not apply for IRE.
- The vicinity of major blood vessels (specifically hepatic veins and large portal branches) is associated with significantly reduced efficacy due to the heat sink effect and is a risk factor for local recurrence. This can be overcome surgically to some degree by flow manipulation such as the Pringle maneuver or outflow obstruction and thus is not considered an absolute contraindication.

- Chemical ablation with injection (usually percutaneously) of ethanol or acetic acid was used mainly for HCC, because this tumor is soft and accepts the fluid injected well. Currently, use of chemical ablation is not common mainly due to inferior efficacy, as compared to thermal ablation and the need for repeated treatments.[6]
- RFA
    - RFA uses alternating electric field delivered through a needle or multiple needle electrodes. It can be inserted percutaneously, laparoscopically, or at laparotomy (**FIGS 1** and **2**).
    - Ions in the tissue follow the direction of the rapidly changing current. This causes frictional energy to produce heat and coagulative necrosis.
    - As temperatures approach 100°C, changes in the physical properties of the tissue increase impedance and limit the flow of current (tissue desiccation due to evaporation of tissue fluid, charring, and the formation of electrically insulating gas between the electrode and the tissue due to boiling). This limits treatment of larger tumors.
- MWA[7]
    - MWA uses electromagnetic radiation, much higher on the spectrum of electromagnetic radiation than

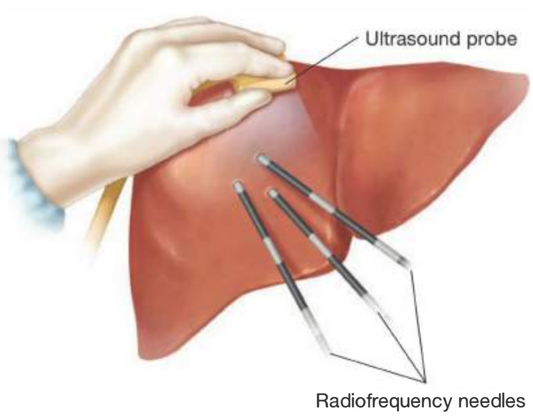

FIG 1 ● Three RF needles liver insertion.

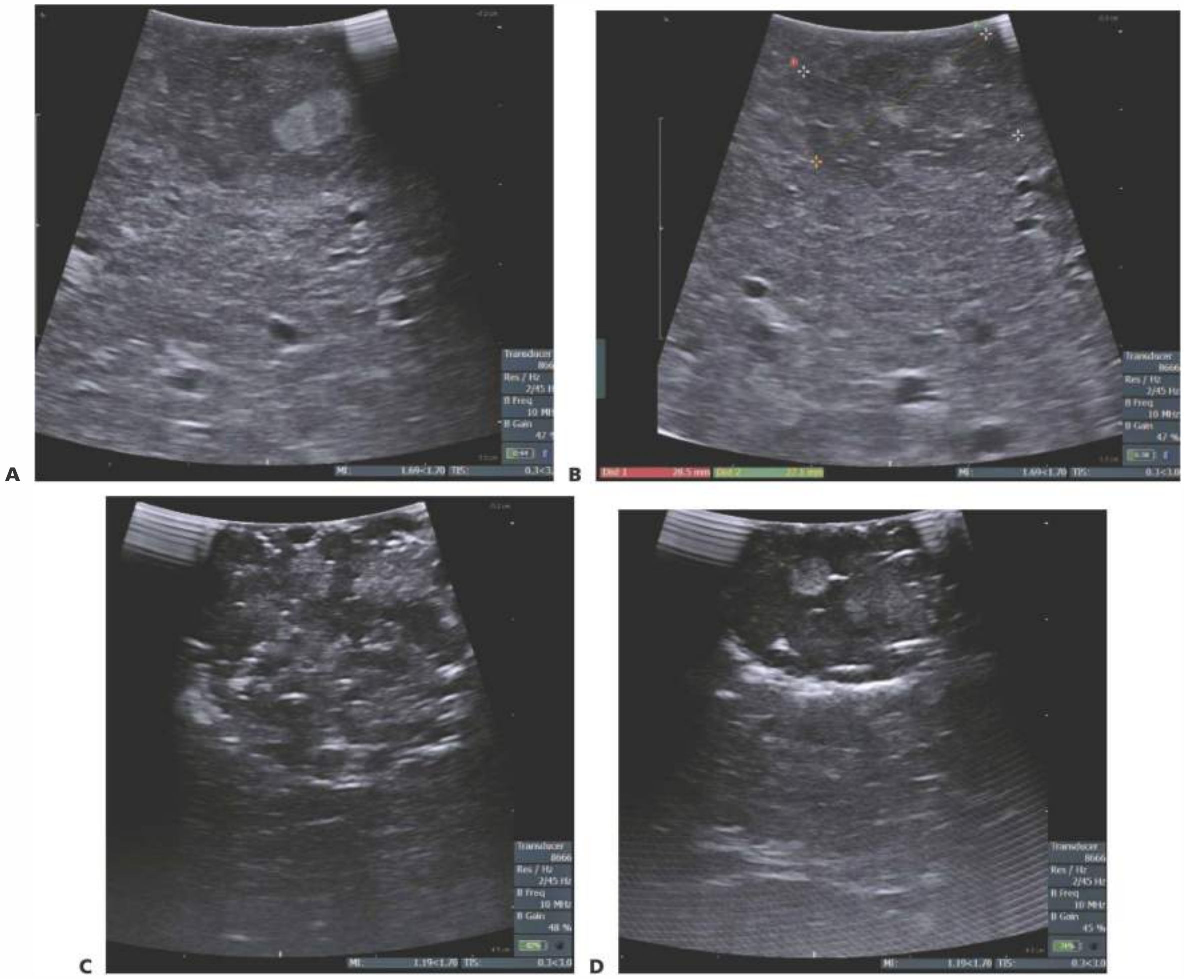

FIG 2 ● Laparoscopic ultrasound (US)-guided RFA of a peripheral HCC. **A.** Before ablation. **B.** Lesion measurements. **C.** During ablation. **D.** Immediate postablation. Note the typical artifacts created by the gas formed by tissue boiling.

RFA (usually in the range of 900 to 2,450 MHz) (**FIGS 3** and **4**).

- Polar molecules in the electromagnetic field (mainly water) try to align in the direction of the current. As the direction changes constantly, continuous realignment causes friction and heating effect. Like RFA, the heat causes cell death by coagulative necrosis.
- Unlike RFA, MW causes oscillation of water molecules in the entire field, so heat is uniformly distributed in the MW field throughout the activation. This achieves immediate and homogeneous heating and therefore faster tissue destruction.
- Heat is conducted outside of that field, so the ultimate ablation size is the sum of the microwave field and the conductive heat zone.
- The size of the microwave field is determined by the wavelength and the antenna design.
- Within the microwave field, heat sink and current sink effects are not present. Outside the microwave field (in the conduction zone) there will be a heat sink effect, similar to RFA.[8]
- MWA does not require point-to-point currents.
- No current flows through the patient and no grounding pads are required.

- IRE[9]
  - IRE is a new technique, based on nonthermal tissue destruction.
  - IRE is performed by placing electrodes into the tissue and delivering multiple high-voltage electrical pulses to induce pores in the lipid bilayer of cell membrane. This starts a process that leads to cell death.
  - IRE is not influenced by the heat sink effect.
  - Because the location of IRE activity is the cell membrane, acellular structures are preserved. Because hilar structures are wrapped in a fibrous sheet, they are protected. This allows for application of IRE to lesions in the vicinity of intrahepatic vital structures, unlike thermal ablation.[10]

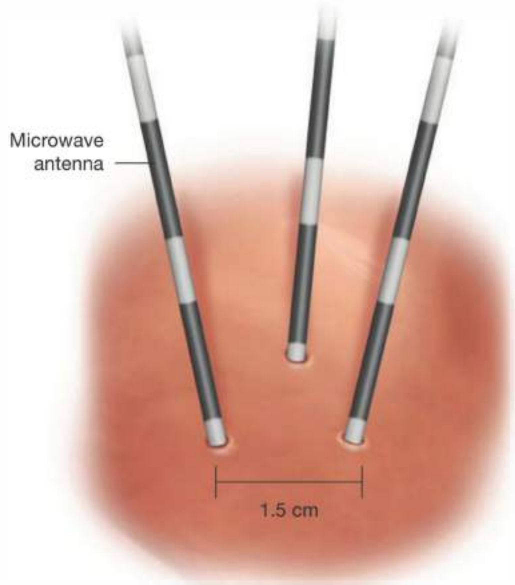

FIG 3 ● Three microwave antennas arrayed to ablate a large lesion.

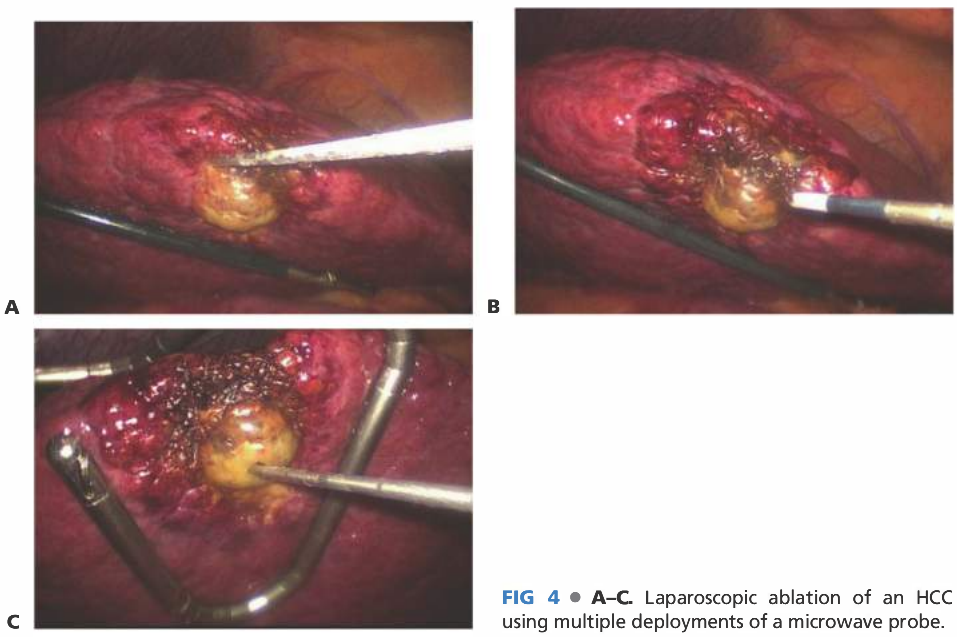

FIG 4 ● **A–C.** Laparoscopic ablation of an HCC using multiple deployments of a microwave probe.

PEARLS AND PITFALLS

Indications	■ Resection is not an option. ■ The lesion is not too big. ■ The lesion is not adjacent to a heat sink or vital structure. ■ Ultrasound in cirrhotic livers is technically challenging.
Technique	■ Confirm appropriate probe placement with ultrasound—Record the images. ■ Confirm complete destruction of the lesion by ultrasound—Record the images. ■ Precoagulation prior to parenchymal transection (**FIG 5**)

FIG 5 ● MWA as a precoagulant strategy prior to parenchymal transection.

OUTCOMES

- Factors influencing outcome include the following:
  - Tumor size. Best results are achieved for the treatment of small tumors less than 3 cm for RFA. MWA achieves effective results in somewhat larger lesions but is also limited by lesion size.[11]
  - Ablation margin. In order to minimize the chance for local recurrence, it is advised to leave a rim of 1 cm of ablated tissue beyond the tumor margin.
  - Vicinity to major vascular structures, mainly large veins, due to the heat sink effect
  - Mode of application. Surgical application usually achieves better outcome than percutaneous.
  - Ablation is operator dependent and therefore experience plays a major role.
- Assessing the isolated effect of ablation is difficult. In most cases, ablation is not considered curative; therefore, it is usually combined with other treatment modalities. Also, there are no high-quality randomized studies, the follow-up is usually short, and the devices used are in constant evolution.
- The most representative benchmark of ablation efficacy is local recurrence at the ablation site. This is widely variable, and in the case of RFA, runs from 2% to 60%.[12]
- HCC
  - In a large study on nearly 3,000 RFA treatments done on more than 1,000 patients, the 5- and 10-year survival rates were 60.2% and 27.3%, respectively, and the 5- and 10-year local progression rates were both 3.2%.[13]
  - Complete pathologic response for HCC smaller than 3 cm is as high as 65% with RFA and similar results had been shown with MWA.[14–16]
  - Combining eight studies and more than 1,000 patients, Giacomo et al.[6] found that RFA was superior to PAI or PEI with regard to survival, complete tumor necrosis, and local recurrence.
- CLM
  - During the past decade, RFA has superseded other ablative therapies, due to its low morbidity, mortality, safety, and patient acceptability. In the near future, MWA may become the leading modality due to some benefits over RFA.
  - Multiple studies have compared RFA to liver resection as a radical approach to CLM. These studies demonstrated higher local recurrence of RFA as compared to resection.[11,17–19]
  - A recent Cochrane analysis comparing RFA to hepatic resection concluded that the current data is insufficient to consider RFA to be as effective as surgery.[5]
  - In the case of nonresectable CLM, the addition of ablation to systemic chemotherapy probably increases the progression-free survival, although it was not found to have significant effect on the overall survival.[20]

COMPLICATIONS

- Morbidity and mortality are relatively low. Complications include bleeding, vascular thrombosis, abscess formation, and injury to intrahepatic structures (mainly bile ducts and gallbladder) and extrahepatic organs (colon, duodenum, etc.).
- In the case of RFA, morbidity had been reported in about 10% of cases and mortality is very rare.[12]
- For MWA, Martin et al.[21] reported an overall 90-day mortality and morbidity rate of 0% and 29%, respectively, from a cohort of 100 patients treated with a total of 270 ablations. Only 1 patient developed hepatic abscess (**FIG 6**), and there were no bleeding complications.
- Needle track seeding is extremely rare. For percutaneous MWA, it was found to be 0.47% per tumor and 0.75% per patient.[22]

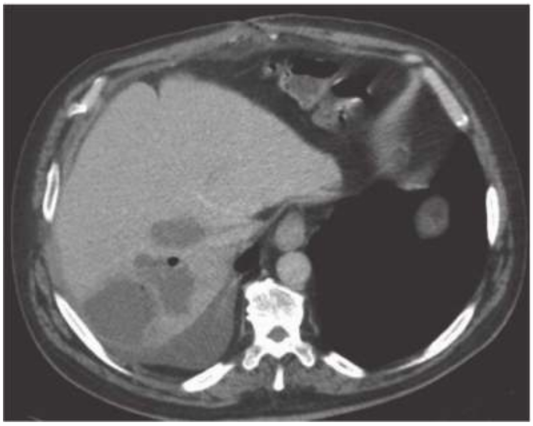

FIG 6 ● A liver abscess in an RFA site.

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Chapter 20

Catheter-Based Treatment of Hepatic Neoplasms

Darren W. Postoak

DEFINITION

- Catheter-based treatment of hepatic neoplasms is a percutaneous, minimally invasive, image-guided therapy in which the anticancer regimen is delivered to the arterial supply of the tumor. The most common therapies are transarterial chemoembolization (TACE) and radioembolization using yttrium 90 (^{90}Y).

DIFFERENTIAL DIAGNOSIS

- Differential diagnosis of the different types of hepatic neoplasms is made by using tissue biopsies, tumor markers, and imaging characteristics. Dynamic computed tomography (CT)/magnetic resonance imaging (MRI) demonstrating intense arterial uptake followed by venous or delayed phase "washout" of contrast is considered to be diagnostic of hepatocellular carcinoma (HCC).[1]
- TACE and radioembolization are usually performed in patients with liver-dominant disease. These tumors may be primary liver malignancies or metastatic disease where the liver is the dominant site of the disease.

PATIENT HISTORY AND PHYSICAL FINDINGS

- A thorough history should be obtained prior to treatment including a past medical history, medications, and allergies. Prior therapy should be evaluated, especially if radioembolization is being considered and the patient has previously had external beam radiation to the liver.
- Performance status (ECOG [Eastern Conference Oncology Group] or Karnofsky) must be evaluated. Patients with poor performance status may not be suitable candidates for intra-arterial therapy.
- Arterial pulse examination is needed for planning of the arterial access site. Typically, the puncture site is the common femoral artery, but this may need to be adjusted if the patient has severe iliofemoral atherosclerotic disease.

IMAGING AND OTHER DIAGNOSTIC STUDIES

- All patients should have a preprocedural multiphase CT or MRI examination. A positron emission tomography/CT may be helpful in some instances.
- Imaging should be evaluated for tumor number, tumor volume, and portal vein invasion/thrombosis. The vascular anatomy should be evaluated for vascular disease and anatomic variants as this may change the treatment plan.
- Laboratory evaluation should include a complete blood count, coagulation profile, creatinine, albumin, and liver function studies.
- Exclusionary criteria include immediate life-threatening extrahepatic disease, tumor volume greater than 50% to 70%, uncorrectable flow to the gastrointestinal (GI) tract, and significant hepatopulmonary shunting.

SURGICAL MANAGEMENT

Preoperative Planning

- Patients need to be well hydrated, typically with 150 to 300 mL per hour of normal saline prior to and during the procedure.
- Preprocedure medications may include antiemetics and steroids.
- Antibiotics are administered as needed. This is important in patients without an intact sphincter of Oddi due to sphincterotomy, biliary stent or catheter placement, and surgical biliary-enteric anastomosis. The regimen is 2 weeks in total, beginning 2 days prior to the embolization procedure.[2,3]
- Radioembolization is a multistep procedure with a need for arterial embolization of vessels leading to the GI tract and a simulation of the procedural injection prior to the actual injection of ^{90}Y particles. This will be discussed in more depth in the "Techniques" section.
- Proton pump inhibitors are started about 2 weeks prior to radioembolization.
- Octreotide pretreatment is indicated in patients with metastatic carcinoid to help prevent a carcinoid crisis. Typically, 250 μg is administered intravenously about 1 hour prior to the procedure.

Positioning

- The patient is placed supine with both groins prepped and draped (**FIG 1**). If there are iliac arterial occlusions or other technical problems, then brachial artery access is the next choice with the left arm being preferred. For brachial access, the arm is extended 45 to 90 degrees away from the body.

FIG 1 • The patient is supine with both groins prepped and draped. The C-arm fluoroscopic unit and monitors are in position to visualize the puncture site in the common femoral artery and the entire abdomen.

TRANSARTERIAL CHEMOEMBOLIZATION

Superior Mesenteric Arteriogram with Venous Phase Imaging

- A 4- or 5-Fr catheter is used to selectively catheterize the superior mesenteric artery (SMA). The arterial phase (**FIG 2**) is inspected for anatomic variants such as a replaced right hepatic artery (**FIG 3**) or other anatomic variants. The potential for "parasitized" blood flow recruited from the SMA to the liver must also be assessed.
- The venous phase (**FIG 4**) is inspected to evaluate patency of the portal vein and to evaluate for hepatofugal flow. TACE can be performed in cirrhotic patients with hepatofugal portal flow, but a smaller volume of liver should be embolized each time.

Celiac and Common Hepatic Arteriograms

- The 4- or 5-Fr catheter is used to selectively catheterize these vessels. The arteriograms (**FIG 5**) are evaluated for anatomic variants such as a replaced or accessory left hepatic artery arising from a gastrohepatic trunk (**FIG 6**) and phrenic arteries, which may arise at the origin of the celiac.
- If the celiac artery is occluded, the occlusion can often be crossed and possibly stented to allow access or the procedure may be performed from the superior mesenteric artery in a retrograde approach via the pancreaticoduodenal arcade (**FIG 7**).
- Evaluate where the arterial supply to the tumors is arising. Try to limit embolization of branches that do not supply the tumors.

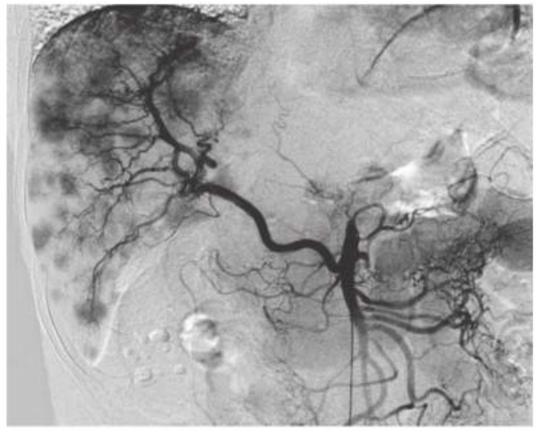


FIG 3 ● The replaced right hepatic artery is one of the anatomic variants more commonly seen. The replaced right hepatic artery arises as a branch of the superior mesenteric artery.

Advancement of the Catheter to Point of Embolization

- Commonly, this will be performed using a coaxial microcatheter.
- Advance the catheter as selectively as possible; however, a lobar embolization may be required if the tumors are scattered throughout the liver.
- In patients with intact gallbladders, evaluate where the cystic artery originates (**FIG 8**). Ideally, embolization

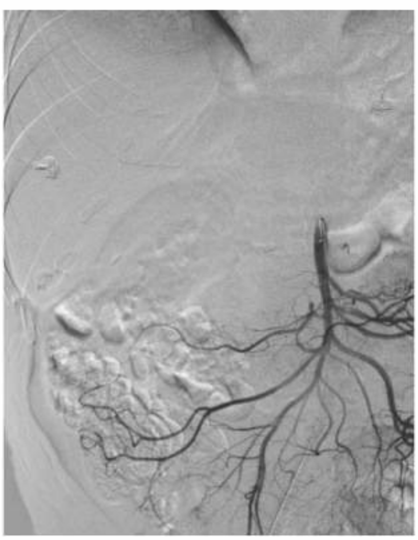


FIG 2 ● A superior mesenteric arteriogram is obtained to evaluate for anatomic variants. The patient is positioned to visualize the portal vein during the venous phase of the exam.

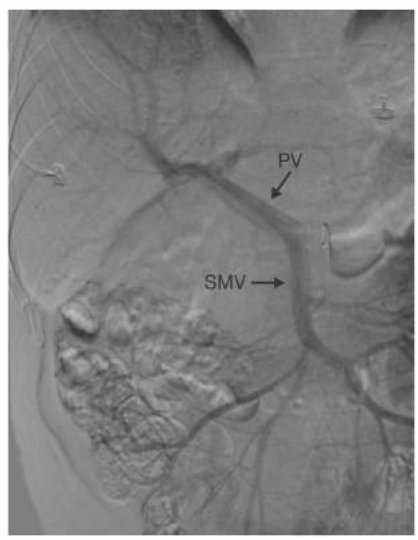


FIG 4 ● Venous phase following a superior mesenteric arteriogram demonstrates patency of the superior mesenteric and portal veins (same patient as **FIG 2**). PV, portal vein; SMV, superior mesenteric vein.

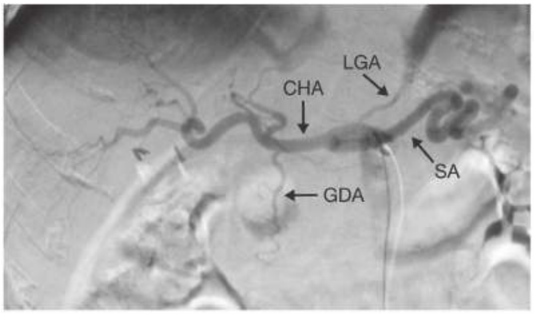


FIG 5 ● Celiac arteriogram demonstrating typical celiac and hepatic arterial anatomy. LGA, left gastric artery; SA, splenic artery; GDA, gastroduodenal artery; CHA, common hepatic artery.

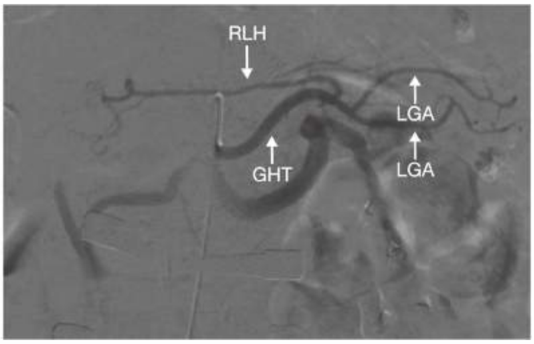
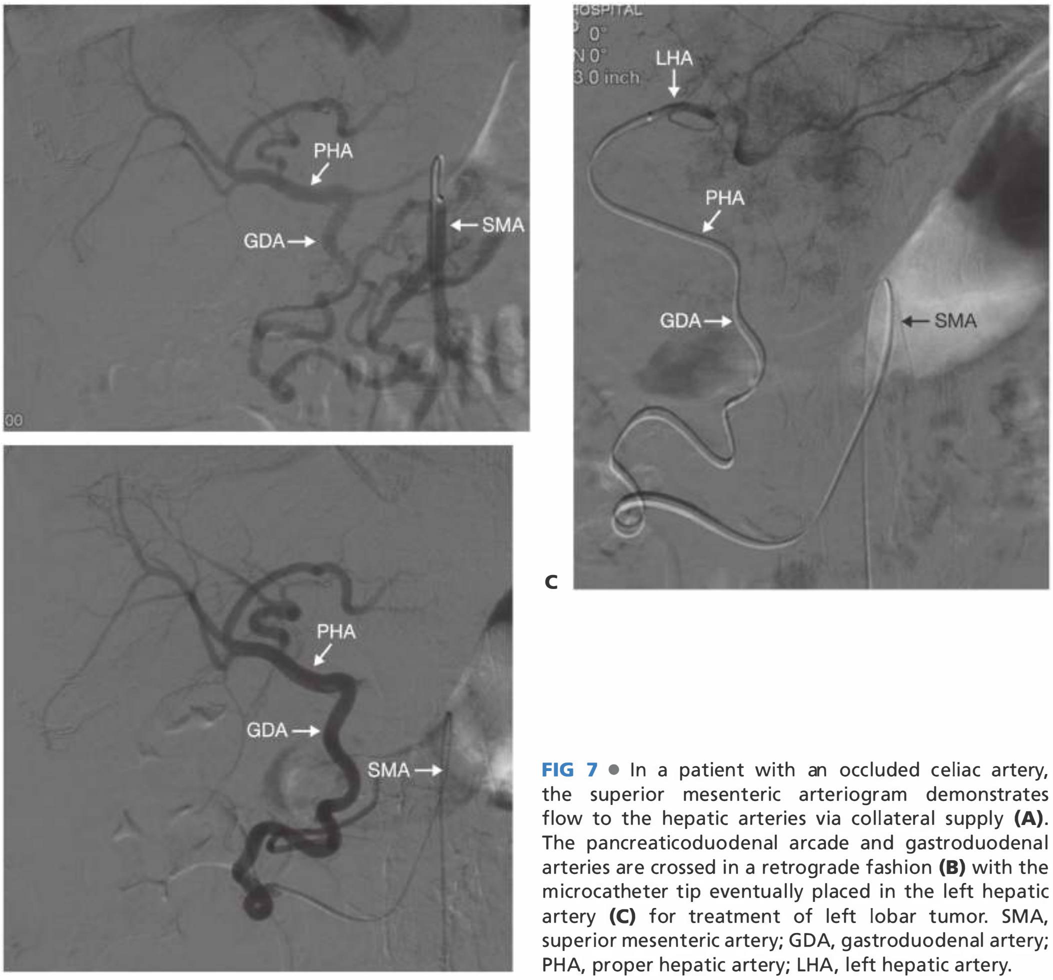


FIG 6 ● The catheter tip is in a gastrohepatic trunk arising from the celiac artery. The replaced left hepatic artery supplies the left hepatic lobe, whereas the remaining left gastric artery branches supply the fundus of the stomach. When embolizing the replaced left hepatic artery, the catheter must be distal to the left gastric artery branches. GHT, gastrohepatic trunk; RLH, replaced left hepatic artery; LGA, left gastric artery branches.

A



B

C

FIG 7 ● In a patient with an occluded celiac artery, the superior mesenteric arteriogram demonstrates flow to the hepatic arteries via collateral supply **(A)**. The pancreaticoduodenal arcade and gastroduodenal arteries are crossed in a retrograde fashion **(B)** with the microcatheter tip eventually placed in the left hepatic artery **(C)** for treatment of left lobar tumor. SMA, superior mesenteric artery; GDA, gastroduodenal artery; PHA, proper hepatic artery; LHA, left hepatic artery.

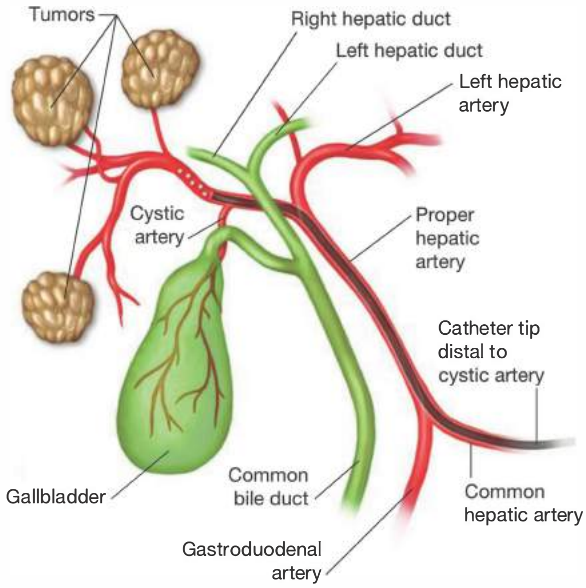


FIG 8 ● The catheter tip is placed distal to the origin of the cystic artery prior to chemoembolization to prevent a chemical cholecystitis.

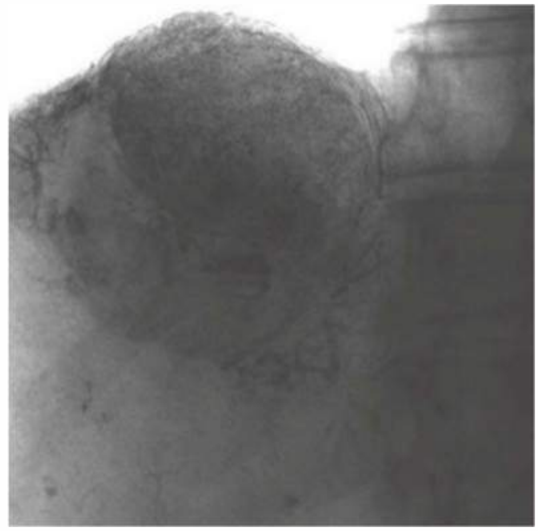


FIG 9 ● Fluoroscopic image following oily chemoembolization shows the Ethiodol mixture within the tumor.

should be performed distal to the cystic artery. Treatment proximal to the cystic artery can cause a chemical cholecystitis with a more severe postembolization syndrome.
- Arteriogram to evaluate selective cannulation of the feeding vessel(s) and to assess for arteriovenous shunting

Embolization Using the Embolic Material

- Oily chemoembolization
  - Ethiodol is a poppy seed oil-based contrast. The Ethiodol vehicle is mixed, most commonly with a combination of cisplatin, doxorubicin, and mitomycin-C. The Ethiodol acts as a carrier and the chemotherapy is released slowly from the mixture. The Ethiodol is retained within the tumor and the neovasculature of the tumor (FIG 9). This is followed by particulate embolization of the target vessels.
- Drug-eluting microspheres
  - LC beads are a polyvinyl alcohol-based microsphere and QuadraSpheres are a copolymer microsphere.
  - 50 to 75 mg of doxorubicin is loaded into each vial of microspheres with a maximum of two vials being used per procedure. 100 to 300 micron LC beads™ and 50 to 100 micron QuadraSpheres™ are commonly used. The particles are then injected (FIG 10) until there is significant slowing of flow within the target vessels.
  - Irinotecan has been used, instead of doxorubicin, in treating patients with colorectal cancer that has metastasized to the liver.
- Transarterial embolization (TAE), also known as bland embolization, has also been performed. TAE uses Ethiodol embolization, particulate embolization, or a combination of both without the addition of any chemotherapeutic agent.

Removal of the Catheters and Sheath

- The puncture site is closed using manual pressure or an arterial closure device.

Follow-up

- Labs in about 4 weeks to evaluate liver function
- Repeat imaging if needed.
- Repeat embolization, if needed, in about 4 to 6 weeks.

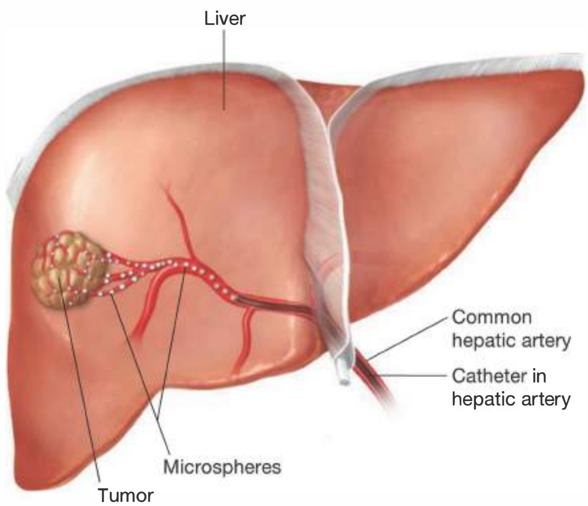


FIG 10 ● Drug-eluting microspheres block the arterial supply to the tumor and then the chemotherapy drug is slowly released directly to the tumor.

RADIOEMBOLIZATION

Sir-Spheres™ or TheraSphere™

- ^{90}Y binds to particles that are less than 35 microns in size. Sir-Spheres**™** are resin-based particles, whereas the TheraSphere™ particles are nonbiodegradable glass microspheres.

Superior Mesenteric, Celiac, and Common Hepatic Arteriograms

- The initial steps are similar to TACE. The arteriograms are evaluated for vessel patency and anatomic variants.

Arteriograms of the Gastroduodenal, Right, and Left Hepatic Arteries

- Evaluation of anatomy is performed with special attention paid to branches that lead to the GI tract such as the right gastric and supraduodenal arteries (**FIG 11**).
- Branches connecting to the GI tract, such as the gastroduodenal artery (GDA), are embolized (**FIG 12**). These branches must be embolized as ^{90}Y particles in the GI tract can cause severe, slow-healing ulcers.

Lobar Injection of Technetium-99m (Tc 99m) Macroaggregated Albumin

- The Tc 99m macroaggregated albumin (MAA) particles are used to simulate the ^{90}Y particles. Nuclear imaging is then performed to evaluate for activity in the GI tract and the amount of shunting to the lungs (**FIG 13**).
- If there is activity in the GI tract following MAA injection, with no obvious feeding vessel that can be embolized, ^{90}Y therapy should not be administered.

Return for Injection of Yttrium 90 Particles

- This is performed subsequent to the initial assessment of anatomy, appropriate embolization of vessels feeding the GI tract, and MAA evaluation. The catheter is placed in the same position as during the Tc-99m MAA injection. The catheter position is similar to **FIG 8** when performing right lobar embolization.
- The ^{90}Y particles are injected with extreme care to prevent spillage of radioactive particles (**FIG 14**).
- If there is 10% to 15% hepatopulmonary shunting on the MAA study, then the Sir-Spheres™ dose is decreased by 20%. If the shunting is 15% to 20%, then the dose is decreased by 40%.
- If hepatopulmonary shunting is greater than 20%, then Sir-Spheres™ are not administered.
- When using TheraSphere™, the limitation of what can be administered to the lungs is based on the cumulative dose, irrespective of the lung shunt.

Removal of the Catheters and Sheath

- The puncture site is closed using manual pressure or an arterial closure device.

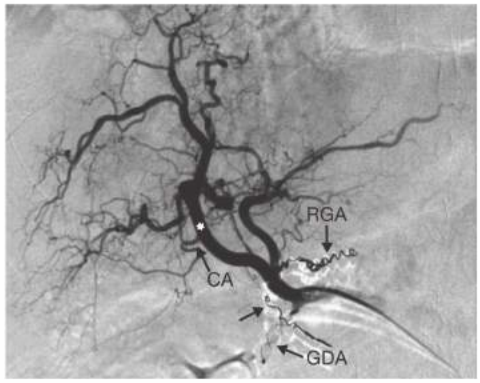


FIG 12 ● An Amplatzer plug has been used to embolize the GDA with microcoils within the right gastric artery (RGA) and supraduodenal arteries (SDA). The microcatheter would then be placed distal to the cystic artery origin for right lobar Tc-99m MAA and ^{90}Y injections *(asterisk)*.

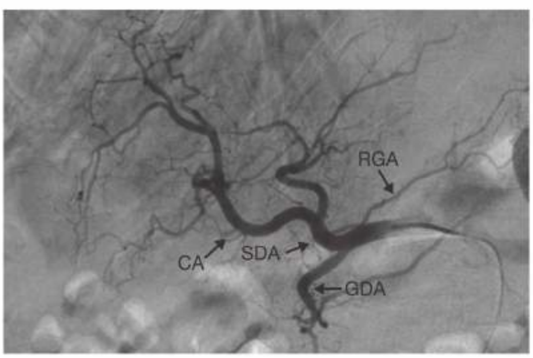


FIG 11 ● Common hepatic arteriogram demonstrates the anatomy prior to Tc-99m MAA particle injection. Branches leading to the GI tract will need to be embolized to prevent ^{90}Y particle reflux to these branches with subsequent injury. GDA, gastroduodenal artery; SDA, supraduodenal artery; RGA, right gastric artery; CA, cystic artery.

FIG 13 ● Nuclear imaging following Tc-99m MAA administration demonstrates no activity within the GI tract and 13.4% shunting to the lungs. The dose of Sir-Spheres™ to be given would be reduced by 20% due to the degree of shunting.

Follow-up

- Labs in about 4 weeks to evaluate liver function
- Repeat imaging if necessary.
- Workup for the second lobar injection is begun about 4 to 6 weeks after the initial side if labs and imaging are adequate. The patient will need an arteriogram and repeat Tc-99m MAA injection as well, prior to radioembolization of the second lobe, if needed.

FIG 14 ● The Sir-Spheres™ particles are connected to the catheter via a special delivery system to prevent spillage of radioactive material.

PEARLS AND PITFALLS

Patient history and physical findings.	■ Patients without an intact sphincter of Oddi are at much higher risk of abscess formation and need extended antibiotic prophylaxis. ■ Do not overtreat in patients with borderline hepatic function. The procedure can always be repeated at a later time.
Imaging and other diagnostic studies	■ C-arm CT scan may be helpful to verify that the catheter is in the correct arterial branch as it may be difficult to tell with lesions that are not well visualized. (**FIG 15**). ■ Hepatic tumors may be supplied by nonhepatic vessels, especially subcapsular lesions. Parasitized flow from the inferior phrenic, internal mammary, and intercostals arteries may need to be embolized (**FIG 16**). ■ It may be difficult to tell if there is arterial tumor enhancement on a contrasted CT scan with Ethiodol in place. A noncontrast scan (**FIG 17**) is needed for comparison or an MRI can be obtained.
Surgical technique (TACE)	■ Arterial-portal shunts can be embolized with large particles or coils prior to TACE. ■ There are more postembolization syndrome symptoms with oily chemoembolization than with drug-eluting microspheres. ■ Embolization of dome lesions may cause right shoulder pain or hiccups. Steroids (Medrol Dosepak) may be helpful.
Surgical technique (^{90}Y)	■ Even though the GDA and right gastric arteries are embolized, do not inject ^{90}Y via the common or proper hepatic arteries.

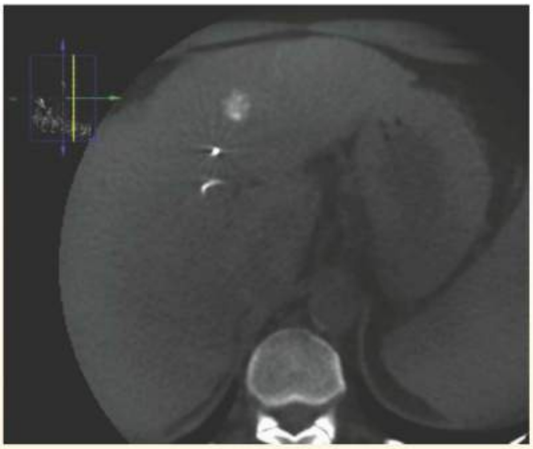


FIG 15 ● C-arm CT shows tumoral enhancement demonstrating that the microcatheter is within the correct arterial branch prior to chemoembolization. The tumoral enhancement was not appreciated by conventional arteriography.

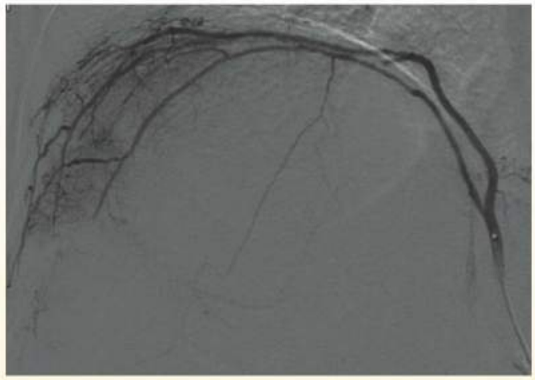


FIG 16 ● Right inferior phrenic arteriogram demonstrates tumor enhancement in the dome of the liver supplied by the distal phrenic branches. These branches were then embolized.

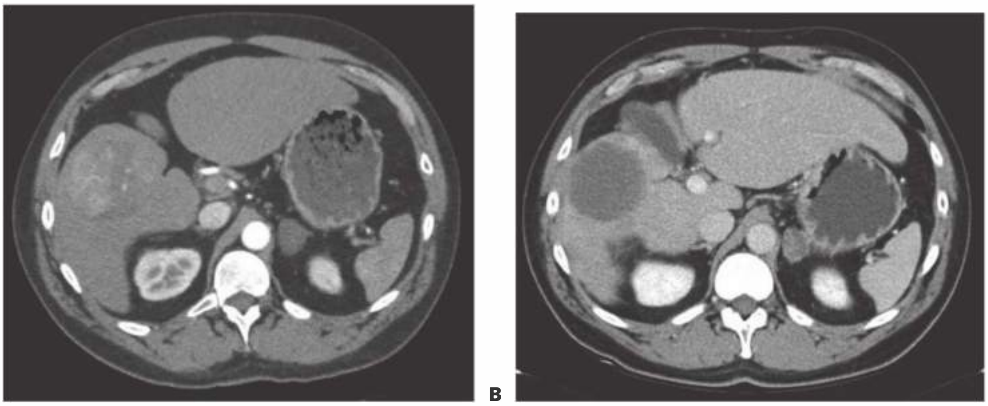
FIG 17 ● CT scan demonstrates residual Ethiodol within a tumor on a noncontrast examination. A noncontrast exam must be obtained prior to the contrast-enhanced exam to demonstrate the difference between contrast enhancement and residual Ethiodol.

POSTOPERATIVE CARE

- Pain medications
- Antiemetics
- Proton pump inhibitor (radioembolization)
- Steroids (Medrol Dosepak)
- Antibiotics (as indicated)
- Hospitalization for TACE is typically overnight for microsphere embolization and up to several days for oily chemoembolization. Patients that receive radioembolization can typically be discharged the same day.
- Repeat labs and imaging are typically obtained. Protocols are institution-specific and not typically driven by data.
- Further embolization procedures as needed. Imaging after TACE is about 4 to 6 weeks after the completion of embolization. If there is tumor identified on repeat imaging, then embolization is again performed. If no further tumor is identified, then imaging is performed every 3 months (**FIG 18**).
- Imaging after radioembolization is performed 2 to 3 months after the last lobe is embolized as it can take longer to see the effects.

OUTCOMES

- In 2002, two separate studies demonstrated that TACE for HCC had a statistically significant survival advantage over the best supportive care that was available.[4,5] Since then, other studies have confirmed these findings in patients with well-compensated cirrhosis.
- In patients with limited hepatic reserve or decreased performance status, there have been better outcomes with drug-eluting microspheres as compared to oily chemoembolization.[6] In addition, the treatment was better tolerated by the patients.
- Treatment using drug-eluting microspheres loaded with doxorubicin demonstrated a statistically longer time to progression and fewer recurrences when compared to bland embolization.[7]



A B

FIG 18 ● **A.** Initial CT scan demonstrates a large, contrast-enhancing HCC in the right lobe of the liver prior to treatment. **B.** A follow-up CT 5 weeks after treatment using doxorubicin-loaded LC beads shows that the tumor is slightly smaller and there is no further contrast enhancement. Repeat imaging would then be performed about 3 months later.

- Patients with HCC and Child-Pugh A disease survive significantly longer following ^{90}Y radioembolization than do those patients with Child-Pugh B disease, 17.7 versus 7.7 months, respectively.[8]
- In a study of patients with unresectable, chemoresistant liver metastases treated with ^{90}Y radioembolization, the median survival for patients was 15.2 months for those with colorectal tumors, 25.9 months for those with neuroendocrine tumors, and 6.9 months for those with noncolorectal, non-neuroendocrine tumors.[9]

COMPLICATIONS

- Groin hematoma/pseudoaneurysm
- Liver insufficiency
- Severe postembolization syndrome
- Routine postembolization syndrome is not an unexpected event. Postembolization syndrome includes pain, fever, and nausea/vomiting. Severe postembolization syndrome would necessitate an extended hospital stay or readmission.
- Hepatic abscess
- Cholecystitis
- Nontarget embolization with GI tract ulceration

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Chapter 21 Segmental Hepatectomy

Neil H. Bhayani   Eric T. Kimchi   Niraj J. Gusani

DEFINITION

- A segmental hepatectomy consists of surgical resection of one or more functional anatomic segments of the liver, as originally classified by Couinaud (**FIG 1**). Nomenclature for liver resections was standardized in the Brisbane conference.[1]
- The most common anatomic segmental resections are (1) right posterior sectionectomy (segments 6 and 7), (2) left lateral sectionectomy (segments 2 and 3), and (3) caudate lobe resection (segment 1).
- Smaller resections of a single segment or nonanatomic subsegmental resections will not be covered in this chapter. Usually, these involve simple excisions without formal inflow or outflow occlusion or delineation of the segmental vascular or biliary anatomy.

PATIENT HISTORY AND PHYSICAL FINDINGS

- Patients should be good medical candidates for major surgery.
- Preoperative planning requires a thorough history of previous abdominal surgeries.
- If performing a metastasectomy, there should be a thorough evaluation of extrahepatic disease. The presence of extrahepatic disease should be considered in conjunction with the tumor type and extent of resection to determine if the patient will benefit from surgical intervention involving the liver or extrahepatic sites.
- Episodes of jaundice, hepatitis exposure, alcohol, illicit drug abuse, and treatment with chemotherapy should be elicited to ascertain the health of the liver parenchyma.
- A complete viral hepatitis panel should be obtained as part of screening surgical candidates.
- Liver function can be assessed by the Child-Pugh classification and/or the Model for End-Stage Liver Disease (MELD). Neither metric has been definitively shown to be superior in determining a patient's ability to tolerate surgery.[2]

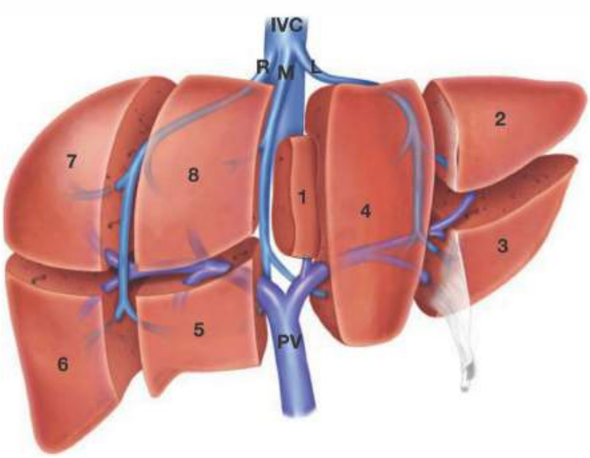

FIG 1 ● Couinaud segments with vascular anatomy.

IMAGING AND OTHER DIAGNOSTIC STUDIES

- Multiphase, contrast-enhanced cross-sectional imaging with either computed tomography (CT) or magnetic resonance imaging (MRI) is necessary for planning surgery. Both imaging modalities are of similar sensitivity and may often be used interchangeably or in combination to better define certain pathologic processes.
- In a normal, healthy liver, a future (postresection) hepatic remnant composed of at least two contiguous segments with adequate inflow and outflow and measuring 25% of the complete liver volume is sufficient functional liver to allow for full hepatic recovery. However, in a damaged or cirrhotic liver, a remnant of greater than 40% is often recommended, although the percentage of viable remnant liver may need to be greater, depending on the amount of damage/dysfunction of the liver. Segmental hepatic resections rarely induce hepatic insufficiency unless the remnant liver is severely diseased.
- Concern for significant hepatic dysfunction should be investigated by objective testing of the liver. Transjugular measurement of the portal pressure gradient (normal <5 to 8 mmHg), routine serum liver function tests, and biopsy (to evaluate steatosis or cirrhosis) are the most common modalities to evaluate the extent of hepatic disease.
- In Asia, indocyanine green clearance testing is often performed to quantify liver health. This is rarely performed in the United States.
- In patients with evidence of decompensated cirrhosis (Child's B and C) and pathologic conditions that have demonstrated benefit from transplantation (hepatocellular cancer, neuroendocrine malignancies, and some hilar cholangiocarcinomas), surgeons should consider a referral for transplantation.

SURGICAL MANAGEMENT

- The indications for hepatectomy include diagnostic uncertainty, symptomatic benign lesions, and malignancy (Table 1).
- The strongest evidence for hepatic metastasectomy shows that R0 resection prolongs survival and is potentially curative for colorectal carcinomas and neuroendocrine tumors.

Table 1: Indications for Hepatectomy

Diagnosis	Premalignant disease
Focal nodular hyperplasia vs. hepatocellular adenoma	Hepatocellular adenoma
	Biliary cystadenoma
Symptoms	Malignancy
Hemangioma	Metastasis
Simple cysts	Hepatocellular carcinoma
Benign disease	Cholangiocarcinoma
Refractory abscesses/cholangitis	
Severe hepatolithiasis	

Preoperative Planning

- Ideally, preoperative cross-sectional imaging should be discussed with skilled radiologists before surgery and be available throughout the procedure.
- Vascular, particularly hilar, arterial anomalies are common. Inadvertent injury at surgery may be prevented by thorough multiplanar analysis of preoperative imaging.
- 3-D reconstruction is not mandatory, but understanding of all the lesions and their relation to hepatic and portal venous structures is imperative. This should be combined with intraoperative ultrasound.
- For postoperative pain control, we employ epidural catheters, administered by a dedicated pain service, placed preoperatively.
- Low central venous pressure (CVP) anesthesia is a cornerstone in reducing blood loss in hepatic surgeries. To maintain low CVP (5 to 8 mmHg), good communication with the preoperative nursing and anesthesia teams is critical.
- Patients receive appropriate prophylactic antibiotics due to transection of the biliary tree (clean-contaminated surgery). We consider cases with an indwelling biliary device as contaminated procedures secondary to colonization of the biliary tract.
- Most patients undergoing hepatectomy are at high risk for venous thromboembolic (VTE) disease due to age, presence of malignancy, and complex and long major abdominal surgery. Unfractionated heparin is given subcutaneously prior to induction and redosed every 8 hours as needed. Patients undergoing hepatectomy for malignant diagnoses are usually sent home on a 30-day course of low-molecular-weight heparin for VTE prophylaxis.

Positioning

- Supine with arms abducted. Laparoscopic resections may be facilitated by use of the modified lithotomy position or of a split-leg table. For extreme lateral right liver lesions, full lateral positioning may be used.

TECHNIQUES

RIGHT POSTERIOR SECTIONECTOMY (SEGMENTS 6 AND 7)

Exposure

- A subcostal, chevron, or midline incision can be used. It is our preference to operate through a midline incision.
- A fixed traction system is employed. Retraction of the costal margin is critical.

Mobilization

- The round ligament is ligated but kept long to allow its use for countertraction and exposure. The falciform ligament is divided close to the liver, thus minimizing interference from this structure during intraoperative ultrasonography (IOUS).
- Dissection of the apex of the right triangular ligament proceeds from medial to lateral. The peritoneum and areolar tissue surrounding the anterior and lateral aspects of the right hepatic vein (RHV) is cleared. To continue laterally and inferiorly, the liver can be retracted medially and compressed posteriorly.
- If caval compression induces hypotension, temporary release of retraction may be all that is required. Alternatively, raising the inferolateral edge of the right liver will expose the final attachments of the right triangular ligament.
- Complete mobilization of the right liver requires extensive exposure of the lateral and anterior surface of the inferior vena cava (IVC). Medial retraction and cephalad rotation of the inferolateral edge raises the liver off the IVC.
- A variable number of short hepatic vein branches drain the right hepatic lobe directly into the IVC. These should be carefully ligated using 4-0 ties and clips. We avoid use of clips on the hepatic side of these small vessels as they may interfere with parenchymal transection and reserve their use for the branches on the caval side.
- At the proximal and lateral aspect of the IVC, there is a ligamentous band/parenchymal bridge, which extends from segment 7 to the retroperitoneal tissue behind the IVC. Release of this band is critical in the exposure and safe dissection of the RHV. This band can be vascular and transection should be performed by ligation, stapling, or use of bipolar transection of this tissue.

Hilar Dissection and Vascular Control

- Anterior and cranial fixation of the falciform ligament exposes the hilum.
- Antegrade cholecystectomy is performed to expose the right lateral hilar plate.
- IOUS should be used routinely to examine the hepatic parenchyma for known and occult lesions. IOUS confirms vascular anatomy, identifies major vascular branches, and maps the proximity of hepatic and portal vein branches near the lesions.
- After creating an aperture through the gastrohepatic ligament, an umbilical tape is placed around the porta hepatis. Creation of a loose Rummel tourniquet permits a rapid Pringle maneuver in the event of bleeding.
- Dissection begins at the right lateral edge of the hepatic plate. Dissection on the contralateral side should be avoided to prevent inadvertent injury and to minimize scarring in case subsequent hepatectomy is required.
- In the right hilum, the right hepatic artery (RHA) is superficial and is accordingly dissected first. The RHA typically bifurcates as it enters the right liver. Both the anterior and posterior branches should be identified. A vascular loop facilitates gentle traction, and a bulldog clamp is then placed on the right posterior artery (FIG 2).
- Perfusion in the right anterior and proper hepatic artery (in the porta hepatis) as well as the left hepatic artery (LHA) should now be confirmed. Manual palpation or Doppler exams are sufficient. IOUS in the hilum or of the parenchyma can be used for confirmation.

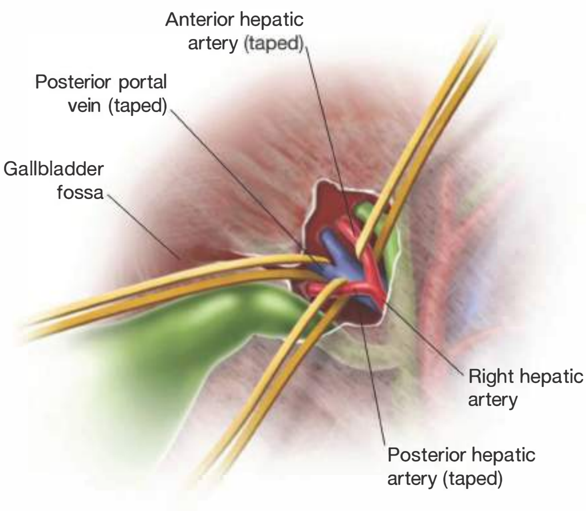

FIG 2 ● The right portal pedicle is exposed, and the anterior and posterior branches are visualized prior to ligation of the right posterior hepatic artery or portal vein.

- If no deficit is noted, then the clamp may be removed and the posterior branch of the RHA can be divided between 2-0 silk ligatures and 3-0 suture ligatures. Division should expose the right portal vein (RPV) posteriorly and cephalad to the RHA.
- The RPV dissection should identify anterior and posterior branches and also the RPV or left portal vein (LPV) bifurcation. Correct identification of the bifurcation of the RPV and LPV is imperative to avoid ligating or narrowing the main portal trunk or the takeoff of the LPV. During this exposure, posterior branches of the RPV to the caudate (segment 1) can easily be avulsed. These should be preemptively ligated or avoided as the dissection proceeds to avoid unnecessary bleeding. Further dissection along the circumference of the RPV should allow identification and isolation of the right anterior and right posterior branches. In some circumstances, a short segment hepatotomy of segment 6 may be used to access the posterior portal vein. Isolation of the posterior branch may be confirmed by IOUS. The posterior branch of the RPV is encircled with a vessel loop or a ¼-in Penrose drain to allow gentle traction.
- We routinely transect the posterior portal vein with a vascular stapler. An articulating stapler is useful in obtaining the optimal angle for transection. Extreme care is taken during passage of the jaws of the stapler to avoid disruption of nearby vascular branches. If difficulty is encountered, often, the narrow jaw can be inserted into the opening of the Penrose drain and gentle withdrawal of the Penrose guides the stapler in the appropriate plane.
- We do not routinely perform extrahepatic division of the right posterior hepatic duct. Rather, we prefer to ligate and divide it intraparenchymally during the parenchymal transection with the stapler. This technique allows us to safely ligate the duct distal to the bifurcation and avoids unnecessary hilar dissection, which can devascularize or injure the biliary system.
- The posterior section should begin to demarcate. Inflow occlusion is now complete.
- The RHV is not routinely isolated for posterior sectionectomy, but branches are ligated intrahepatically during parenchymal transection.

Parenchymal Transection

- To begin transection, we use cautery to disrupt Glisson's capsule and mark the line of transection. This process is continued circumferentially. IOUS may be helpful to identify the extent of the lesion and to mark an appropriate medial margin.
- This circumferential groove will serve as a guide for the completion of the hepatic transection with staplers. The importance of creating a fully circumferential groove (especially posteriorly) in order to provide tactile and visual guide for stapling cannot be overstated.
- The next 1 to 2 cm of liver parenchyma can be transected with an energy source. Bipolar, radiofrequency, or ultrasonic-generated heat energy can be used at the surgeons' preference. We find superior hemostasis with saline-radiofrequency devices, which seal vasculature and bile ducts alike.
- A Pringle maneuver may be applied at this point to occlude collateral flow through the liver remnant. This prevents unexpected bleeding during parenchymal transection.
- Stapling of the remaining hepatic parenchyma is our preferred means of completing the transection. Having two staplers permits the use of one while the other is being reloaded, allowing for rapid transection. The thin (metal) end of the stapler is tunneled bluntly into the hepatic parenchyma. Alternatively, a groove for insertion of this end can be created by gentle passage of a closed curved clamp. Closure of the stapler is analogous to crushing the hepatic parenchyma with a metal clamp during the classical crush-clamp hepatic transection.
- The stapler should be passed through the parenchyma without resistance. Resistance may indicate that the stapler is encountering the sidewall of a vessel. Forcing the stapler through these branches may cause significant bleeding.
- Smaller bites with the stapler results in slow, sequential parenchymal compression and avoids tearing of vessels. Pushing out excess tissue allows superior staple formation, minimizing the chance of bleeding or bile leak.
- Difficulty in closing or firing the stapler may be encountered when (1) too much tissue is between the jaws or (2) the right hepatic duct (RHD) is ligated and divided.
- With the left hand holding the right liver, the line of transection can be controlled. With the fingers in the posterior groove, the IVC is protected and the endpoint of the transection is known at all times. The entire transection continues with repeated firings of the stapler.
- For a complete or formal right posterior sectionectomy, the plane of transection should parallel the lateral aspect of the RHV (**FIG 3**).

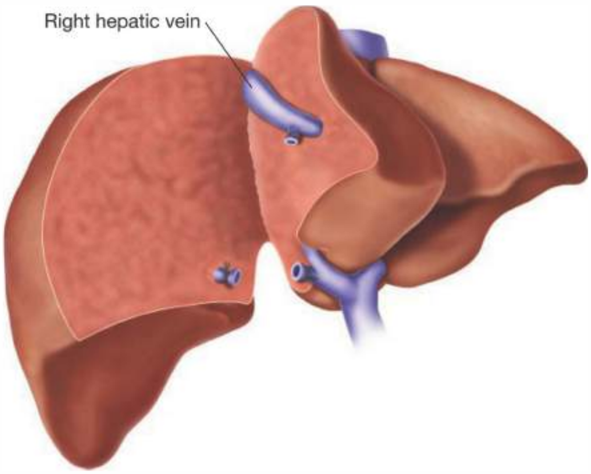

FIG 3 ● For a complete or formal right posterior sectionectomy, the plane of transection should parallel the lateral aspect of the RHV.

Completion

- After the parenchyma is divided, the specimen is removed from the field. We routinely work with the pathologists to orient the specimen, ink the appropriate margins, and assess gross margins intraoperatively.
- Hemostasis is achieved at the cut edge of the liver. We prefer the bipolar, saline-perfused radiofrequency ablation (RFA) device, which is effective in sealing small vessels and bile ducts.
- Care should be taken to avoid coagulating major biliary branches, as this may lead to subsequent stricture. Any area of bile leak, which might be near a larger bile duct, can also be ligated with absorbable monofilament suture.
- For areas of bleeding near the hilum, where energy devices may risk damage to crucial structures, we employ manual pressure and/or topical hemostatic agents and precise suturing when necessary.
- A large, closed suction drain may be placed adjacent to the transected parenchyma at the surgeon's preference.
- We reapproximate the falciform ligament to prevent lateral rotation of the remnant that may result in kinking and possible occlusion or thrombosis of the hepatic veins.

LEFT LATERAL SECTIONECTOMY (SEGMENTS 2 AND 3)

Mobilization

- Dissection of the apex of the left triangular ligament proceeds from lateral to medial. It may be helpful to place a laparotomy pad posterior to the left triangular ligament to help protect the gastric cardia and gastroesophageal junction.
- The peritoneum and areolar tissue surrounding the lateral aspect of the left hepatic vein (LHV) is cleared. Anterior retraction may aid in doing this safely.

Hilar Dissection and Vascular Control

- IOUS is used to locate and mark the capsule where the LHV will be encountered during transection. This visual reminder can be useful during parenchymal division.
- The gastrohepatic ligament is divided, including any aberrant LHA. An umbilical tape can now be placed around the porta hepatis in preparation for a rapid Pringle maneuver in the event of bleeding.
- Dissection begins at the left lateral edge of the round ligament, passing into the umbilical fissure. Dissection on the main porta hepatis or the contralateral side should be avoided to prevent inadvertent injury and to minimize scarring in case subsequent hepatectomy is required.
- The branches of the LHA and LPV supplying the left lateral section can be individually isolated and ligated on the left side of the round ligament. More proximal dissection on the main LHA and LPV is not necessary. Vascular control can be obtained by Pringle, if needed (**FIG 4**).

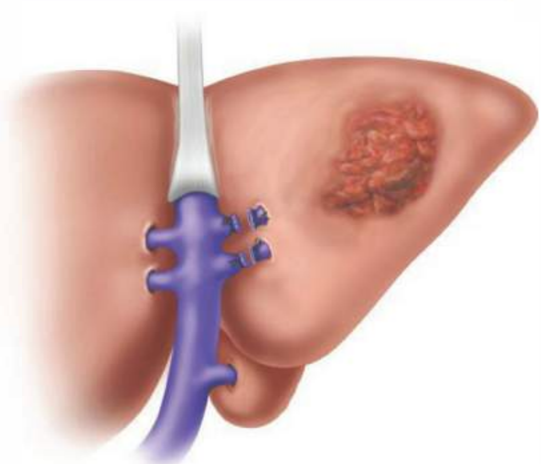

FIG 4 ● The LPV is shown in the umbilical fissure. The left-sided branches to segments 2 and 3 require ligation.

- The LHV is not isolated extrahepatically for a left lateral sectionectomy but is ligated intrahepatically during transection. Tumor location may require extrahepatic ligation of the LHV.

Parenchymal Transection and Completion

- As described above
- At the most cranial part of the parenchymal transection, the LHV will be encountered. This is best ligated with a vascular stapler; it is usually larger than recommended for energy-sealing device (**FIG 5**).

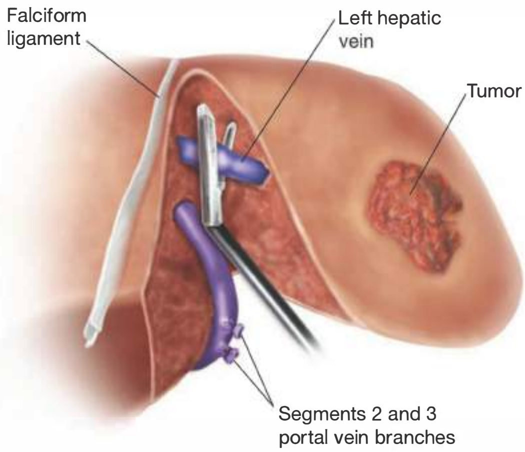

FIG 5 ● The LHV is ligated intraparenchymally with a stapler.

CAUDATE LOBE RESECTION (SEGMENT 1)

Mobilization

- Dissection of the apex of the left triangular ligament proceeds from medial to lateral. The left triangular ligament should be divided as described earlier.
- For larger tumors or tumors that are close or involve the caudate isthmus, complete mobilization of the right liver is also necessary. This requires ligation of the short hepatic branches between the posterior liver and the IVC.
- The peritoneum and areolar tissue surrounding the lateral aspect of the LHV is cleared. Anterior retraction may aid in doing this safely.
- The gastrohepatic ligament is divided. If an aberrant LHA is present, there should be an attempt to preserve it. However, division of the LHA may be necessary for adequate exposure. After this mobilization is complete, the left liver can be rotated anteromedially to visualize the caudate lobe (**FIG 6**).
- IOUS examines the liver for known and occult lesions.
- The arterial and portal venous inflow arises as smaller posterior branches off the main or left hilar structures.
- The caudate branches to the hilar vessels and bile duct are identified on the anterior surface of the caudate. These can be ligated using energy devices, ligatures, or clips.
- Dissection begins by dividing the parenchyma, sometimes called the "caudate isthmus." This bridge of tissue crosses anterior to the IVC and fuses with segment 6 at the left lateral edge of the ligamentum teres passing into the umbilical fissure. Sequential sealing of this bridge can be performed with monopolar, radiofrequency, bipolar, or staplers. Alternatively, a right-angled clamp can be used to isolate small packets of parenchyma, which are then ligated between 3-0 ties.
- Caudate outflow is via small veins directly into the IVC and the RPV. These should be ligated individually, as described above.

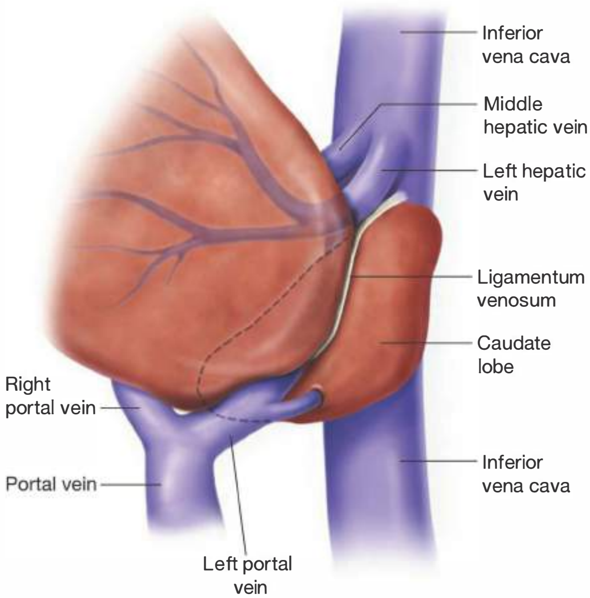

FIG 6 ● With rotation of the left liver, the caudate lobe is seen in relation to the LHV, ligamentum venosum, the IVC, and a major branch from the LPV.

- The posterior surface of confluence of the hepatic veins, particularly the middle and LHVs, overlies the cephalad most aspect of the caudate lobe (**FIG 7**). Safe dissection here requires good mobility of the right and left lobes of the liver.

Parenchymal Transection and Completion

- As described above

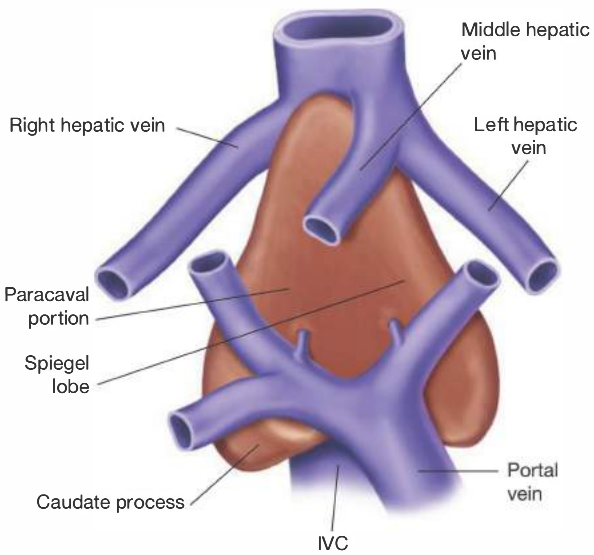

FIG 7 ● The upper pole of the caudate lobe lies between the IVC and the confluence of the middle and left hepatic veins.

PEARLS AND PITFALLS

Patient history	■ Suggestion of hepatic insufficiency or damage should be aggressively evaluated to reduce postresection hepatic failure.
Imaging and testing	■ High-quality imaging and a thorough understanding of hepatic anatomy is essential for proper surgical planning. ■ Liberal use of volumetry is warranted. ■ Vascular abnormalities should be detailed on preoperative imaging.
Vascular isolation	■ Avoid unnecessary dissection in order to minimize the risk of contralateral injury.
Parenchymal transection	■ Low CVP anesthesia is essential to minimize intraoperative blood loss during hepatic transection. ■ Stapling quickly divides the hepatic parenchyma, vasculature, and bile ducts, minimizing blood loss and bile leaks. ■ Small venous bleeders encountered during dissection can be simply tamponaded, sealed with an electrosurgical device, or on occasion, sutured or clipped.
Hemostasis	■ Use of energy near major biliary or hilar structures should be avoided.

POSTOPERATIVE CARE

- VTE prophylaxis is continued, including doses on the day of surgery as appropriate to the dosing schedule.
- Antibiotics are only continued to complete less than 24 hours of prophylaxis.
- All patients are given supplemental magnesium (6 g/IV once), phosphate (sodium phosphate, 30 mmol/IV TID), and vitamin K (phytonadione, 5 mg/SC q8h) to aid in liver regeneration and production of normal levels of vitamin K–dependent factors. This is given regardless of serum levels.
- Drains are checked for bilirubin on postoperative day 3. If the level is less than or equal to serum levels and the output is less than 100 mL per day, the drain is removed.

OUTCOMES

- In experienced centers, mortality is now less than 3% and morbidity is approximately 20%.[3]
- Overall and disease-specific survival at 5 years can reach 69% and 72%, respectively, varying with the underlying pathology.[4]
- Neoadjuvant or adjuvant systemic treatment, a total of 6 months of perioperative therapy, is recommended.[5]

COMPLICATIONS

- Volume-outcomes relationships are prominent in hepatic resection.
- Outcomes specific to hepatectomy include bile leaks (5.9%), perihepatic abscesses (3.7%), hemorrhage (0.9%), and hepatic insufficiency (3.1%).[6]

- Bile leaks can be managed by percutaneous drainage or endoscopic retrograde cholangiopancreatography (ERCP) with sphincterotomy to facilitate internal drainage.

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Chapter 22

Minimally Invasive Sectional and Segmental Hepatic Resection

Kevin T. Nguyen

DEFINITION

- The International Hepato-Pancreato-Biliary Association (IHPBA) Brisbane 2000 terminology of liver anatomy and resections[1] defines a segmental hepatic resection as a liver resection of one of nine anatomic Couinaud's segments and a sectional hepatic resection as a liver resection of anatomic sections or sectors (right posterior section [Couinaud's segments 6 and 7], right anterior section [Couinaud's segments 5 and 8], left anterior section [Couinaud's segment 4], or left lateral section [Couinaud's segments 2 and 3]).

PATIENT HISTORY AND PHYSICAL FINDINGS

- The indications for liver resection include primary or metastatic malignant liver lesions or symptomatic benign liver lesions in patients who are surgical candidates. Patients who are candidates for an open liver resection should be considered for a possible minimally invasive approach.

IMAGING AND OTHER DIAGNOSTIC STUDIES

- Eovist™-enhanced liver magnetic resonance imaging (MRI) or triphasic, contrast-enhanced computed tomography (CT) scan of the abdomen are virtually equivalent for assessment of disease. They can be complementary in characterizing lesions and determining the probable pathology.
- Localize the tumor(s) with respect to the portal structures and hepatic veins to evaluate for resectability. Can an R0 liver resection be performed with curative intent, namely obtaining adequate margins, while leaving a sufficient functional liver remnant with preserved vascular inflow and outflow?
- Pay attention to anatomic variants (i.e., replaced/accessory left hepatic artery, replaced/accessory right hepatic artery, trifurcation of the main portal vein, takeoff of the right anterior or right posterior portal vein from the left portal vein, the presence of large inferior hepatic veins, etc.).

SURGICAL MANAGEMENT

Preoperative planning

- Where is the transection plane to achieve a negative margin and preserve adequate functional liver reserve?
- Where should the port positions be to provide optimal triangulation?

Positioning

- Supine with arms abducted. Split-leg positioning is an option preferred by some liver surgeons.

TECHNIQUES

LAPAROSCOPIC LEFT LATERAL SECTIONECTOMY

- A purely laparoscopic left lateral sectionectomy can be attempted for hepatic lesions located within segments 2 and/or 3 of the liver (**FIG 1**).

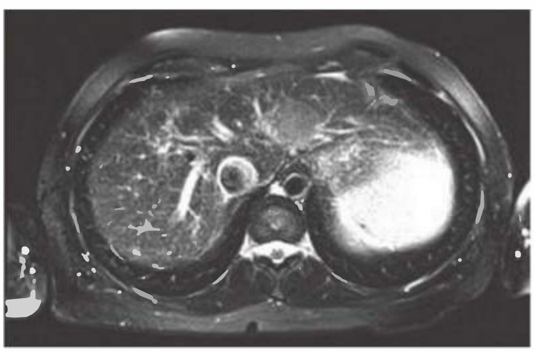

FIG 1 ● Left lateral sector hepatocellular carcinoma.

Port Placement

- Initial trochar placement: open Hasson approach at a periumbilical position, Veress needle approach in left upper quadrant, or optical separator approach in the left upper quadrant
- **FIG 2** shows the suggested port positions for a purely laparoscopic left lateral sectionectomy. A 12-mm port at the periumbilical incision, a 12-mm port in left upper quadrant midclavicular line for laparoscopic ultrasound and Endo GIA stapler, a 5-mm port in left upper quadrant midclavicular line, and a 5-mm left subcostal/left flank port.

Mobilization of the Left Lateral Segment

- Using a thermal energy device of choice through the right upper quadrant 12-mm port, divide the round ligament at the abdominal wall. The assistant provides countertension through the left-sided 5-mm ports.
- Using hook cautery through the right upper quadrant 12-mm port, divide the falciform ligament toward the insertion of hepatic veins into the inferior vena cava (IVC). The assistant provides countertension through the

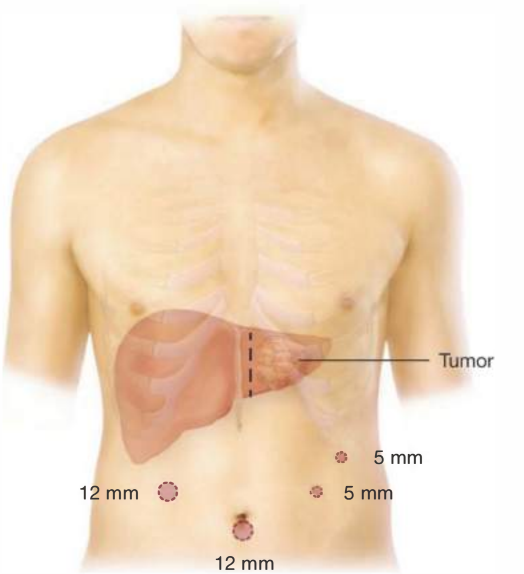

FIG 2 ● Port positions for purely laparoscopic left lateral sectionectomy.

left-sided 5-mm ports by compressing the liver posteriorly and inferiorly. The avascular adventitia protecting the hepatic veins should be divided to fully expose the anterior aspect of the common trunk of the middle and left hepatic vein.

- Using the hook cautery through the left upper quadrant 5-mm port, divide the left triangular ligament. Optional: Protect the stomach and spleen with a 4 × 4 gauze between the left triangular ligament and stomach.
- Using the hook cautery through the left-sided ports, divide the hepatogastric ligament, and identify any replaced or accessory left hepatic artery. The assistant lifts the left lateral section through the right upper quadrant 12-mm port. Clip and ligate any replaced/accessory left hepatic artery.
- Rarely, obtaining an adequate margin will dictate extraparenchymal dissection of the portal structures supplying segments 2 and 3. The author's favored approach is to identify the left hepatic artery near the porta hepatis and dissect it distally to identify and divide the segmental branches of all of the portal structures.

Parenchymal Transection of the Liver

- Ultrasound the liver and ensure that the liver mass(es) is/are localized only in the left lateral sector of the liver and that the transection plane achieves an adequate oncologic margin (≥1 cm).
- Mark the transection plane just to the left of falciform ligament with the hook cautery.
- The first 2 cm of parenchymal depth can be divided safely with an energy device of choice (**FIG 3**). The optimal trajectory for the liver parenchymal transection is through the right upper quadrant 12-mm port heading toward the insertion of the left hepatic vein. The camera is at the periumbilical port and the assistant uses an atraumatic grasper and suction/irrigator from the left-sided 5-mm ports.
- As the dissection progresses deeper into the parenchyma, expect to encounter the crossing segments 2 and 3 portal veins, biliary branches, and hepatic vein branches. Using a flat, blunt instrument (e.g., laparoscopic bowel grasper), create a tunnel in the liver parenchyma below these crossing branches (**FIG 4**). The tunnels creates an easy path for the Endo GIA stapler (2.5-mm vascular loads are preferred) (**FIG 5**). The blunt instrument and lower blade of the stapler should easily slide through liver parenchyma. If the instrument meets resistance, it suggests a crossing vascular or biliary branch along that path and the instrument needs to be redirected. The last division to free the liver section is the division of the left hepatic vein approximately 2 cm from the insertion into the IVC with Endo GIA vascular load.
- A 4 × 4 gauze can be used to dry the cut surface of the liver to identify any areas of bleeding or bile leak.

FIG 3 ● Superficial parenchymal transection with Harmonic scalpel.

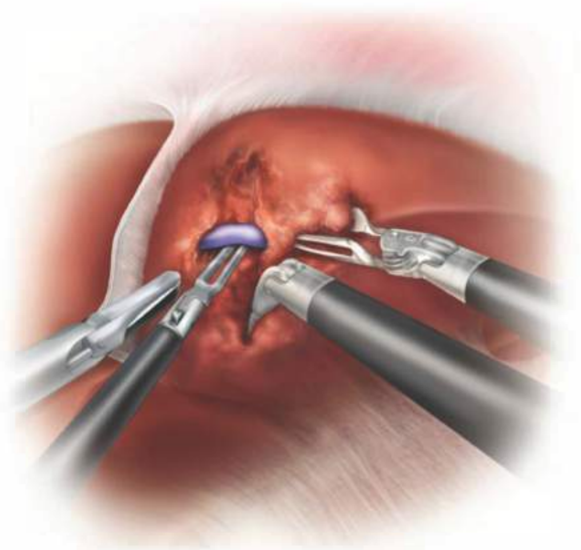


FIG 4 ● Creating a tunnel through the liver parenchyma using a flat laparoscopic blunt grasper.

The laparoscopic energy source is then used to control any small bleeders or oozing. (The author advises against using the laparoscopic argon beam due to the risk of argon embolism.) Any large vessels or bile leaks should be controlled with sutures.

- Place a specimen retrieval bag through a Pfannenstiel or an enlarged periumbilical incision to extract the specimen.
- Incisions larger than 12 mm are closed with the 0 Vicryl using the Carter-Thompson device or with a standard open closing technique.

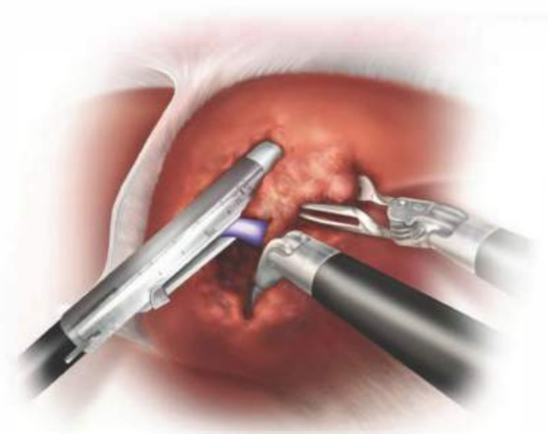


FIG 5 ● Stapling and crossing large vascular branches with the Endo GIA vascular load stapler.

LAPAROSCOPIC RIGHT POSTERIOR SECTIONECTOMY

- A purely laparoscopic right posterior sectionectomy can be attempted for hepatic lesions located within segments 6 and/or 7 of the liver (**FIG 6**).

Port Placement

- **FIG 7** shows the suggested port portions for a purely laparoscopic right posterior sectionectomy: a 12-mm port at the periumbilical incision, a 12-mm port in right upper quadrant midclavicular line and 2 cm above the level of the umbilicus for laparoscopic ultrasound and Endo GIA stapler, a 5-mm port in right flank, a 5-mm port in the left upper quadrant/midclavicular line, and a 5-mm port in the subxiphoid/epigastric region.

Mobilization of the Right Lobe of the Liver

- Using a thermal energy device of choice, through the right upper quadrant 12-mm port, divide round ligament from the abdominal wall.

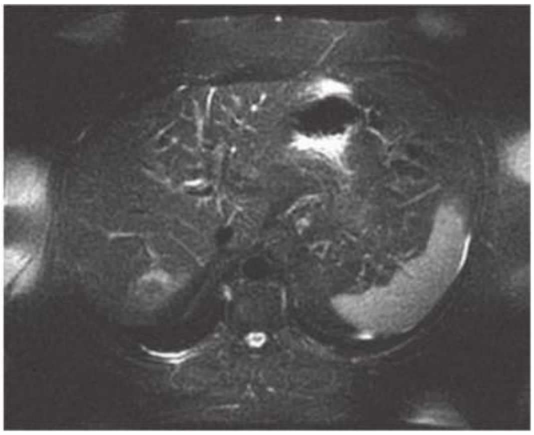

FIG 6 ● Colorectal metastasis to the right posterior sector of the liver.

- Using the hook cautery, divide the falciform ligament toward the insertion of hepatic veins into the IVC. The avascular adventitia protecting the hepatic veins should be divided to fully expose the anterior aspect of the right hepatic vein. This can be more easily reached through the epigastric 5-mm port.
- Mobilize the right lobe of the liver off the retroperitoneum. The assistant on the left uses a nontraumatic, expanding retractor through the left upper quadrant 5-mm port to lift the right lobe of the liver. This will expose the plane by placing tension on the posterior peritoneum attachments to the liver. The surgeon is on the right side with the suction/irrigator on the left hand through the right flank 5-mm port and hook cautery in the right hand through the right upper quadrant 12-mm port. Divide the peritoneum close to but not on the liver and enter the avascular plane. The assistant continually lifts the right lobe of the liver anteriorly and toward the left to further expose the dissection plane. The right kidney and adrenal gland should be swept posterior by the surgeon using the suction/irrigator in the left hand. Dissect superiorly toward the diaphragm and right triangular ligament and toward the IVC.

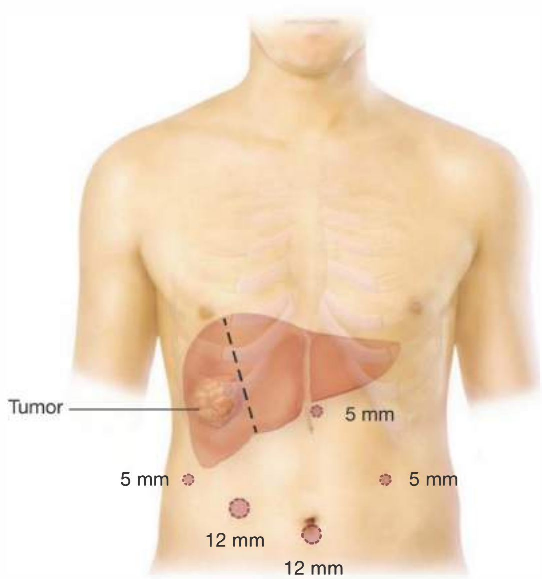

FIG 7 ● Port positions for purely laparoscopic right posterior sectionectomy.

- Using the hook cautery through the right flank 5-mm port, divide the right triangular ligament and the diaphragmatic attachment of the right lobe toward the right hepatic vein.
- Additional mobilization can be achieved when necessary by isolating and dividing the short veins from the caudate lobe entering the vena cava. Most can be safely controlled with bipolar electrocautery or ultrasonic shears. Some will require clipping. An accessory right hepatic vein should be expected. This vessel is best controlled and divided with a vascular staple load (2.5 mm).
- Perform a laparoscopic cholecystectomy in standard fashion.
- Ultrasound the liver and confirm the lesion(s) are in the right posterior section (Couinaud's segments 6 and 7). If a right posterior sectionectomy is planned, then mark liver using the hook cautery along an imaginary line from the right of the gallbladder fossa to 2 to 3 cm to the right of the right hepatic vein. This imaginary line of transection should be parallel but lateral to Cantlie's line of transition for an anatomic right or left hepatectomy.

Parenchymal Transection of the Liver

- The first 2 cm of parenchymal depth can be divided with an energy device of choice. This can also be performed along the posterior surface of the liver along the planned transection plane. The laparoscopic energy device can be used to dry the cut surface of the liver periodically.
- As the dissection proceeds, repeat performance of ultrasound evaluation can assist in the intraparenchymal identification of the segments 6 and 7 portal veins, biliary branches, and hepatic vein branches. Use a flat, blunt instrument (e.g., laparoscopic bowel grasper) to create a tunnel below these crossing branches to apply the Endo GIA stapler (vascular loads [2.5 mm] are preferred). The instrument should easily slide through the liver parenchyma. If the instrument meets resistance, it suggests a crossing vascular or biliary branch and the instrument should be redirected. The last division to free the liver section is the division of the right hepatic vein approximately 2 to 3 cm from the insertion into the IVC with Endo GIA vascular load.
- A 4 × 4 gauze can be used to dry the cut surface of the liver to identify any areas of bleeding or bile leak. The laparoscopic energy device is used to control any small bleeders or oozing. Any larger vessels or bile leaks should be controlled with sutures.
- Place specimen retrieval bag through a Pfannenstiel or enlarged periumbilical incision to extract the specimen.
- Incisions larger than 12 mm are closed with the 0 Vicryl using the Carter-Thompson device or with a standard open closing technique.

TECHNIQUES

LAPAROSCOPIC SEGMENT 6 SEGMENTECTOMY

- A purely laparoscopic segment 6 segmentectomy can be attempted for hepatic lesions located within segment 6 of the liver (**FIG 8**).

Port Placement

- **FIG 9** shows the suggested port portions for a purely laparoscopic segment 6 segmentectomy. A 12-mm port at the periumbilical incision, a 5-mm port in right upper quadrant midclavicular line and 1 cm above the level of the umbilicus, a 5-mm port in right flank, and a 12-mm port subcostal/midclavicular line.

Mobilization of the Right Lobe of the Liver

- Mobilize the right lobe of the liver off the retroperitoneum as described earlier.
- Perform a laparoscopic cholecystectomy in standard fashion.
- Ultrasound the liver and confirm the lesion is in segment 6 of the liver. If a segment 6 segmentectomy is planned, then mark the liver surface that is approximately 2 cm around the lesion(s). Confirm the transection plan by ultrasonography of the shadow from the marked cauterized surface of the liver. This line starts along the transection plane of a right posterior sectionectomy but then takes a sharp left turn toward the lateral surface of the right lobe of the liver as confirmed by ultrasound to achieve a margin of at least 1 to 2 cm by ultrasound along each transection plane.

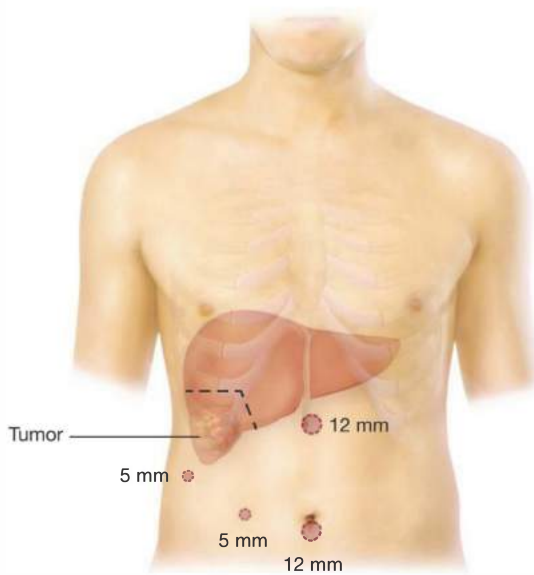

FIG 9 ● Port positions for purely laparoscopic segment 6 segmentectomy.

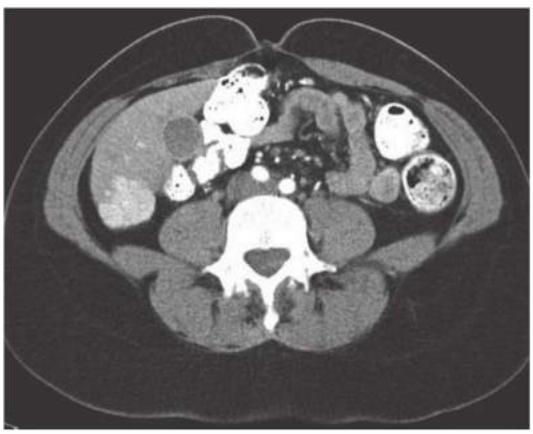
FIG 8 ● Segment 6 pedunculated hepatic adenoma.

Parenchymal Transection of the Liver

- This should be performed along the anterior and posterior surface of the liver along the planned transection plane. The laparoscopic energy device can be used to dry the cut surface of the liver periodically.
- To control the segment 6 portal veins, biliary branches, and hepatic vein branches, a vascular stapler is applied as earlier. In contrast to earlier, this load is typically inserted transversely via the subxiphoid port.

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Chapter 23

Right Hepatectomy

Neil H. Bhayani Niraj J. Gusani Kevin Staveley-O'Carroll

DEFINITION

- A right hepatectomy (or hemihepatectomy) consists of surgical resection of the right liver, consisting of Couinaud segments 5 to 8 (**FIG 1**). Nomenclature for liver resections was standardized in the Brisbane conference.[1]

PATIENT HISTORY AND PHYSICAL FINDINGS

- Medical evaluation and suitability for major abdominal surgery is tantamount.
- Health of the liver can be ascertained by questions regarding episodes of jaundice, hepatitis exposure, alcohol, illicit drug abuse, and treatment with chemotherapy.
- In addition to standard preoperative laboratories, it is our practice to obtain a complete viral hepatitis panel on all potential surgical candidates. Regardless of the metric or risk scoring system employed, thorough assessment of the health of the remnant liver is mandatory.
- Previous history of abdominal surgery, especially abdominal foreign bodies (e.g., mesh), may alter the approach.
- Physical exam findings of chronic liver disease or hepatic insufficiency should prompt more invasive testing if the patient remains a surgical candidate.
- If performing a metastasectomy, there should be a thorough evaluation for extrahepatic disease. Computed tomography (CT) is considered standard of care; a positron emission tomography (PET) scan is currently considered optional but used commonly by the authors. Findings of extrahepatic disease should prompt reconsideration of hepatectomy or planning for multiple staged procedures.
- In appropriate, medically operable patients, resectability is now only limited by the need to preserve adequate functional hepatic reserve.

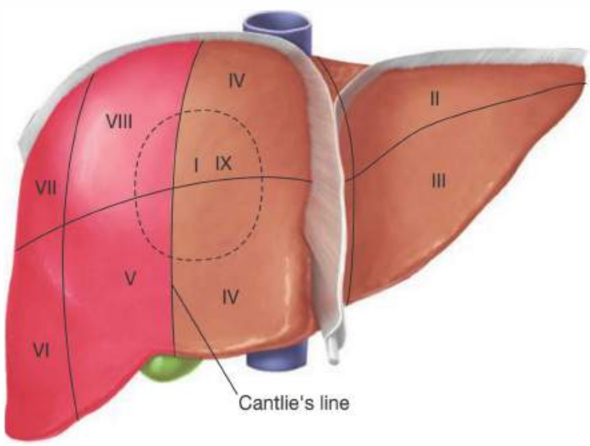

FIG 1 ● Couinaud segments with right hepatectomy pictured.

- Liver function can be assessed by the Child-Pugh classification or Model for End-Stage Liver Disease (MELD). Neither metric has been definitively shown to be superior.[2,3]
- Specific biochemical testing of liver function is more prevalent in Asia but rarely performed in the United States.

IMAGING AND OTHER DIAGNOSTIC STUDIES

- Noncontrast, arterial, and venous contrast cross-sectional imaging is essential in diagnosis and evaluation of suitability for surgery. CT and magnetic resonance imaging (MRI) are of similar sensitivity.
- In a normal, healthy liver, a remnant measuring 25% of a complete liver volume should constitute sufficient functional liver. However, in a damaged or cirrhotic liver, a remnant of greater than 40% is recommended. When performing a right hepatectomy, the remnant hemiliver is usually of adequate size in a healthy liver. In most cases, this does not require formal volumetric analysis; however, liberal use of volumetry should decrease the risk of postoperative hepatic insufficiency (**FIG 2**). In the event of marginal remnant volume, preoperative portal vein embolization on the side of resection can induce hypertrophy of the planned liver remnant.
- Hepatic steatosis can be evaluated by comparison of the densities of liver and spleen on noncontrast images. Alternatively, biopsy of the liver can provide quantitative assessment of fat content. Significant steatosis can suggest a liver remnant at risk of postoperative failure. Current practice would advocate strategies for preoperative hypertrophy to ensure a remnant that is at least 30% of the native volume of the liver.
- Patients with history, laboratory, or radiographic findings concerning for significant hepatic injury or dysfunction are referred for invasive testing of the liver, such as transjugular measurement of the portal pressure gradient (normal <5 to 8 mmHg) and biopsy (to evaluate steatosis or cirrhosis).
- Patients with evidence of decompensated cirrhosis (Child's B and C) are not candidates for right hepatectomy but may be candidates for liver transplantation in clinical settings of hepatocellular carcinoma, cholangiocarcinoma, or metastatic neuroendocrine tumors.

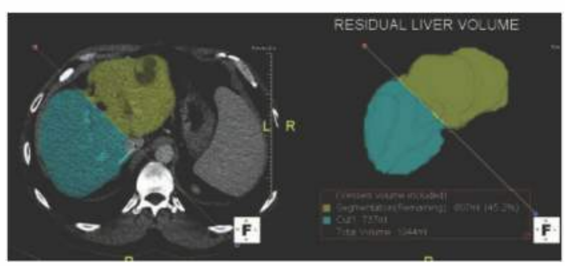

FIG 2 ● CT volumetry for a right hepatectomy. The calculated liver remnant represents 45% of the liver volume.

SURGICAL MANAGEMENT

- The indications for hepatectomy include diagnostic uncertainty, symptomatic benign lesions, and malignancy (Table 1).
- The strongest evidence for hepatic metastasectomy shows that R0 resection prolongs survival and is potentially curative for colorectal carcinomas and metastatic neuroendocrine tumors.

Preoperative Planning

- Preoperative cross-sectional imaging should be reviewed with skilled radiologists before surgery and be available throughout the procedure.
- Vascular, particularly hilar, arterial anomalies are common. Inadvertent injury at surgery may be prevented by thorough study and multiplanar analysis (**FIG 3**).
- Three-dimensional (3-D) reconstruction is not mandatory, but understanding of all the lesions and their relation to hepatic and portal venous structures is imperative. This should be combined with intraoperative ultrasound (IOUS).
- For postoperative pain control, preoperatively placed epidural catheters, administered by a dedicated pain service, have been shown to be effective and impact respiratory complication rates.
- Low central venous pressure (CVP) anesthesia is a cornerstone in reducing blood loss. To maintain low CVP (5 to 8 mmHg), good communication with the preoperative nursing and anesthesia teams is critical.
- Patients receive prophylactic antibiotics due to transection of the biliary tree (clean-contaminated surgery). The authors consider cases with an indwelling biliary device as contaminated.
- Patients undergoing hepatectomy are at high risk for venous thromboembolic (VTE) disease due to age, presence of malignancy, and complex, long major abdominal surgery. Unfractionated heparin is given subcutaneously prior to induction and redosed every 8 hours as needed.

Table 1: Indications for Hepatectomy

Diagnosis	Premalignant disease
Focal nodular hyperplasia vs. hepatocellular adenoma	Hepatocellular adenoma
	Biliary cystadenoma
Symptoms	Malignancy
Hemangioma	Metastasis
Simple cysts	Hepatocellular carcinoma
Benign disease	Cholangiocarcinoma
Refractory abscesses/cholangitis	
Severe hepatolithiasis	

Positioning

- Supine with arms abducted

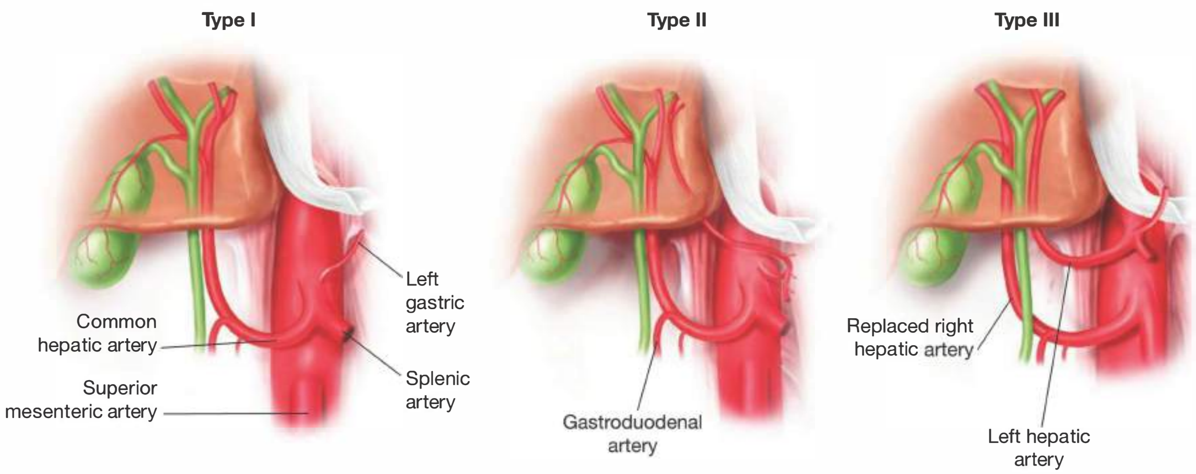

FIG 3 ● Common variants of hepatic arterial anatomy. Type 1 is considered "standard." Type 2 shows an accessory left hepatic artery (HA) (native left HA present). Type 3 shows an aberrant right HA (native right HA absent).

INCISION AND EXPOSURE

- A right hemihepatectomy can be performed through a subcostal, chevron, or midline incision. It is the authors' preference to operate through a midline incision.
- A fixed traction system is employed with emphasis on the cephalad and lateral retraction of the costal margin to provide adequate exposure.

MOBILIZATION

- The falciform ligament is ligated but kept long to use as a handle. The ligament is divided close to the liver surface to minimize interference with the ultrasound exam.
- Dissection continues at the apex of the right triangular ligament, working from medial to lateral. The peritoneum and areolar tissue surrounding the anterior and lateral aspects of the right hepatic vein (RHV) is cleared (**FIG 4**).
- To continue laterally and inferiorly, the liver can be retracted medially and compressed posteriorly. If caval compression induces hypotension, temporary release of retraction may be all that is required. Alternatively, raising the inferolateral edge of the right liver will expose the final attachments of the triangular ligament.
- Complete mobilization of the right liver requires extensive exposure of the lateral and anterior surface of the inferior vena cava (IVC). Medial retraction and cephalad rotation of the inferolateral edge raises the liver off the IVC (**FIG 5**).
- Variable short branches from the right hepatic lobe draining into the IVC (short hepatic veins) will be exposed from distal to proximal IVC. These should be carefully dissected and ligated using 4-0 silk ties and/or endoclips. Limit the use of endoclips on the hepatic side of these small vessels as they may interfere with parenchymal transection with staplers and are prone to dislodgement during subsequent retraction needed to provide adequate exposure (**FIG 6**).
- At the proximal and lateral aspect of the IVC, there is a ligamentous band/parenchymal bridge, which extends from segment 7 to the retroperitoneal tissue behind the IVC. Release of this band is critical in the exposure and safe dissection of the RHV. This band can be vascular and transection with a 45-mm endoscopic stapler with 2.0-mm staples (grey load) is an attractive, safe option.
- After mobilization of the liver, use IOUS to examine the hepatic parenchyma. This is cross-referenced with preoperative imaging. All known lesions are identified and the liver is examined for occult lesions. IOUS can confirm vascular anatomy, identify major vascular branches, and map the proximity of hepatic vein and portal vein branches near lesions.

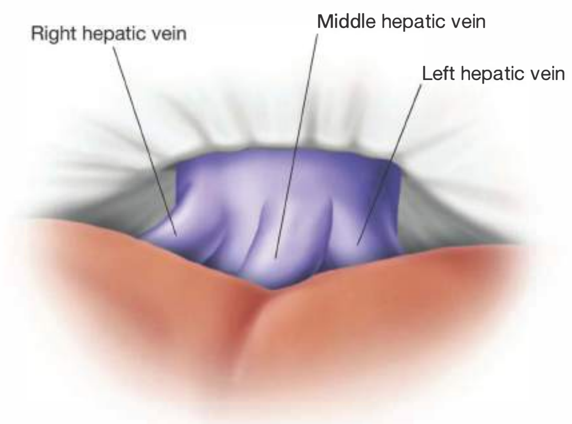

FIG 4 ● Hepatic veins at the apex of the falciform ligament. Dissection along the liver surface exposes this confluence. Dissection proceeds from medial to lateral, exposing the RHV without unnecessary dissection of contralateral structures.

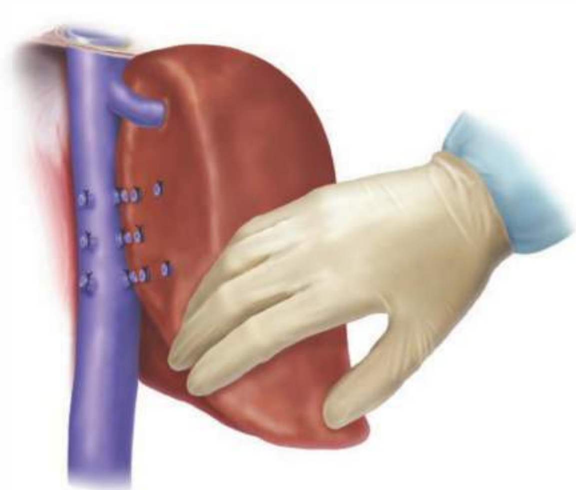

FIG 5 ● Exposure of the short hepatic veins and IVC. This exposure is obtained by medial rotation and anterior retraction of the right liver. The short hepatic veins from the IVC into the liver parenchyma are ligated.

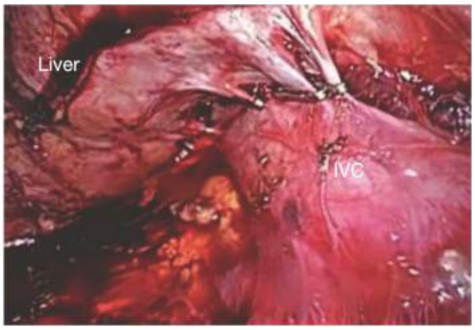

FIG 6 ● Laparoscopic view of right liver mobilization. The dissection of the IVC yields short hepatic veins for ligation with both clips and energy.

DISSECTION OF THE RIGHT HEPATIC VEIN

- In a formal right hepatectomy, it is ideal to isolate and ligate the RHV outside the liver. In "subtotal" right hepatectomies, intraparenchymal ligation may be employed to preserve liver tissue.
- Full exposure and control of the RHV prior to hilar dissection and inflow division is important. This sequence allows the surgeon to abort the procedure in the case of major venous injury to the outflow of the intended remnant and/or bleeding, prior inflow ligation, which is a "point of no return."
- The RHV is isolated only after the IVC is fully exposed. Liver retraction is released and dissection then resumes from over the top of the liver. The medial border of the RHV is dissected off the middle hepatic vein. The RHV is dissected close to the liver to leave a long cuff of RHV on the IVC in the event of injury. Once fully dissected, the RHV is isolated with a ¼-in Penrose drain or vessel loop.
- To avoid congestion of the liver, the hepatic vein is not ligated at this time.

HILAR DISSECTION AND VASCULAR CONTROL

- The exposure of the hilum is ensured by anterior and cranial fixation of the falciform ligament. Antegrade cholecystectomy is performed. The gallbladder can be removed at this time or may be left attached by the cystic duct.
- After creating an aperture through the gastrohepatic ligament, an umbilical tape is placed around the porta hepatis. Creation of a loose Rummel tourniquet permits a rapid Pringle maneuver in the event of bleeding.
- In the hilum, the dissection proceeds at the level of the hepatic plate. Dissection on the contralateral side should be avoided to prevent inadvertent injury and to minimize scarring in case subsequent hepatectomy is required.
- In the right hilum, dissection of the right hepatic artery (RHA) is the first priority. The RHA (or its branches) should be isolated as they enter the right liver. A vascular loop facilitates gentle traction, and a bulldog clamp is then placed on the segment of the artery to be divided.
- Perfusion in the proper hepatic artery as well as the opposite hepatic artery should now be assessed. IOUS in the hilum or of the parenchyma can be used for confirmation.
- If no deficit is noted, then the clamp may be removed and the RHA divided between 2-0 silk ligatures and 3-0 suture ligatures. Division should expose the right portal vein (RPV) posteriorly and cephalad to the RHA.
- The RPV dissection should establish enough length to permit safe ligation. The first branch, the RPV to the caudate, is often divided for adequate length. Dissection must be carried out to identify the bifurcation of the RPV into anterior and posterior branches and to ensure that the visualized vessel is the RPV and not the main portal vein. Isolation of the RPV may be confirmed by IOUS. The RPV is circled with a vessel loop or a ¼-in Penrose drain to allow gentle traction.
- We routinely transect the RPV with a vascular stapler. We typically use an articulating stapler to obtain the optimal angle for transection. Extreme care is taken during passage of the jaws of the stapler to avoid disruption of nearby vascular branches. If difficulty is encountered, try inserting the narrow jaw of the stapler into the opening of the Penrose drain that was previously looped around the RPV. Withdrawing the Penrose drain guides the stapler into place (**FIG 7**).
- At this point, the right liver should begin to demarcate, showing ischemia along Cantlie's line.
- Unless an oncologic margin is at risk, do not routinely perform extrahepatic division of the right hepatic duct (RHD). Rather, ligate and divide it intraparenchymally

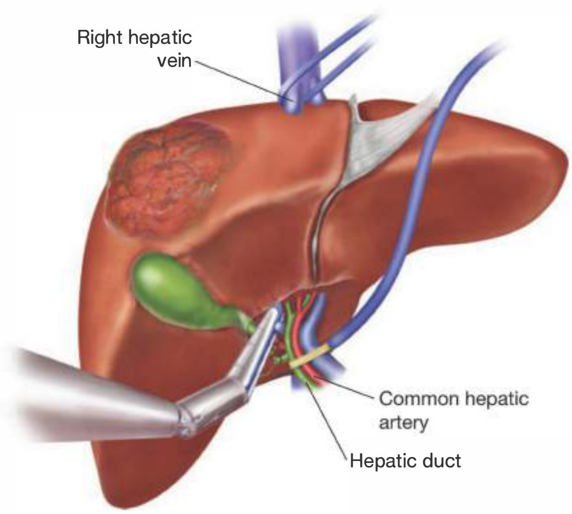

FIG 7 ● Stapler division of the RPV. The hilar structures are approached from the right lateral hilar plate. After thorough exposure of the anatomy, the portal vein can be ligated with a stapler.

with a stapler. This technique allows the safe sealing of the duct proximal to the bifurcation and avoids unnecessary hilar dissection, which can devascularize or injure the common hepatic duct.

- When ligating the RHD at the hilum, pass a clamp from the right edge of the gallbladder fossa through the hepatic parenchyma exiting at the caudate isthmus, thus creating a tunnel through which the narrow jaw of the stapler may be passed and fired.
- The previously isolated hepatic vein is divided using an articulating stapler. Vascular occlusion is now complete (**FIG 8**).

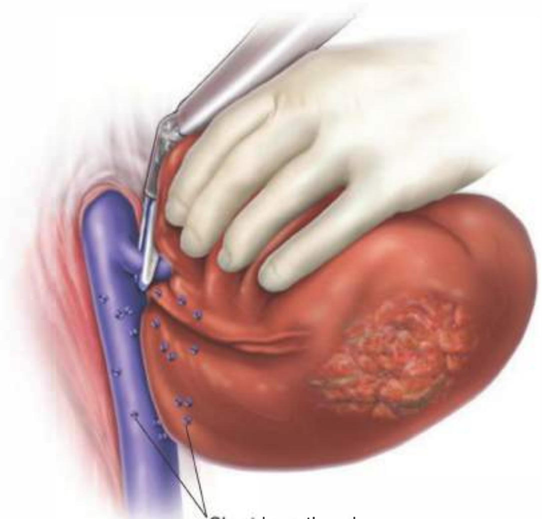

FIG 8 ● Stapler division of the RHV. This is the last step of the vascular isolation after completion of the inflow ligation.

PARENCHYMAL TRANSECTION

- To begin transection, use electrocautery to disrupt Glisson's capsule and mark the line of transection. For lesions of segment 5 or 8, IOUS may be helpful to mark an appropriate medial margin. This process is continued circumferentially.
- The next 1 to 2 cm of liver parenchyma can be transected with an energy source. Bipolar, radiofrequency, or ultrasonic-generated heat energy can be used at the surgeons' preference. The authors find superior hemostasis with saline-radiofrequency devices that purportedly seal vasculature and bile ducts.
- This circumferential groove will serve as a guide for the completion of the hepatic transection with staplers. The importance of creating a fully circumferential groove (especially posteriorly) in order to provide tactile and visual guidance for stapling cannot be overstated.
- At any point during the transection, IOUS can be used to confirm the line of resection to ensure adequate margins.
- A Pringle maneuver may be applied to occlude collateral flow through the liver remnant should brisk bleeding be encountered.
- Stapling of the hepatic parenchyma is our preferred means of transection. This is performed with two staplers on the surgical field. While one is in use by the surgeon, the other is being reloaded for use to ensure rapidity and avoid delays when encountering bleeding. The thin (narrow) end of the stapler is tunneled bluntly into the hepatic parenchyma. Alternatively, the path of the stapler can be guided by creating a parenchymal tunnel with a curved clamp. Closure of the stapler is analogous to crushing the hepatic parenchyma with a clamp, although much faster than the traditional crush-clamp technique (**FIG 9**).

FIG 9 ● Parenchymal transection. This step includes intraparenchymal ligation of the left hepatic duct. The stapler used to transect the liver obtains hemostasis and also ligates biliary radicals to help prevent bile leaks.

- If there is resistance to the passage of the stapler through the parenchyma, do not apply additional force. Instead, the stapler is redirected, as such resistance usually indicates that the stapler is encountering the sidewall of a vessel. Forcing the stapler through these branches will cause significant hemorrhage.
- Slow, sequential compression of the hepatic parenchyma avoids tearing of vessels and excludes excess tissue. Although the instinct is to grab large bites of parenchyma, smaller bites permit superior staple formation, minimizing the chance of bleeding or bile leak.
- Difficulty in closing or firing the stapler may be encountered when (1) too much tissue is between the jaws or (2) the RHD is ligated and divided.
- With the left hand holding the right liver, the line of transection can be controlled. With the fingers in the posterior groove, the IVC is protected and endpoint of transection is known at all times. The entire transection continues with repeated firings of the stapler.

COMPLETION

- After the parenchyma is divided, the specimen is removed from the field. Gross margins should be assessed by pathology intraoperatively (**FIG 10**).
- Hemostasis is achieved at the cut edge of the liver. Most bleeding is from venules and will cease with 10 minutes of gentle tamponade. The authors favor using a saline-perfused radiofrequency ablation (RFA) device to complete the process of obtaining hemostasis.
- Care should be taken to avoid coagulating major biliary branches, as this may lead to subsequent stricture. Any area of bile leakage should be controlled with fine monofilament sutures.
- For areas of bleeding near the hilum, energy devices may risk damage to crucial structures; employ manual pressure and/or topical hemostatic agents, that is, cellulose matrices or fibrin sprays or foams.
- A cholangiogram with methylene blue or other colored agents can mitigate against potential bile leaks.
- A large, closed suction drain may be placed adjacent to the transected parenchyma at the surgeon's preference.
- Reapproximate the falciform ligament to prevent lateral rotation of the remnant; kinking of the middle and left hepatic veins is incompatible with life.

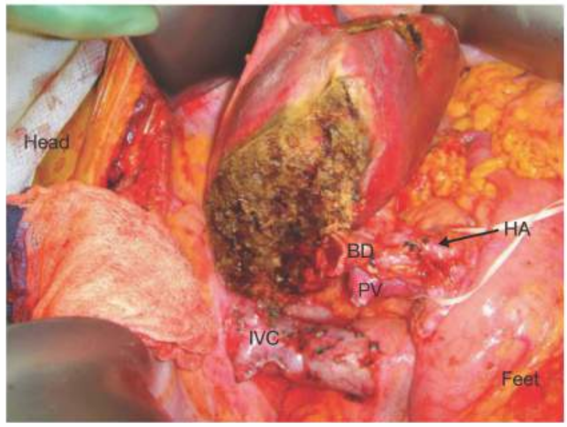

FIG 10 ● Completed right hepatectomy. *BD*, bile duct; *HA*, hepatic artery; *IVC*, inferior vena cava; *PV*, portal vein.

PEARLS AND PITFALLS

Patient history	■ Suggestion of hepatic insufficiency or damage should be aggressively evaluated to reduce postresection hepatic failure.
Imaging and testing	■ Liberal use of volumetry is warranted. ■ Vascular abnormalities should be detailed on preoperative imaging.
Vascular isolation	■ Early isolation of the RHV avoids hilar dissection if surgery is aborted. ■ Starting dissection at the right hilar plate minimizes risk of contralateral injury to the remnant vasculature. ■ Minimize dissection of the contralateral liver if there is a chance of repeat hepatectomy.
Parenchymal transection	■ Low CVP anesthesia is key. ■ A circumferential groove facilitates later transection. ■ Stapling the hepatic parenchyma is fast and seals vessels and bile ducts alike. ■ Small venous bleeders encountered during dissection can be simply tamponaded.
Hemostasis	■ Use of energy near major biliary or hilar structures should be avoided

POSTOPERATIVE CARE

- VTE prophylaxis is continued, including doses on the day of surgery as appropriate to the dosing schedule.
- Antibiotics are only continued to complete less than 24 hours of prophylaxis.
- All patients are given supplemental magnesium (6 g/IV once), phosphate (sodium phosphate, 30 mmol/IV TID), and vitamin K (phytonadione, 5 mg/SC q8h) to aid in liver regeneration. This is given regardless of serum levels.
- Drains are checked for bilirubin on postoperative day 3. If the level is less than serum levels and output is less than 100 mL per day, the drain is removed.

OUTCOMES

- In experienced centers, mortality is now less than 3% and morbidity is 20%.[4]
- Overall and disease-specific survival at 5 years can reach 69% and 72%, respectively.[5]
- Neoadjuvant or adjuvant systemic treatment is nearly universal.

COMPLICATIONS

- Volume-outcomes relationships are prominent in hepatic resection.
- Outcomes specific to hepatectomy include bile leaks (5.9%), perihepatic abscesses (3.7%), hemorrhage (0.9%), and hepatic insufficiency (3.1%).[6]
- Bile leaks can be managed by percutaneous drainage or endoscopic retrograde cholangiopancreatography (ERCP) with sphincterotomy to facilitate internal drainage.

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Chapter **24**

Minimally Invasive Right Hepatectomy

Shirin Sabbaghian Allan Tsung

DEFINITION

- Minimally invasive right hepatectomy is defined as resection of segments 5 to 8 using minimally invasive techniques (see Part 3, Chapter 15, FIG 2). These techniques include the following:
  - Pure laparoscopic
  - Hand assisted—The surgeon's hand is used to assist during the laparoscopic approach.
  - Hybrid—The liver is mobilized laparoscopically followed by minilaparotomy to divide the liver.
  - Robotic—The liver is resected with robotic technique.

PATIENT HISTORY AND PHYSICAL FINDINGS

- A thorough history and physical exam should be performed for each patient.
- A patient's history is important and should include careful attention to the following:
  - Medical history—Is the liver neoplasm benign or malignant? If the neoplasm is malignant, is it a primary of the liver or a metastasis? If the lesion is malignant, has the patient had chemotherapy? Does the patient have underlying liver disease such as cirrhosis? If cirrhosis exists, does the patient have manifestations of advanced liver disease such as esophageal varices, splenomegaly and hypersplenism, ascites, or hepatic encephalopathy? Is the patient healthy enough to withstand liver resection?
  - Surgical history—Has the patient had abdominal surgery in the past? If so, what type of operation and how many operations? Has the patient had prior liver or biliary tract surgery?
  - Social history—Alcohol use is important for consideration of concurrent liver disease.
  - Functional status should be considered when deciding goals of care and whether surgery is appropriate for an individual patient.
- Physical exam should include evaluation for the presence of advanced liver disease such as jaundice/scleral icterus (can also be present with biliary obstruction), gynecomastia, splenomegaly, ascites, and caput medusa. Findings of advanced malignancy, including supraclavicular lymphadenopathy, should be recognized.

IMAGING AND OTHER DIAGNOSTIC STUDIES

- Abdominal imaging using computed tomography (CT) or magnetic resonance imaging (MRI) within a short interval of time (within 4 to 6 weeks) prior to surgery is necessary. Attention should be focused on the number of lesions, the location of the lesions (particularly in relation to the hepatic and portal veins [PVs] as well as the inferior vena cava), the character of the background liver (normal, cirrhosis, steatosis), and the proportion of liver that will be left in situ once all hepatic disease is resected.
- For CT scan, a dynamic bolus, contrast-enhanced, multidetector CT using at least a three-phase protocol is ideal. Noncontrast images of the liver are followed by rapid bolus of contrast and images are immediately obtained during peak arterial enhancement (arterial phase) as well as during PV enhancement (portal venous phase). Hypervascular tumors and tumors that receive their blood supply primarily from the hepatic artery (HA) are best visualized on arterial phase. During the portal venous phase, the liver is maximally enhanced and hypovascular lesions on a background of bright-appearing parenchyma can be well-distinguished (**FIG 1**).
- Enhanced hepatic MRI is an equivalent alternative.
- Tissue sampling with core biopsy by ultrasound or CT guidance can be useful to make or confirm a diagnosis.
- Additional diagnostic studies that are necessary prior to operation are basic labs, including a hepatic function panel and coagulation studies. A complete blood count including a platelet count is important to help detect advanced portal hypertension if the patient has cirrhosis. If disease-specific tumor markers are elevated, they are helpful to confirm a diagnosis as well as to follow patients during treatment.

SURGICAL MANAGEMENT AND OPERATIVE TECHNIQUE

- There are several advantages of laparoscopic liver resection when compared to an open technique. These include decreased blood loss, less postoperative pain, quicker return to diet, and a shorter length of stay.[1] These advantages have been demonstrated in case-controlled studies. Additionally, oncologic outcomes (margins, survival) are not compromised when laparoscopic technique is used for patients with hepatocellular carcinoma and metastatic colorectal cancer.[2–4]

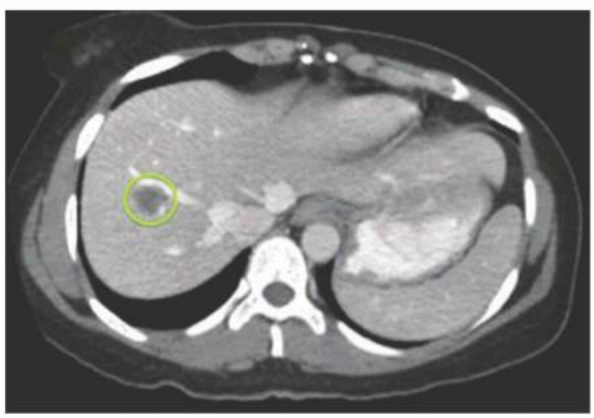


FIG 1 ● CT image of liver, portal venous phase. Encircled is a metastatic colon lesion to the right liver.

- During the World Consensus Conference on Laparoscopic Surgery in 2008, the international position on laparoscopic liver surgery was created—this should be used as a guide to determine which patients are eligible for minimally invasive hepatic resection.[5] This statement recommends surgery with minimally invasive technique for patients with a single lesion of 5 cm or less located in segments 2 to 6. It suggests that major liver resection can be performed with minimally invasive technique but only by those experienced both with liver surgery as well as minimally invasive liver resection. Some surgeons in high-volume centers may choose to operate beyond these criteria in certain settings. Importantly, the consensus conference suggests that the surgeon should be facile with minimally invasive technique, including the skill of intracorporeal suturing should bleeding become an issue.
- The decision to use hand-assisted versus pure laparoscopic technique is surgeon specific and mostly depends on comfort with either technique. As our own experience in laparoscopic hepatectomy has grown, so has our comfort with performing anatomic hepatic resection in a pure laparoscopic manner. When comparing pure laparoscopic technique to hand-assisted or hybrid technique in 113 patients undergoing anatomic liver resection, we found similar results for estimated blood loss and complications; however, interestingly, shorter operative times were noted in the pure laparoscopic group (188 minutes vs. 264 minutes for the pure vs. hand-assisted technique, $P < .05$).[6]
- Consideration of the background liver is important to help decide which patients are appropriate for resection—up to 80% of a healthy liver in a relatively healthy patient can be resected without major consequence. This percentage decreases if the liver is cirrhotic.
- The technique of minimally invasive right hepatectomy is, as intended, the same as for open surgery except minimally invasive equipment is used.
- Two surgeons who are experienced in hepatobiliary and minimally invasive surgery are appropriate for these cases. An assistant to hold the camera is optimal, thus allowing both hands of both surgeons to be free.

HAND-ASSISTED LAPAROSCOPIC RIGHT HEPATECTOMY

- The patient is positioned supine with the arms tucked. Padded barriers are secured at the patient's feet to prevent sliding with the anticipated use of steep reverse Trendelenburg during the case.
- Access is gained to the abdominal cavity via a 5-mm port ideally in the left upper quadrant (LUQ), and pneumoperitoneum of 12 mmHg is created. Additional ports are placed using a 5-mm 30-degree scope for visualization (**FIG 2**). These ports include an 8-cm hand access site in the supraumbilical position. Two 12-mm ports are placed in the subxiphoid and right paramedian position, and two 5-mm ports are placed in right subcostal positions. The camera is switched to a 10-mm 30-degree scope in the right paramedian port.
- The lesion is identified.
- Standing at the patient's left, the surgeon places his or her nondominant hand through the hand access device.
- The round and falciform ligaments are divided using a sealing device, exposing the anterior surface of the hepatic veins.
- The ligamentous attachments of the right liver are dissected. With the patient in reverse Trendelenburg position and with the right side up, the gallbladder fundus is retracted superiorly via a grasper in the LUQ port. The right lobe of the liver is retracted anteriorly using a closed grasper in the subxiphoid port. With a hand retracting the colon inferiorly, the hepatic flexure is dissected using a cautery device. The colon is reflected inferiorly. Attachments to the duodenum are dissected from the liver as necessary. Using hand assistance for ligament exposure, the right triangular and coronary ligaments are dissected up to the right hepatic vein (RHV)/inferior vena cava (IVC), also using a sealing device (**FIG 3**).
- Laparoscopic ultrasound of the liver is performed via the 12-mm subxiphoid port to confirm anatomy and ensure that the procedure will include the pathology that is anticipated.

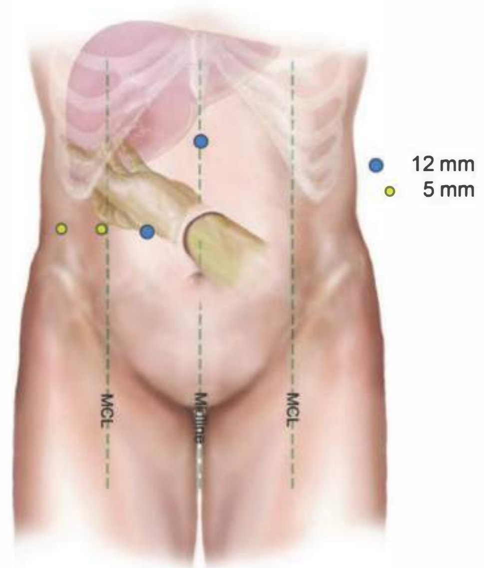


FIG 2 ● Port placement for minimally invasive right hepatectomy. For the pure laparoscopic method, a 12-mm port is used instead of a hand port in the supraumbilical position. *MCL,* middle clavicular line. Used with kind permission from Randal S. McKenzie/McKenzie Illustrations.

FIG 3 ● Dissection of the ligamentous attachments of the right liver. Used with kind permission from Randal S. McKenzie/McKenzie Illustrations.

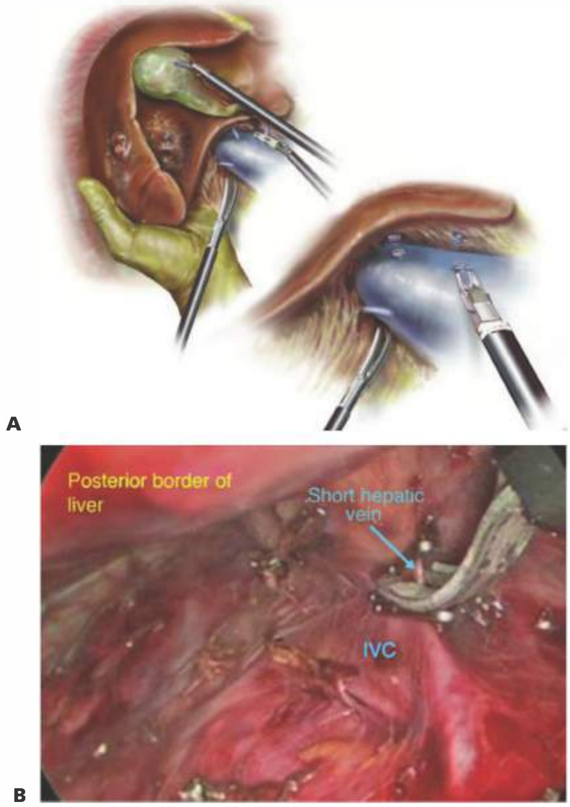


FIG 4 ● **A.** Dissection of the short hepatic veins from the IVC. Short hepatic veins are defined with a dissector and ligated using a sealing device or clips and shears. **B.** Dissection of the short hepatic veins from the IVC. Short hepatic veins are clipped and divided with shears. Used with kind permission from Randal S. McKenzie/McKenzie Illustrations.

- The IVC is dissected (FIG 4A,B). For exposure, the gallbladder is retracted superiorly from a grasper in the LUQ port. Hand assistance is used to retract the liver anteriorly, exposing the IVC. The liver is mobilized from the inferior vena cava by identifying and ligating short hepatic veins. Ligation is performed using clips, and endoscopic shears or a sealing device is used to cut the veins. This is performed up to the RHV.
- Cholecystectomy and portal dissection. The hand is removed from the abdominal cavity, and the liver is allowed to rest back in normal position. A 5-mm assist port is placed in the hand access device. The gallbladder is grasped and dissected for cholecystectomy in standard laparoscopic manner. After identifying the critical view, the cystic artery and duct are clipped. The cystic artery and duct are transected. While maintaining superior retraction of the gallbladder, portal tissue is retracted laterally via a grasper in one of the lateral 5-mm ports. The hepatoduodenal ligament is dissected using a combination of an endoscopic dissector and hook cautery via the subxiphoid port. The right HA is identified and defined (FIG 5). If space allows, this is stapled using a vascular load roticulating stapler through the 12-mm subxiphoid port. Otherwise, this can be tied laparoscopically, clipped, and then transected. Next, the right PV is identified and defined (FIG 6). A silk tie is placed around it (this is not tied), and a grasper in one of the right lateral ports retracts this tie superolaterally to ex-

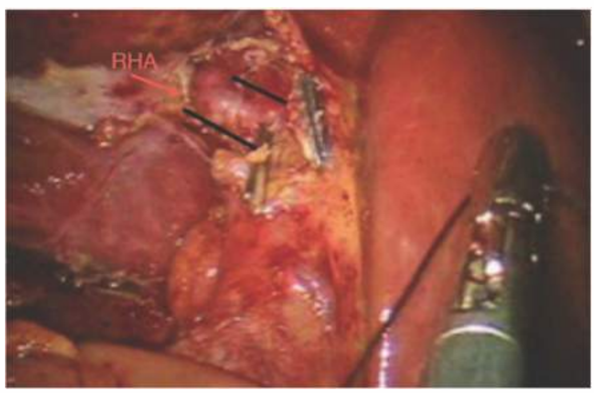


FIG 5 ● Portal dissection. Exposure of the right hepatic artery (RHA).

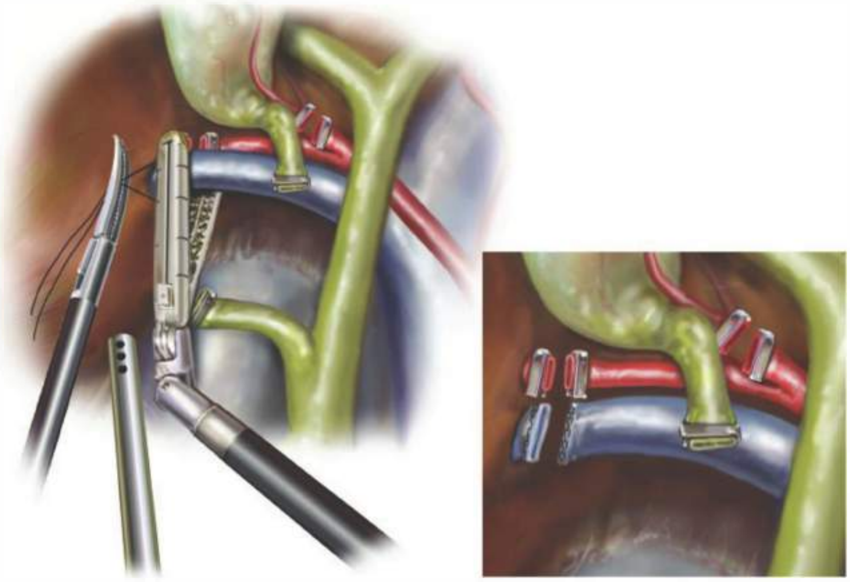


FIG 6 ● Portal dissection, ligation of the right PV. Used with kind permission from Randal S. McKenzie/McKenzie Illustrations.

pose the full length of the vein. A vascular load roticulating stapler is used to ligate and transect the right PV. The right hepatic duct (HD) is identified and defined. It is tied distally, then transected proximally. It is important to identify bile coming from the proximal duct (**FIG 7**). Once bile is identified, the proximal duct can be clipped to maintain a clean field. The free, distal end of the right HD is doubly clipped to prevent leak. After the portal dissection is completed, the gallbladder is dissected from the gallbladder fossa.

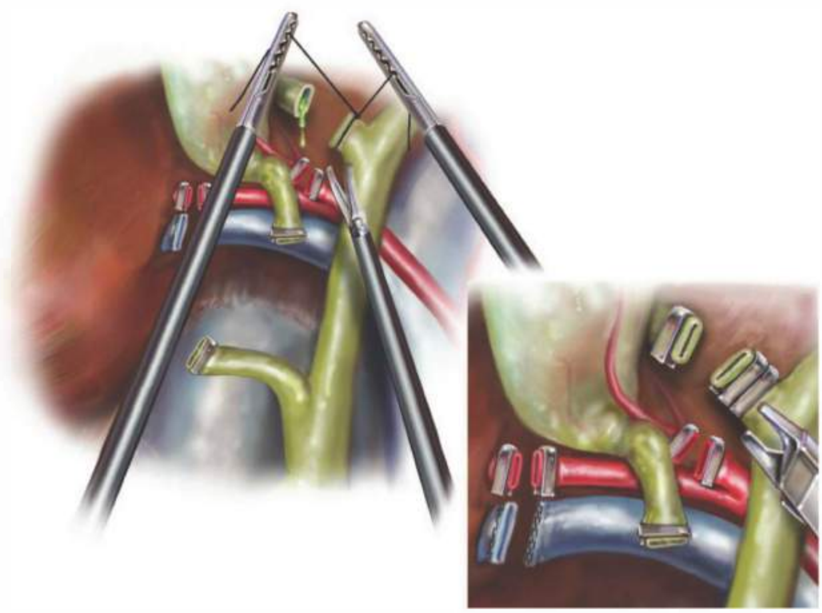


FIG 7 ● The right HD is identified and defined. It is tied distally, then transected proximally. It is important to identify bile coming from the proximal duct. Used with kind permission from Randal S. McKenzie/McKenzie Illustrations.

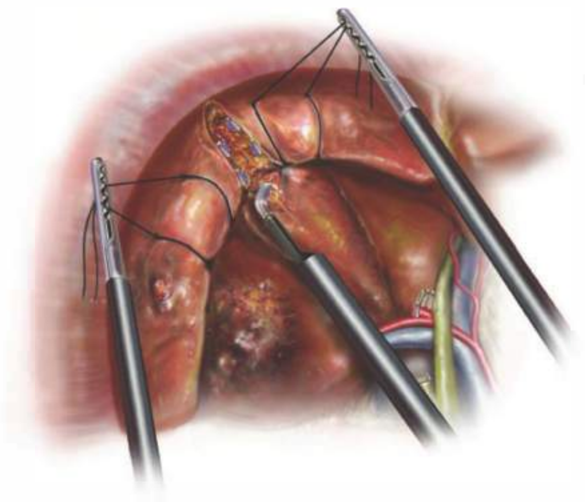
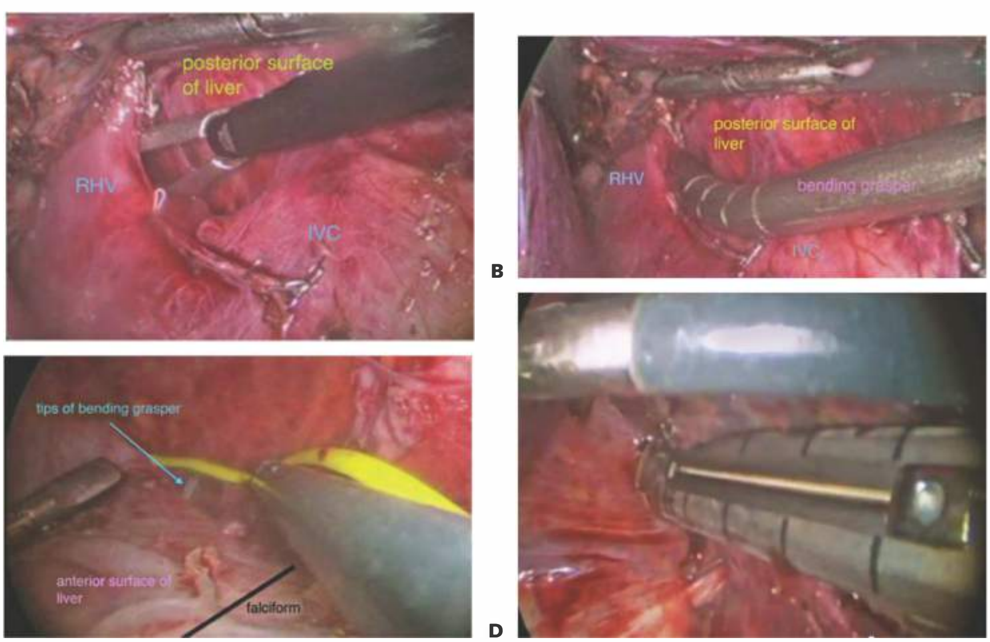


FIG 8 ● Parenchymal transection. Used with kind permission from Randal S. McKenzie/McKenzie Illustrations.

- The parenchyma is transected. All retracting instruments are removed, allowing the liver to drop. The line of transection is defined using hook cautery, following the line of demarcation on the liver's anterior surface. Ultrasonography is repeated to ensure again that the pathology will be included in the point of transection. Figure-of-eight stitches using 0-Polysorb are placed on either side of the line of transection, and these are retracted to either side with graspers (**FIG 8**). The parenchyma is coagulated, placing clips when appropriate. Progress is made along the line of transection until the RHV is encountered. Using a vascular load roticulating stapler through the 12-mm assist port, the RHV is stapled intraparenchymally. The remaining parenchyma is divided as necessary.
- For tumors that are close to the RHV-IVC junction, the RHV can be isolated and transected in an extrahepatic manner. To accomplish this, first the anterior surface of the RHV is dissected along its medial edge, creating a window to the undersurface of the liver. The short hepatic veins should have already been dissected and ligated along the IVC at this point. The RHV is dissected from the undersurface of the liver using a dissecting instrument while lifting the liver anteriorly (**FIG 9A**). A bending grasper is placed anterior to the RHV and advanced through the window that has been created toward the anterior surface of the liver (**FIG 9B**). The liver is allowed to fall back into place, and the bending grasper is visualized from the anterior surface of the liver through the window created. A vessel loop is fed to the grasper, and the grasper gently pulls back through to the undersurface of the liver. The other end of the vessel loop is fed around the lateral border of the RHV from an anterior approach as well. The lateral edge of the liver is retracted anteriorly again, and both



A B C D

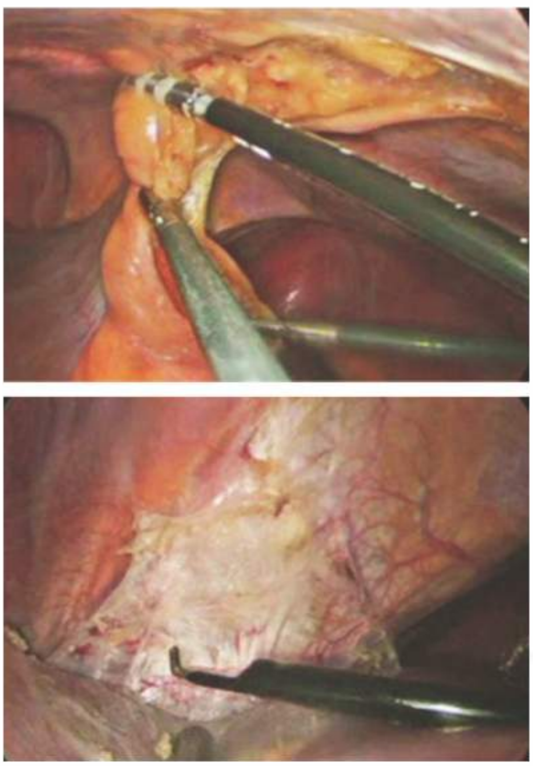
FIG 9 ● **A.** Dissection of the RHV extrahepatic ligation. **B.** Maneuvering around the RHV with a bending grasper. **C.** Isolating the RHV with a vessel loop. The bending grasper comes anterior to the RHV from the undersurface of the liver. With the liver allowed to fall back into place, a vessel loop is fed to this bending grasper, which then pulls the vessel loop under the liver.

ends of the vessel loops should be around the RHV, thus having a defined isolation of this vein (**FIG 9C**). The vessel loop can then retract the vein gently, acting as a guide while a stapler is introduced. The vessel is ligated and transected with a vascular load roticulating stapler.

- The specimen is collected using a laparoscopic bag. Hemostasis on the resection bed of the liver is ensured.
- Saline and contrast cholangiograms are performed through the cystic duct to confirm no biliary leak. The gallbladder is removed from the abdomen using a laparoscopic bag.
- The abdomen is closed. Laparoscopic equipment is used to remove ports under direct visualization and close fascia using a port site closure device. Fascia at the hand site is closed from the outside in standard manner. The skin is closed.

PURE LAPAROSCOPIC RIGHT HEPATECTOMY

- Patient positioning and port placement are similar to that used for the hand-assisted procedure described. Instead of a hand port, however, an additional 12-mm port is used in the supraumbilical position. All steps are the same as described for the hand-assisted procedure except that a laparoscopic instrument is used instead of a hand.
- The round and falciform ligaments are divided using a sealing device, exposing the anterior surface of the hepatic vein (**FIG 10A,B**).



A

B

FIG 10 ● **A.** Laparoscopic dissection of the falciform ligament. **B.** Exposure of the anterior surface of the left/middle hepatic veins after dissection of the falciform ligament.

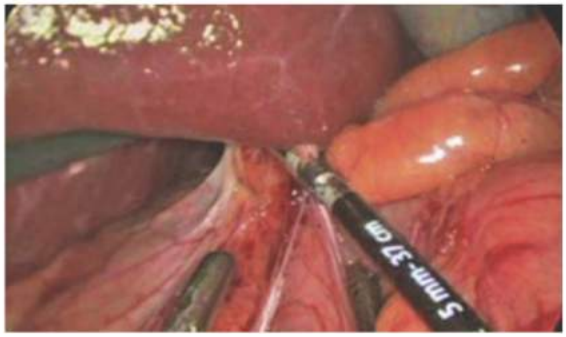


FIG 11 ● Laparoscopic dissection of ligamentous attachments of the right liver.

- The ligamentous attachments of the right liver are dissected. With the patient in reverse Trendelenburg position and with the right side up, the gallbladder fundus is retracted superiorly via a grasper in the LUQ port. The right lobe of the liver is retracted anteriorly using a closed grasper in the subxiphoid port. With a grasper retracting the colon inferiorly, the hepatic flexure is dissected using a cautery device. The colon is reflected inferiorly. Attachments to the duodenum are dissected from the liver as necessary. The right triangular and coronary ligaments are dissected up to the RHV/IVC (**FIG 11**).
- Laparoscopic ultrasound of the liver is performed via the 12-mm subxiphoid port.
- The IVC is dissected. For exposure, the gallbladder is retracted superiorly from a grasper in the LUQ port. A closed grasper is used via the supraumbilical port to retract the liver anteriorly, exposing the IVC. The liver is mobilized from the inferior vena cava by identifying and ligating short hepatic veins (**FIG 4B**).
- Cholecystectomy, portal dissection, parenchymal transection. This is similar to what is described in the hand-assisted section.
- The specimen is collected using a laparoscopic bag. Hemostasis on the resection bed of the liver is ensured.
- Saline and contrast cholangiograms are performed through the cystic duct to confirm no biliary leak. The gallbladder is removed from the abdomen using a laparoscopic bag.
- The abdomen is closed. Laparoscopic equipment is used to remove ports under direct visualization and close fascia using a port site closure device. The skin is closed.

PEARLS AND PITFALLS

Patient selection	■ A careful evaluation of history, exam, and laboratory findings is essential to avoid encountering unexpected liver disease. ■ High-quality imaging is essential for operative planning to ensure an adequate margin can be obtained.
Operative technique	■ Pre- and intraoperative restrictive resuscitation reduces blood loss. ■ Attention to hemostasis is essential for laparoscopic liver resection. ■ Use the shafts of instruments or specifically designed, expanding instruments to retract the liver—puncturing or lacerating the capsule must be avoided. ■ Be constantly vigilant of potential gas embolism—use reduced insufflation pressure when possible.
Postoperative care	■ Venous thromboembolism remains a risk, even if the international normalized ratio (INR) is elevated. Use chemoprophylaxis.

POSTOPERATIVE CARE

- It is imperative that postoperative care is maintained by a team of individuals familiar with these patients and cases. It is also imperative that care is maintained in a facility equipped to provide care for patients who suffer major postoperative complications, for example, patients who require prolonged intubation or urgent hemodialysis postoperatively. Labs, including a hepatic function panel and coagulation panel, should be followed and trended.

OUTCOMES

- Laparoscopic liver resection, including hand assisted as well as purely laparoscopic, has been used with increasing frequency. There are several advantages to this procedure and they include decreased blood loss, less postoperative pain, faster return to diet, and shorter length of stay when compared to open surgery. Oncologic outcomes are not compromised with these techniques, and survival is similar when compared to survival in patients with hepatocellular carcinoma or metastatic colorectal cancer who undergo open surgery. It is technically demanding and should be performed by surgeons experienced with hepatobiliary surgery.

COMPLICATIONS

- Bleeding
- Infection
- Bile leak
- Liver failure
- Kidney failure in association with liver failure
- Close or positive margins

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Chapter 25

Left Hepatic Lobectomy

Jon S. Cardinal

DEFINITION

- The liver has a segmental anatomy that is defined by the intrahepatic distribution of the portal triad structures. There are eight liver segments (**FIG 1**) with the left hepatic lobe being constituted by segments 2 to 4 and the right lobe being constituted by segments 5 to 8. Segment 1, the caudate lobe, which is distinct from both the left and right lobes.
- The boundary between the right and left lobes of the liver is an imaginary line, known as Cantlie's line, which runs from the gallbladder anteriorly to the inferior vena cava (IVC) posteriorly.
- Left hepatic lobectomy is considered a major anatomic liver resection and is defined by the removal of the liver segments that constitute the left hepatic lobe (2 to 4).

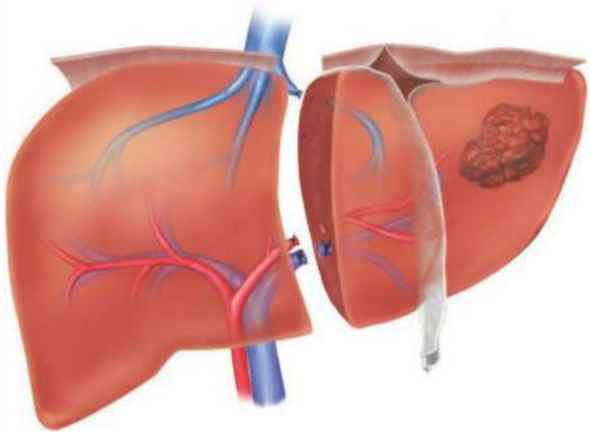


FIG 2 ● Drawing illustrating the segments to be excised during left hepatic lobectomy. Left hepatic lobectomy involves removal of segments 2 to 4 and requires division of the left hepatic artery and left portal vein (inflow structures) as well the left hepatic duct and left hepatic vein (outflow structures).

DIFFERENTIAL DIAGNOSIS

- Indications for left hepatic lobectomy include both benign and malignant etiologies, neoplastic and nonneoplastic processes, and conditions that are either primary or secondary to the liver itself.
- Generally, left hepatic lobectomy will need to be performed when the condition that is being treated requires division of any (or all) of the major inflow (portal vein, hepatic artery) and/or outflow (left or middle hepatic vein, left hepatic duct) structures to the left lobe of the liver (**FIG 2**).

PATIENT HISTORY AND PHYSICAL FINDINGS

- The single biggest preoperative factor to account for when considering patients for major anatomic liver resection, including left hepatic lobectomy, is the health of the native background liver.
- In a patient with a healthy background liver, anatomic trisegmentectomy can be performed and tolerated; however, in patients with chronic liver disease of any kind, the extent of resection needs to be carefully weighed against the possibility of postoperative liver insufficiency and/or failure.
- Among others, historical factors that may indicate the presence of underlying chronic liver disease include accurate quantification of alcohol use (current and past); identification of risk factors for viral hepatitis exposure (intravenous [IV] drug abuse, tattoos, promiscuous sexual behavior, history of blood transfusions); comorbidities that predispose to nonalcoholic fatty liver disease (NALFD) such as hypertension, hyperlipidemia, diabetes, and high cholesterol; prior chemotherapy exposure(s) in cases of patients who are being considered for liver resection for oncologic purposes, the type and duration of which can predispose to chemotherapy-associated steatohepatitis (CASH); and past history suggestive of liver decompensation including prior episodes of jaundice, gastrointestinal (GI) bleeding, ascites production, and so forth.
- Findings on physical examination of the stigmata of cirrhosis are indicative of advanced chronic liver disease and are generally considered as contraindications for major liver resection (Table 1).

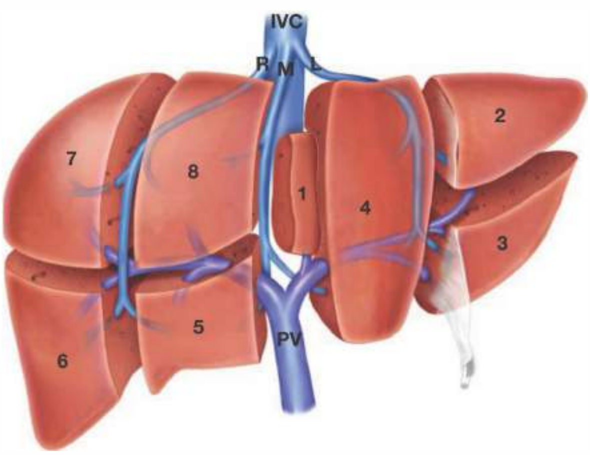


FIG 1 ● Drawing illustrating the segmental anatomy of the liver. The liver is divided into eight anatomic segments with the left and right lobes being separated by Cantlie's line (an imaginary line between the gallbladder fossa anteriorly and the IVC posteriorly). The left lobe is made up of segments 2 and 3 (left lateral segments) and segment 4 (left medial segment).

IMAGING AND OTHER DIAGNOSTIC STUDIES

- Standard blood work including a complete blood count, complete metabolic panel, and coagulation panel are required prior to proceeding with any major liver surgery.

Table 1: Clinical History and Physical Examination Findings Associated with Cirrhosis

History
Fatigue or weight loss
Jaundice (icterus; skin, urine, and stool color)
Anorexia, cachexia
Abdominal pain
Edema
Ascites
GI bleeding, hemorrhoids
Loss of libido or menstrual cycle
Encephalopathy
Physical Examination
Malnutrition
Fetor hepaticus
Jaundice, scleral icterus
Spider angiomata
Clubbing, palmar erythema
Gynecomastia, testicular atrophy
Ascites
Abdominal hernia
Caput medusa
Hepatosplenomegaly
Asterixis

GI, gastrointestinal.

When the history and/or physical examination points to a chronic, underlying liver disease, additional serologic testing for any of the viral hepatitides as well as other obscure causes of cirrhosis (hemochromatosis, Wilson's disease, etc.) may be advisable. In cases of liver tumors, carcinoembryonic antigen (CEA), α-fetoprotein (AFP), and/or carbohydrate antigen 19-9 (CA19-9) levels occasionally can provide diagnostic clarity and therefore should routinely be obtained.

- Ultrasonography can identify cirrhotic liver morphology by providing information on the size, contour, and echotexture of the liver. While this modality has the advantage of being noninvasive, it is also highly operator dependent.
- When planning major liver surgery, high-quality cross-sectional imaging is a prerequisite. Either computed tomography (CT) or magnetic resonance imaging (MRI) can be used. Contrast enhancement, which should include both an early hepatic arterial phase as well as a delayed portal venous phase (so-called liver protocol scan), is the best manner in which to obtain detailed images of the liver as well as the relationship of tumor(s) to the major intra- and extrahepatic structures.
- Additionally, liver protocol scans can, in some instances, obviate the need for invasive biopsy and the risks associated therein due to the fact that certain liver tumors including simple cysts, hemangioma, focal nodular hyperplasia, and hepatocellular carcinoma have radiographic appearances that can be diagnostic in the appropriate clinical setting.
- MRI/magnetic resonance cholangiopancreatography (MRCP) may be preferred in cases in which bile duct resection/reconstruction is a possibility, as this modality provides superior anatomic definition of the biliary anatomy in comparison to CT scan alone.
- Specifically, in regard to left hepatic lobectomy, careful attention should be paid to the relationship of any tumor(s) within the left lobe to the left hilar structures as well as the left hepatic vein and/or common trunk (**FIG 3A**). Well-described anatomic variants, such as a replaced or accessory left hepatic artery (**FIG 3B**) or a right posterior hepatic duct arising from the main left hepatic duct (**FIG 3C**), should be carefully evaluated for as their presence may alter the conduct of the operation.

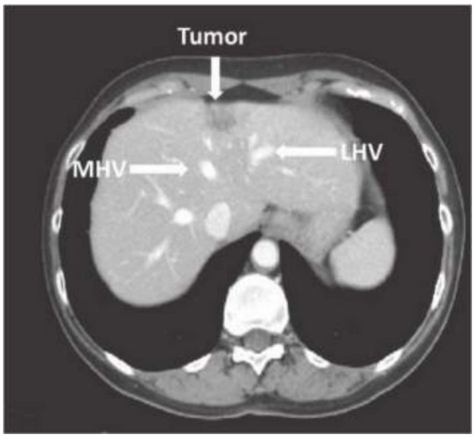
SURGICAL MANAGEMENT

Preoperative Planning

- The most important step prior to performing any major liver operation is thorough and careful review of the available preoperative imaging studies. Understanding the relationship of tumor to major intra- and extrahepatic structures allows the surgeon to anticipate and plan strategies for dealing with point(s) during the parenchymal transection that may be challenging or where close margins may be anticipated.
- Adequate preparation for major liver surgery involves having blood available (two to four units of crossmatched packed red blood cells [PRBCs]) in the event of intraoperative hemorrhage.
- Preoperative discussion with the anesthesiologist is advisable with important points of consideration to include possible epidural or paravertebral nerve block placement for perioperative analgesia as well as choosing which invasive monitoring devices will be required. For left hepatic lobectomy, it is recommended that a central venous catheter be placed so that low central venous pressure (CVP) (5 mmHg or less) can be maintained up until the point that the parenchymal transection is complete. Additionally, arterial line placement is warranted. A nasogastric tube (NGT) for gastric decompression is recommended.

Positioning

- For left hepatic lobectomy, patients should be positioned supine with the arms out on arm boards at 60 degrees. The area to be prepped and draped starts cranially at the nipple line, extends caudally to the symphysis pubis, and laterally carries down to the table on both sides. A Foley catheter is required, and both lower and upper body forced air heated blankets should be applied to maintain normothermia.



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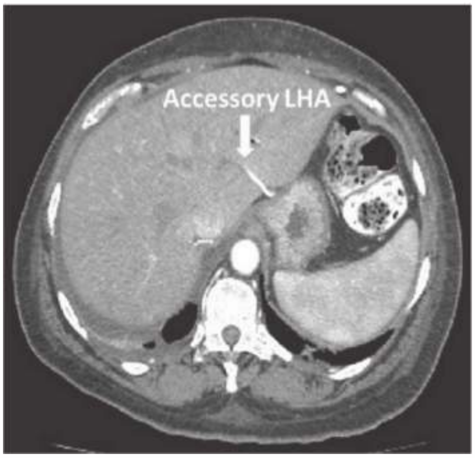

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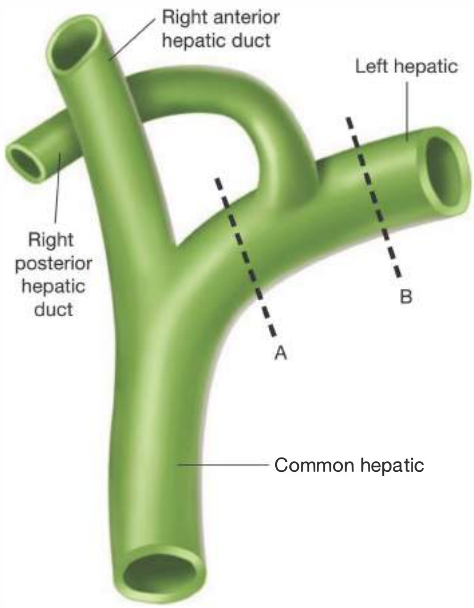

C

FIG 3 ● **A.** CT scan showing the relationship of a metastatic colorectal cancer tumor deposit to the middle hepatic vein (MHV) and left hepatic vein (LHV), respectively. **B.** CT scan showing an accessory left hepatic artery (LHA) coming off of the left gastric artery and coursing through the gastrohepatic ligament. **C.** Drawing showing the right posterior (RP) sectoral duct arising from the left hepatic (LH) duct. When this anatomic variant exists during a left hepatic lobectomy if the LH duct is transected in plane *A*, the RP segments (6 and 7) will be disconnected from the biliary tree. If the LH duct is transected in plane *B*, the RP ducts will remain connected to the main biliary tree and be able to drain.

STEP 1: SKIN INCISION/OPENING THE ABDOMEN

- The optimal incision for any major liver surgery is a right subcostal incision with an upper midline extension. The subcostal incision should be marked out three fingerbreadths below the right costal margin and be carried out laterally to where the floating 12th rib can be palpated (**FIG 4A**). Alternative choices for incision include a bilateral subcostal incision with (Mercedes) or without (Chevron) an upper midline extension. A long midline laparotomy can also be utilized.
- The skin and subcutaneous tissue is opened to expose the anterior fascia. The right anterior rectus sheath is opened first to expose the right rectus muscle, which is followed medially until the midline is identified. The midline is then opened, staying anterior to the preperitoneal fat pad up to the level of the xyphoid process, which can be removed to facilitate exposure if necessary.
- The right rectus and external oblique muscles are then divided with cautery (**FIG 4B**) and the posterior rectus sheath is exposed. Upward traction is placed on the upper and lower skin flaps and the peritoneal cavity is entered along the subcostal portion of the incision.
- The preperitoneal fat pad is excised off of the undersurface of the upper midline portion and the falciform ligament is divided. The round ligament is ligated and divided between 2-0 silk ties (**FIG 4C**).

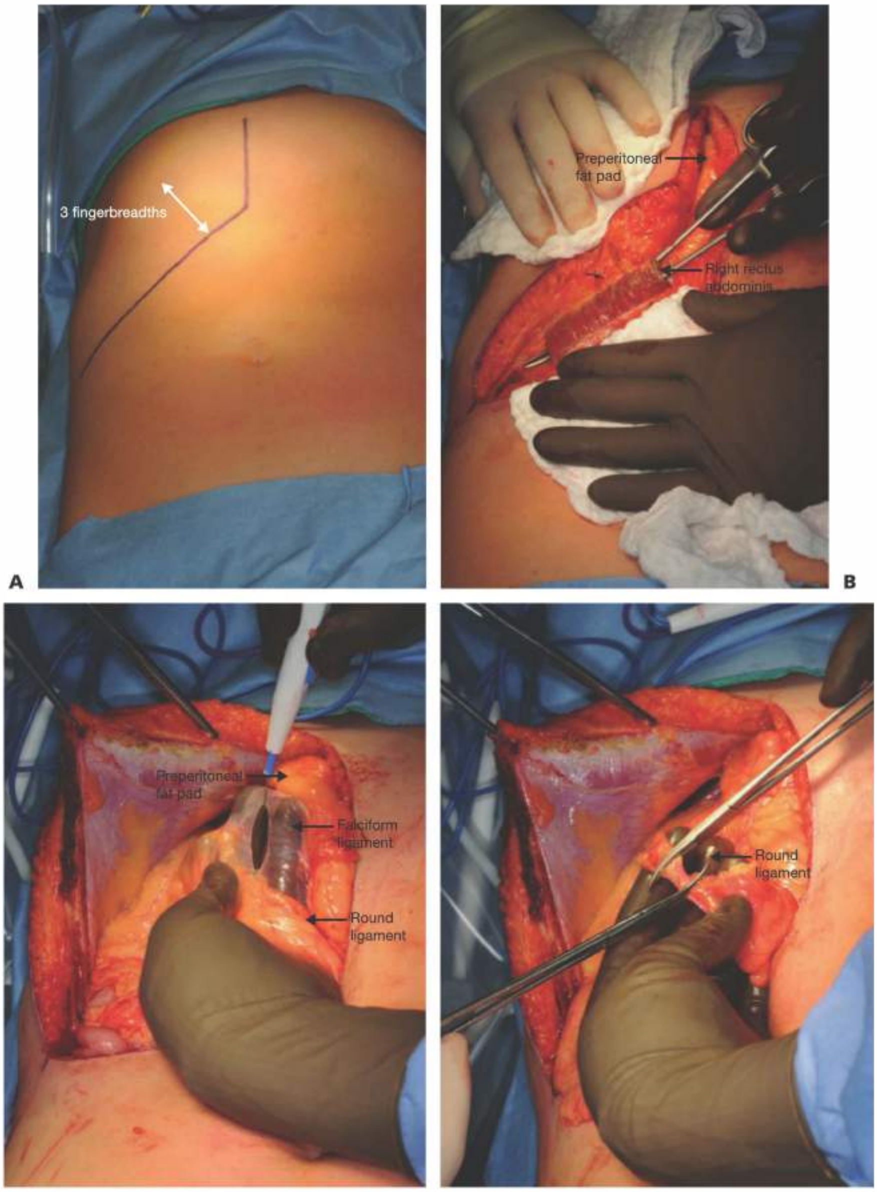

FIG 4 ● Intraoperative photo of proper placement of a right subcostal incision with upper midline extension. The subcostal portion of the incision should be placed three fingerbreadths below the costal margin. **B.** Intraoperative photo of the right rectus muscle which is eventually divided with cautery. **C.** Intraoperative photo showing the division of the falciform and round ligaments.

STEP 2: PLACEMENT OF THE TABLE-MOUNTED RETRACTOR

- Exposure during open liver surgery requires the use of a table-mounted retractor. The preferred retractor for this author is the Thompson-Farley liver retractor. Other options include the Bookwalter or Omni retractor systems.
- Regardless of the chosen retractor, the principles for exposure are the same and include cephalad and lateral retraction of the bilateral rib cages, caudal retraction on the right kidney, caudal and medial retraction on the second portion of the duodenum, and lateral retraction of the stomach (**FIG 5**).
- Initial exposure is gained with upward and lateral retraction on the bilateral rib cages and having the patient placed in slight reverse Trendelenberg position. It is during the hilar dissection that the right kidney, duodenum and stomach blades are placed to facilitate exposure of the hepatoduodenal ligament.

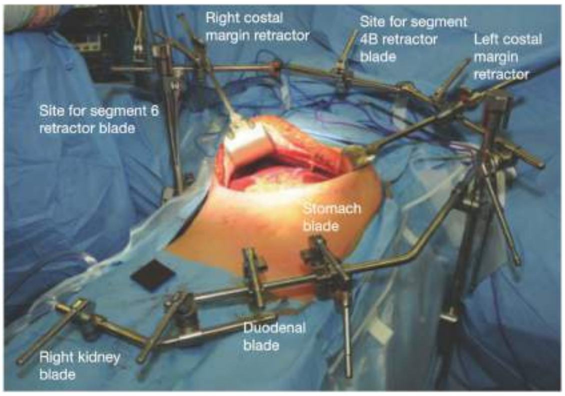

FIG 5 ● Intraoperative photo of the setup of the table-mounted retractor. A thin, malleable blade is used to retract segments 6 and 4B during the open cholecystectomy. Abdominal wall retractors are used to provide cephalad and lateral retraction on the right and left rib cages. The right kidney, duodenum, and stomach are retracted inferiorly, inferomedially, and laterally, respectively, using malleable blades.

STEP 3: EXPOSURE OF THE HEPATIC VEINS/LEFT LOBE LIVER MOBILIZATION

- With the rib cages being retracted as mentioned earlier and solid dorsal and caudal traction being applied to the anterior surface of the liver, the falciform ligament is divided midway between the anterior abdominal wall and liver capsule. The dissection is carried posteriorly toward the diaphragm and hepatic veins.
- Once the falciform ligament begins to splay apart into the right and left triangular ligaments, dissection with a tonsil clamp and cautery to release the right triangular ligament is performed. This will expose the anterior surface of the right hepatic vein. Medially, a notch between the right hepatic vein and the common trunk of the middle and left veins can be palpated with an index finger.
- Next, the left triangular ligament is divided in a similar manner to expose the anterior surface of the common trunk. The left phrenic vein, which drains into the left hepatic vein, serves as a reliable landmark that can aid in the identification of the left vein and common trunk (**FIG 6**).
- Once the anterior surfaces of the hepatic veins are exposed, a lap pad is placed under the left lateral segments of the liver and above the stomach, and the remainder of the left triangular ligament is divided. This exposes the lateral wall of the left hepatic vein and mobilizes the left lateral segments completely.
- The gastrohepatic ligament is opened widely, and an accessory left hepatic artery (if present) is doubly ligated between 2-0 silk ties and divided.
- The ligamentum venosum (Arantius' ligament) is divided caudally. This plane of dissection leads to the left-sided hilar structures.

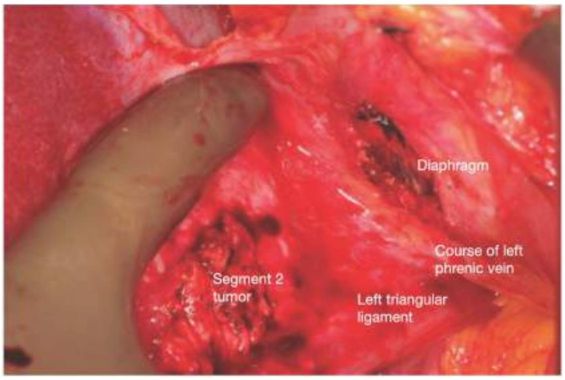

FIG 6 ● Intraoperative photo of a tumor in segment 2 of the left lobe. The relationship of the tumor to the left triangular ligament, diaphragm, and course of the left phrenic vein is identified in the photo. Releasing the left triangular ligament will allow for the left lateral segments to be rotated anteriorly and to the right. The course of the left phrenic vein is an important anatomic landmark during left hepatic lobectomy as it will eventually insert into the left hepatic vein.

STEP 4: OPEN CHOLECYSTECTOMY/ INTRAOPERATIVE LIVER ULTRASOUND

- If the gallbladder is still present, a standard top-down cholecystectomy is performed. The cystic artery is doubly ligated and divided, and the gallbladder is left attached to the cystic duct for saline and contrast cholangiogram at the completion of the case.
- An intraoperative ultrasound is performed next. The right and left hilar structures are easily identifiable by the white, echogenic halo which surrounds them. These structures are followed ultrasonographically into the

hepatic parenchyma and, if the surgery is being done for a neoplastic process, particular attention is paid to the relationship of tumor(s) to the left hilar structures. Similarly, the outflow structures (hepatic veins) are identified ultrasonographically and followed inside the liver with attention again being paid to the relationship of any tumor(s) to the left and middle hepatic veins. Next, a systematic intraoperative liver ultrasonography is performed to rule out any additional tumors within other segments of the liver.

STEP 5: INFLOW AND OUTFLOW CONTROL

- Apply a tonsil clamp to the divided round ligament and retract it with solid anterior and rightward traction.
- Any parenchymal bridges between the left lateral and left medial segments are divided, typically with cautery (**FIG 7**).
- The left hilum is dissected at the base of the umbilical fissure. The left hepatic artery is dissected circumferentially and doubly ligated and divided (after a test clamp is performed and maintenance of the right hepatic arterial pulse is confirmed).
- Next, the left portal vein is dissected at the base of the umbilical fissure and is transected distal to the takeoff of the caudate branch using a vascular load of a linear cutting stapler.
- Next, a hepatotomy is made 1 cm cephalad to the base of the umbilical fissure in segment 4B and a blunt Kelly clamp is passed through the hepatic parenchyma behind the left hilar plate. The Kelly clamp should emerge from the parenchymal tunnel anterior to the caudate lobe. A moistened umbilical tape is passed through the parenchymal tunnel and a vascular load of a linear cutting stapling device is used to transect the left hepatic duct.
- Next, the common trunk of the left and middle hepatic veins are encircled by passing a large, blunt right-angle clamp from the notch between the right vein and common trunk posteromedially behind the common trunk. Once isolated, the common trunk is divided using a vascular load of a linear cutting stapler.

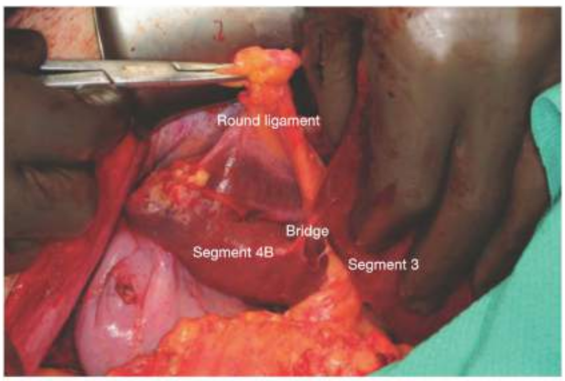

FIG 7 ● Intraoperative photo of a thin parenchymal bridge between segments 4B and 3, the thickness of which can vary. During left hepatic lobectomy, dissection of the left hilar structures begins by dividing this bridge, which allows for exposure of the base of the umbilical fissure, where the inflow structures to the left lobe can be safely identified and dissected out extrahepatically.

STEP 6: PARENCHYMAL TRANSECTION

- At this point, with the inflow and outflow divided, the left lobe will demarcate.
- Repeat ultrasound is performed to confirm the plane of parenchymal transection, which is marked on the liver capsule with electrocautery. Attention is paid to the course of the middle hepatic vein, which should not be bisected inside the liver. The plane of transection can be chosen such that a 1-cm bridge of devascularized liver can be safely left inside the patient in an attempt to avoid the intrahepatic course of the middle hepatic vein (1) if needed and (2) if the surgical margin is not compromised.
- Cautery is used to perform the initial 1 to 2 cm of parenchymal transection after which the LigaSure device is used. When the parenchymal slice is deepened and middle vein branches are encountered, a Pringle maneuver is performed by doubly passing a fat blue vessel loop around the hepatoduodenal ligament and cinching it down with a short, blunt right-angle clamp (**FIG 8**).
- The remainder of the transection is performed by using a blunt kelly clamp to make parenchymal tunnels around hepatic vein branches deep inside the liver through which vascular loads of the linear cutting stapler are fired.
- Once the parenchymal transection is complete, the cut surface of the liver is inspected for surgical bleeding which, when encountered, is suture ligated using figure-of-eight 2-0 silk sutures.
- After all surgical bleeding is controlled, the Pringle tape is released and the cut surface is dried using cautery (**FIG 9**).
- Instruct the anesthesiologist to give 1 L of normal saline and 500 mL of 5% albumin as a bolus due to the fact that up until this point in the case, the fluid administration should have been negligible to maintain an adequately low CVP (<5 mmHg).

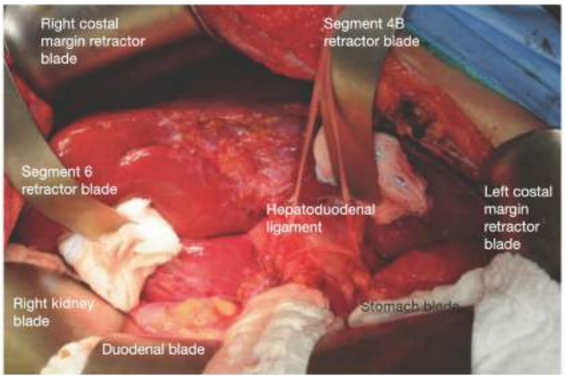

FIG 8 ● Intraoperative photo of a moistened umbilical tape doubly passed around the hepatoduodenal ligament. A fat blue vessel loop can also be used. As the parenchymal transection is deepened, inflow control to minimize bleeding (Pringle maneuver) can be performed by cinching down on the tape or vessel loop and clamping with a short, fat right-angle clamp.

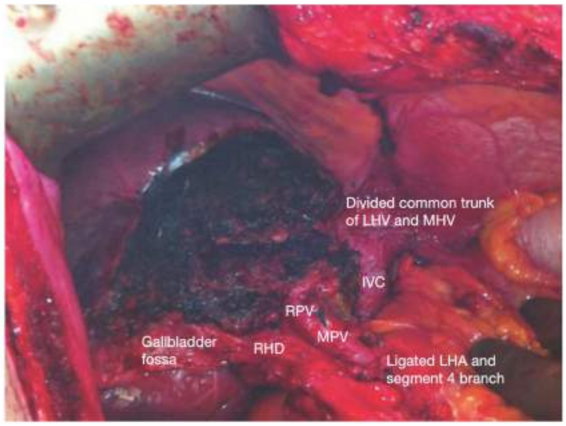

FIG 9 ● Intraoperative photo after completion of the parenchymal transaction. LHV, left hepatic vein; MHV, middle hepatic vein; IVC, inferior vena cava; RPV, right portal vein; MPV, main portal vein; RHD, right hepatic duct; LHA, left hepatic artery.

STEP 7: COMPLETION ULTRASOUND/ SALINE AND CONTRAST CHOLANGIOGRAM/PLACEMENT OF DRAINS AND ABDOMINAL CLOSURE

- A completion intraoperative liver ultrasound is performed with attention being paid to the inflow to and outflow from the remnant right lobe, which, once confirmed, concludes the need for any further ultrasound evaluation.
- A saline cholangiogram is performed through the cystic duct. The common bile duct and parenchymal cut surface are inspected for evidence of saline extravasation, which, if identified, is repaired as deemed appropriate. Next, a contrast cholangiogram is performed to exclude any distal obstruction as well as to confirm adequate biliary drainage from the remnant right lobe. After the completion saline and contrast cholangiogram, the cystic duct is ligated and clipped below the level of the ductotomy and then transected, and the gallbladder is removed and sent for pathologic analysis.
- A closed suction drain is brought through a stab incision in the right lower quadrant, with its tip being oriented along the cut parenchymal surface.
- The midline portion of the wound is closed with simple, interrupted 0-braided nylon sutures and the subcostal portion of the incision is closed in two separate layers using nonabsorbable monofilament suture and the subcostal portion of the incision is closed in two separate layers using absorbable monofilament suture run from lateral to medial and tied in the middle.
- The skin is closed with either surgical clips or, cosmetically, in a running subcuticular manner with 4-0 Vicryl.

PEARLS AND PITFALLS

Indications	■ Patients with chronic liver disease or cirrhosis have an increased risk of postoperative liver insufficiency or failure following left hepatic lobectomy.
Preoperative planning	■ Failure to have adequate IV access and two to four units of crossmatched blood available can lead to problems with resuscitation in the event of significant bleeding. ■ Low CVP (5 mmHg or less) anesthesia is critical for bloodless parenchymal transection.
Exposure of hepatic veins/left lobe liver mobilization	■ Capsular tears in the liver should be avoided as they cause unnecessary bleeding and lead to increased operative duration. ■ The right and left phrenic veins serve as reliable landmarks that can be followed back to their insertion on the right hepatic vein and common trunk, respectively. ■ Careful, steady dissection to expose the anterior surface of the hepatic veins is required as inadvertent injury to these structures can result in massive, uncontrolled bleeding.

Inflow and outflow control	■ Before taking the left hepatic artery, a test clamp should be performed and maintenance of pulsation in the right hepatic hilum should be confirmed. ■ Similarly, inadvertent ligation of the main portal vein as opposed to only the left portal vein can be avoided by taking the left vein high in the umbilical fissure, distal to the takeoff of the branch to the caudate lobe. ■ Dissection to gain control of the common trunk of the middle and left hepatic veins should be done effortlessly as attempts at passing a clamp against resistance can lead to iatrogenic injury to the back wall of the vein or the anterior surface of the vena cava. ■ The left hepatic duct should be taken inside the liver, when possible, in an attempt to stay above the takeoff of an anomalous right posterior duct arising from the left duct, which occurs in roughly 10% to 15% of patients (**FIG 3C**).
Parenchymal transection	■ Several different techniques for parenchymal transection exist. The method described in the text is the preferred method of the author. Familiarization with different techniques is of value; however, one method should be chosen and used as repeatedly as possible. ■ When using the technique described above, the stapler should not be fired until bipolar electrocautery is no longer planned on being used for parenchymal division, as the metal staples interfere with proper functioning of this device. ■ When creating parenchymal tunnels through which staplers can be fired, the Kelly clamp should be passed effortlessly as resistance indicates the presence of a major structure. When resistance is met, a new plane either above or below the one in which the resistance is being encountered should be chosen. ■ Bile leaks from the cut surface should be inspected for carefully and repaired immediately when found.

POSTOPERATIVE CARE

- Admission to an intensive care unit is not necessarily required following left hepatectomy; however, a monitored floor is recommended. This allows for rapid recognition of changes in the patient's vital signs.
- IV fluids should be given liberally (D5 ½ NS + 20 mEq KCl at a rate of 150 mL per hour) for the first 2 postoperative days (PODs).
- The Foley catheter should be maintained for the first 24 to 48 hours postoperatively to ensure adequate urine output. The NGT is left overnight from the night of surgery to the following morning and then is typically removed on POD 1 as long as the output is not too substantial. If removal of the NGT is tolerated, a clear liquid diet can be started on POD 2 and advanced ad libitum.
- While debate about the need for deep venous thrombosis prophylaxis following major liver surgery exists, most now agree that prophylaxis is indicated. Unfractionated heparin given subcutaneously two or three times a day is the preferred method.
- Daily laboratories including complete metabolic panel and blood count should be monitored. Aggressive electrolyte replacement and volume resuscitation are recommended. Particular attention should be paid to the phosphorus level as hypophosphatemia is a relatively typical electrolyte derangement following major liver surgery.
- The volume and character of the drain output should be noted at least once, if not twice daily. The drain can usually be removed the day before or the day of discharge as long as the output is nonbilious in character and not too substantial in regard to volume (<200 mL per day). If the drain is nonbilious but is draining an excessive volume, 25 g of salt-poor albumin (SPA) given twice daily for 48 hours with twice-daily furosemide injections can be given in an attempt to reduce the output. Occasionally, patients need to be sent home with the drain in place simply due to increased ascites production. If this is the case, they should be sent home with a prescription for oral furosemide and be seen back in the clinic in 1 week for possible drain removal.
- Adequate analgesia is a key component of the postoperative care following left hepatectomy. If the patient agreed to epidural or paravertebral catheter placement in the preoperative setting, these are extremely helpful. If regional anesthesia is not being used, a patient-controlled analgesia (PCA) pump is recommended. IV acetaminophen and ketorolac given on a scheduled basis are effective antiinflammatory adjuncts and can minimize the amount of narcotic analgesia that is required. When the patient is tolerating a diet, IV analgesia can be transitioned to an oral regimen.
- Early ambulation and aggressive pulmonary toileting is important to avoid pulmonary complications.

OUTCOMES

- Patients who have undergone an uncomplicated left hepatic lobectomy can typically expect to be discharged to home from the hospital anywhere between PODs 3 and 5.
- Most patients can have their drain removed prior to leaving the hospital (see above) and should be able to participate in most of their usual activities with a few exceptions. These include no heavy lifting (> 10 lb), no driving while requiring narcotic analgesics and no soaking the incision in water.
- When done for benign disease, patients who have undergone following left hepatic lobectomy do not necessarily need to be followed with any specific imaging or laboratory studies. In cases in which the hepatectomy was done for oncologic purposes, the recommended surveillance program includes every 3 months CT scans and tumor markers (when appropriate) for the first year postoperatively, followed by every 6 months for the second year, and then yearly thereafter.

COMPLICATIONS

- Bleeding
- Bile leak. If bilious drainage is noted to be coming from the drain, consideration should be given to endoscopic retrograde cholangiogram and common bile duct stent placement to relieve the back pressure on the biliary tree in an attempt to get the bile leak to seal spontaneously.
- Pulmonary complications
- Postoperative liver insufficiency or failure

SUGGESTED READINGS

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Chapter 26

Minimally Invasive Left Hepatic Lobectomy

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DEFINITION

- A minimally invasive left hepatic lobectomy (also termed left hepatectomy or left hemihepatectomy) is the resection of the liver medial to the midplane of the liver (Cantlie's line) using laparoscopic or robotic assistance and is formally defined as the resection of Couinaud segments 2, 3, and 4.[1]
- A left trisectionectomy or extended left hepatectomy (or hemihepatectomy) would also include the adjacent segments 5 and 8 with or without segment 1. A left lateral sectionectomy involves only segments 2 and 3.
- A liver resection is termed laparoscopic if it is a pure laparoscopic procedure, a hand-assisted procedure, or a hybrid technique procedure (which begins as a pure laparoscopic or as a hand-assisted procedure with the liver resection done through a minilaparotomy incision).[2]
- A left hepatectomy is performed for benign and malignant lesions and for living donor transplantation.

PATIENT HISTORY AND PHYSICAL FINDINGS

- A comprehensive history and physical exam should be performed with attention to signs and symptoms of liver failure, coagulopathy, and cardiac disease.
- The same indications for an open left hepatectomy apply to a minimally invasive left hepatectomy and the indications for benign lesions should not be relaxed due to the minimally invasive approach.[2] The indications for resection include hepatic adenoma, symptomatic hemangiomas, symptomatic focal nodular hyperplasia, symptomatic giant cysts, hepatocellular carcinoma, and colorectal cancer metastases.[3]
- The contraindications for a minimally invasive left hepatectomy include those for an open resection, in addition to decompensated cirrhosis, the inability to tolerate pneumoperitoneum, dense adhesions that are not amenable to minimally invasive adhesiolysis, need for extensive portal lymphadenectomy, need for vascular resection, and lesions that are near major vessels.[3,4] Biliary reconstruction is a relative contraindication for robotic-assisted surgery depending on the experience of the surgeon.[5]
- Lesion characteristics that are most favorable for laparoscopic resection include solitary lesions, size of 5 cm or less, peripheral location, and a lack of involvement of the hilum, major hepatic veins, or the inferior vena cava (IVC).[2]

IMAGING AND OTHER DIAGNOSTIC STUDIES

- Preoperative imaging is required to evaluate lesion resectability and for surgical planning. Imaging is useful for evaluation of lesion size, proximity to major vessels and bile ducts, aberrant anatomy, adequacy of anticipated postoperative liver volume, and for detection of lung or other abdominal metastases for malignant indications.
- Contrast-enhanced computed tomography (CT) (**FIG 1**), magnetic resonance imaging (MRI), and positron emission tomography (PET) can be used for preoperative evaluation.[6] A triple-phase CT (arterial, venous, and delayed venous phase) is useful for its spatial resolution and volumetric assessment. MRI is superior for detecting subcentimeter lesions. PET scans may be useful for detecting other sites of metastasis.

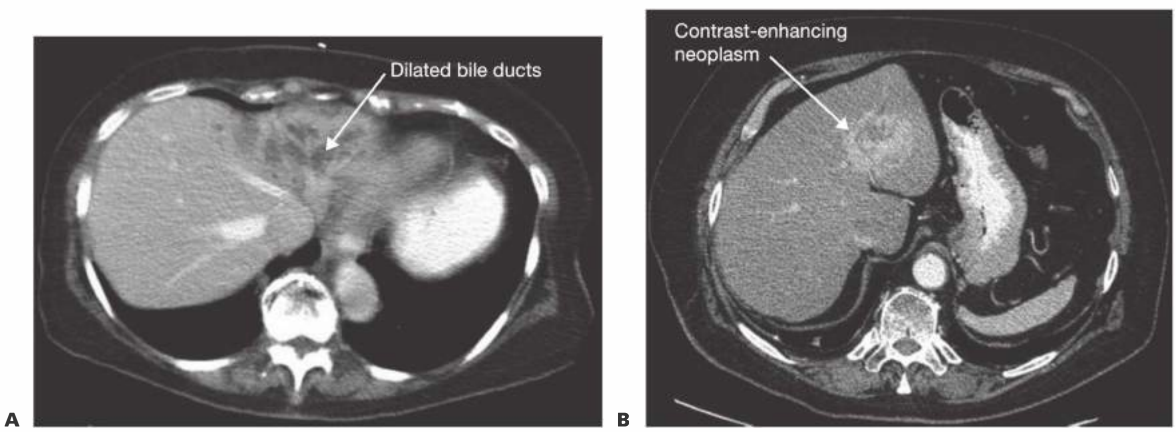


FIG 1 ● **A.** An 84-year-old female with a left hepatic cholangiocarcinoma. The neoplasm cannot be visualized; rather, the defining feature of this imaging is the intrahepatic biliary dilation that is confined to the left lobe of the liver and associated atrophy of the left lobe of the liver. **B.** A 71-year-old male with a left hepatocellular carcinoma (HCC). Consistent with the hypervascular features of many HCC lesions, this HCC enhances with contrast during the arterial phase. Also note the lack of features of cirrhosis. The spleen is small, varices or ascites are not observed, and the architecture of the liver is preserved with a smooth capsule.

- If a quantitative evaluation of liver function is needed, especially for patients who have undergone hepatotoxic chemotherapy, a monoethylglycinexylidide (MEGX) test or indocyanine green clearance test can be used.[6]
- Occasionally, preoperative liver biopsy may be necessary to document the presence or extent of cirrhosis.
- Preoperative laboratory tests include a complete blood count, liver function tests, coagulation profile, and relevant tumor markers in cases of malignant disease.

SURGICAL MANAGEMENT

Preoperative Planning

- Minimally invasive hepatic surgery should be performed by surgical teams experienced in both advanced minimally invasive techniques and major hepatic surgery.
- All potentially necessary equipment should be readily available and the patient should be counseled on the possibility for conversion to an open procedure.
- Preoperative portal vein embolization (PVE) can be considered in order to increase the size of the future liver remnant (FLR) to a minimum of 25% in the absence of cirrhosis and a minimum of 40% to 50% in well-compensated cirrhosis. PVE is less commonly needed in a left hepatectomy as compared to a right hepatectomy.[7]

Positioning

- Arrange the operating room so that the robot can be docked at the head of the table.
- Place the patient in supine position on a split-leg table in slight reverse Trendelenburg position. Video monitors are placed to the right and left of the head of the patient.
- Insert a central venous and arterial lines for hemodynamic monitoring. Give preoperative antibiotic prophylaxis and have crossmatched blood available.
- Judiciously administer intravenous fluids; keep the central venous pressure (CVP) less than 5 cm H_2O.
- For a purely laparoscopic resection (no robotic assistance), the operation can be performed with the surgeon standing between the patient's legs or with the surgeon at the patient's left during the hilar dissection and then moving to the right side for the parenchymal transection.[8]
- For a robotic resection:
  - Laparoscopic portion (liver mobilization): The surgeon stands on the left side, the assistant on the right, and the camera assistant between the legs.
  - Robotic portion (control of vascular inflow, parenchymal transection, hepatic outflow): The surgeon sits at the console and the assistant is between the legs (facilitates retraction, suction/irrigation, bipolar electrocautery, suture exchange, exchange of robotic instruments, and endovascular stapling).

PORT PLACEMENT

- Establish pneumoperitoneum via a 5-mm optical separator port in the left mid-abdomen approximately one handbreadth to the left and 2 in above the umbilicus.
- After pneumoperitoneum is established, place a 10-mm camera port in the right mid-abdomen approximately one handbreadth to the left and 2 in above the umbilicus. This position is a mirror image of the previous port.
- The abdomen is explored for metastatic disease.
- The full complement of ports is then placed as shown in **FIG 2**:
  - Three 8-mm robotic ports—R2 on the right and R1 (initial port upsized to robotic) and R3 on the left
  - One 12-mm camera port
  - One 12-mm laparoscopic assistant port in right lower quadrant (for stapling, suture access, energy device, suction, and clip applier)
  - One 5-mm laparoscopic assistant port in left lower quadrant cases (for energy device, suction, and clip applier)
- For hepatomegaly or with large tumors, the robotic ports are moved inferiorly toward the level of the umbilicus.[8]
- An intraabdominal pressure of less than 12 mmHg is recommended. Although a high intraabdominal pressure can theoretically improve hemostasis during liver transection, a high intraabdominal pressure could also potentially increase the risk of gas embolism, particularly if injury to the hepatic veins is encountered.[9]

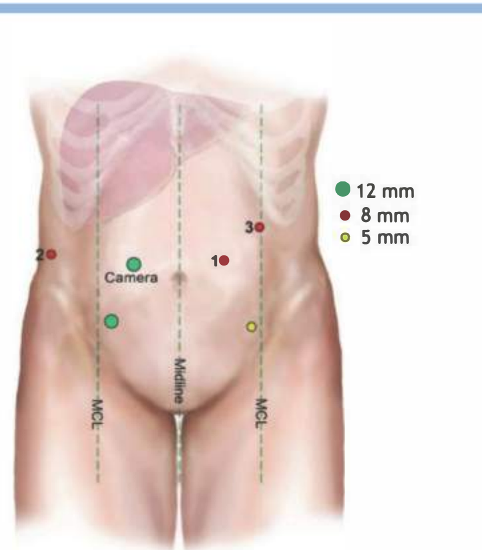


FIG 2 ● Port sites or left robotic hepatic lobectomy. *1*, Usually hook cautery or a grasper; *2*, PK bipolar forceps; *3*, grasper; *red*, robotic arms; *green (upper)*, camera; *green (lower)*, stapler insertion, passage of sutures, GelPort specimen extraction; *yellow*, laparoscopic assistant port (suction, LigaSure). MCL, midclavicular line.

EXPLORATION AND LESION EVALUATION

- The abdominal cavity and the liver surface are again examined for metastases. All suspicious lesions should be sent for frozen section biopsy.
- Laparoscopic ultrasound of the liver is then performed to confirm resectability of the targeted lesion(s) and the proximity to major vessels as well as to rule out other hepatic metastases.

LIVER EXPOSURE AND MOBILIZATION

- This portion of the operation is performed laparoscopically.
- Divide the falciform ligament and the ligamentum teres with hook electrocautery/bipolar electrocautery. Alternatively, this step can be performed prior to the intraoperative ultrasound. The ligamentum teres is left long enough to be used as a grasping point during the portal dissection.
- Divide the left triangular and left coronary ligaments using hook electrocautery or another energy device. (**FIG 3A,B**)
- Open the pars flaccida, staying close to the undersurface of the left lateral section and the caudate lobe. An accessory left hepatic artery may be encountered and is doubly clipped and divided.
- Incise Arantius' ligament using the hook cautery. It runs from the left branch of the portal vein to the left hepatic vein or the common (left and middle) hepatic vein truck. This maneuver must be performed with great care because injury to the left hepatic vein can occur. Alternatively, it can be done after the robot is docked to improve visualization.
- The bridge between the left lateral and medial sections (segments 3 and 4B) is divided.
- A cholecystectomy is performed to facilitate with exposure of the porta hepatis.[10]

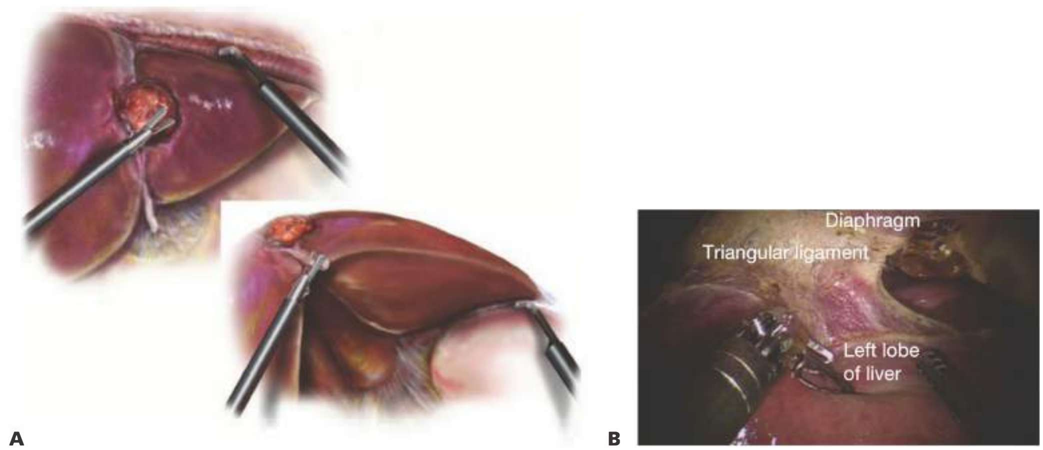


FIG 3 ● **A.** Divide the left triangular ligament using a laparoscopic or robotic hook cautery. Start the dissection lateral and work medial until the left hepatic vein is visualized as it enters the IVC. Using the falciform ligament as a handle *(inset)* for exposure, incise the pars flaccida to expose the ligament of Arantius. Dissect this ligament up to the left hepatic vein. **B.** Intraoperative view of the mobilization of the left lobe of the liver.

ROBOT DOCKING

- The robot is docked over the patient's head.
- The R2 (right) arm has the bipolar grasper, R1 (left) arm has the hook, and R3 (left) arm is a Cadiere grasper.

VASCULAR INFLOW CONTROL

- Encircle the hepatoduodenal ligament with an umbilical tape placed through the foramen of Winslow. This maneuver will facilitate an intermittent Pringle maneuver as needed to prevent blood loss.[11]
- Retract the ligamentum teres anteriorly and cranially to expose the base of the round ligament/umbilical fissure.
- The peritoneum of the left hepatic pedicle is incised and the left hepatic artery is identified, dissected, and vessel looped. After a test clamp ensuring a good pulse/flow

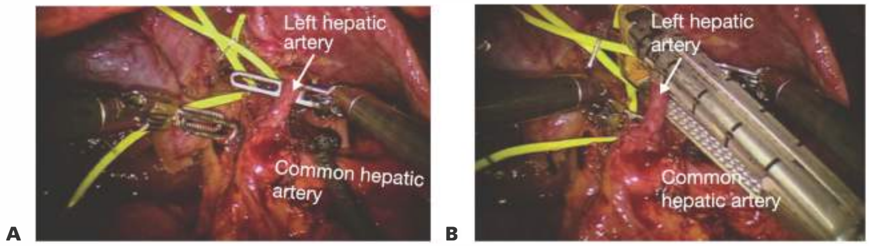


FIG 4 ● Porta hepatis dissection and division of left hepatic inflow. **A.** The left hepatic artery is isolated. **B.** The artery is controlled and divided between 2-0 silk ties reinforced by surgical clips or the use of a vascular staple load.

(on ultrasound) in the right porta, transect the left hepatic artery, either between 2-0 silk ties reinforced by clips or by a stapler vein (**FIG 4A,B**).

- Identify the left portal vein; use a combination of the hook cautery instrument and the Maryland dissector. Control it with a vessel loop. Leftward traction on the vessel loop allows the stapler to transect the vein at an ergonomically comfortable angle that does not compromise the bifurcation of the main portal vein (**FIG 5A,B**).
- Follow the common hepatic duct (**FIG 5C**) superiorly, just beyond the bifurcation, to identify the left hepatic duct. Dissect the left hepatic duct along the undersurface of the liver using the hook cautery tool. The left hepatic duct is divided between double clips or ties reinforced with clips (**FIG 5D**).

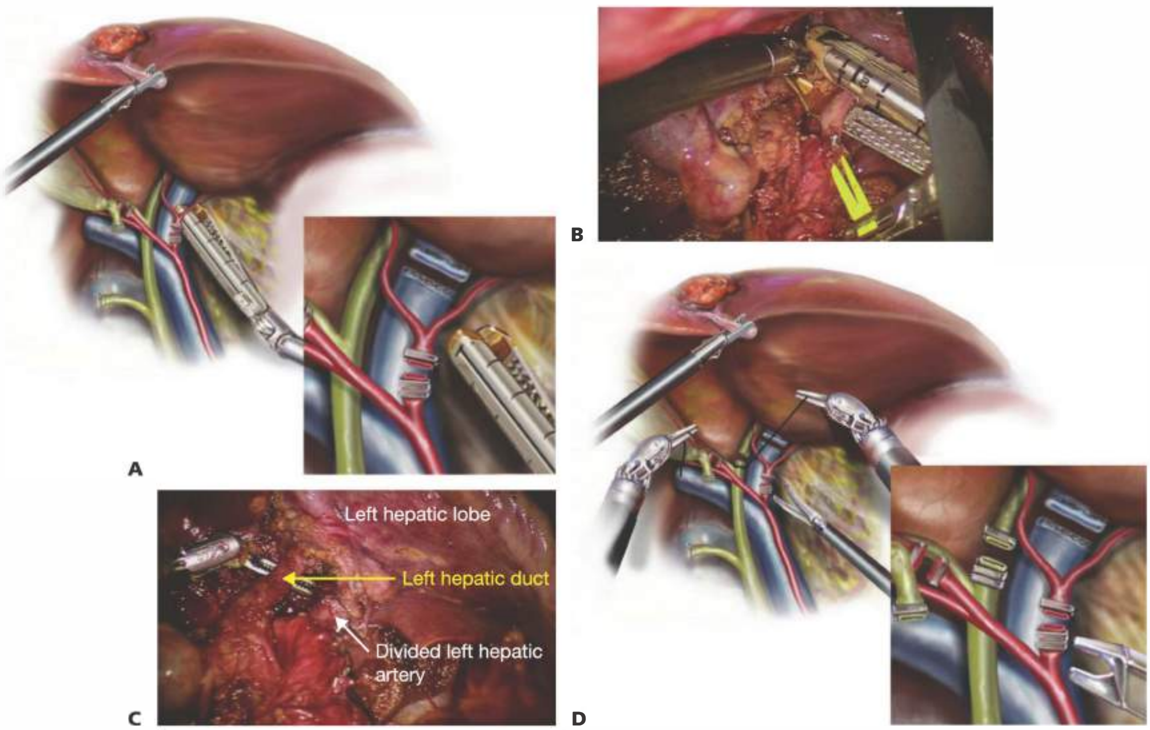


FIG 5 ● **A.** The left portal vein is transected using a vascular linear stapler. Traction on the bifurcation of the main portal vein using a vessel loop (**B**) prevents inadvertent injury or narrowing of the bifurcation. **C.** The left hepatic duct is taken between 2-0 ties reinforced by double clips. **D.** Artist's rendition of the completed dissection with control and division of the left porta hepatis.

PARENCHYMAL TRANSECTION

- Maintain a low CVP during transection to minimize blood loss. Pneumoperitoneum may interfere with CVP readings and visualization of the filling status of the vena cava may help determine if the CVP is, in fact, elevated. Ideally, the IVC will appear flattened by the pneumoperitoneum.
- Never ignore the risk of carbon dioxide (CO_2) venous embolism during parenchymal transaction; a drop in expired CO_2 is the first indication. Be prepared to emergently

decompress the abdomen and reposition the patient to manage this situation.

- Perform the parenchymal transection performed along the line of ischemic demarcation. Mark the plane of transection with electrocautery on the liver capsule just to the left of the line of ischemia. The marked line can be assessed by ultrasound as it appears as a hyperechoic line with an acoustic shadow.[8]
- Place two large figure-of-eight chromic sutures on either side of the ischemia line; use them as handles to help "open book" the liver (**FIG 6A**).
- Our preferred technique for parenchymal transection proceeds as follows:
  - Transection proceeds inferior to superior, anterior to posterior.
  - The first 1 to 2 cm of the transection is performed with robotic hook electrocautery.
  - The next 1 to 2 cm are performed with a bipolar electrocautery device.
  - Deeper dissection uses a combination of the bipolar (clamp and crush technique) (**FIG 6B**), and clips. Robotic stereotactic vision and magnification greatly enhances identification of small blood vessels and bile ducts.
- Other transection techniques have been described based on surgeon preference. Unlike open resections, argon beam coagulation is not used due to the increase in intraabdominal pressure and the potential risk of argon embolism.[12]
- Vessels that are encountered during transection can be clipped and divided with titanium clips (vessels <5 mm), locking nylon clips (vessels <15 mm), or stapler (larger vessels).

FIG 6 ● Parenchymal transection. **A.** Place two figure-of-eight sutures (chromic 2-0 blunt needle) to use as handles to "open book" the liver for parenchymal transection. Use the robotic hook for the first 1 cm, then convert to the PK robotic bipolar or a similar laparoscopic energy device **(B)** for the deeper transection. Larger sized vessels and bile duct tributaries (>3 mm) are clipped as shown in the *inset*.

VASCULAR OUTFLOW CONTROL

- Posteriorly, transection of large tributaries of the left hepatic vein and the left hepatic vein is performed within the liver using vascular loads of the Endo GIA stapler. A total of two to three loads is usually necessary (**FIG 7A,B**).
- Traction on the middle hepatic vein and vena cava should be avoided.
- Alternatively, a technique where vascular inflow and outflow are controlled before parenchymal dissection has been described.[10] The left hepatic vein is located by identifying the Arantius' ligament after lifting the left lobe to the right.

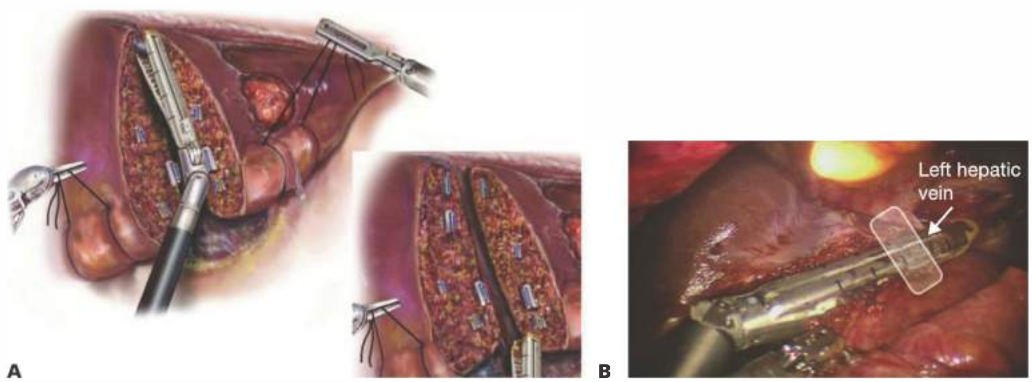
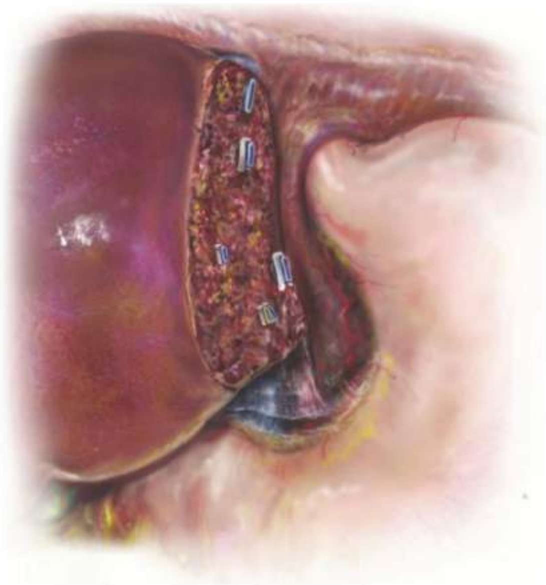


FIG 7 ● Control of the vascular outflow. As the parenchymal dissection nears the cephalad aspect of the liver, **(A)** and **(B)**, control and divide the left hepatic vein using an Endo GIA vascular load cartridge.

EVALUATION OF CUT SURFACE

- The mean arterial pressure and CVP are normalized and confirmation of hemostasis and absence of bile leak on the cut surface is assessed (**FIG 8A,B**).[8] Perform a Valsalva maneuver for further confirmation of hemostasis.
- Larger vessels should be suture ligated robotically with ease using 2-0 silk sutures in a figure-of-eight fashion.
- Fibrin and thrombin sealants may be used.
- A routine cholangiogram is not performed.



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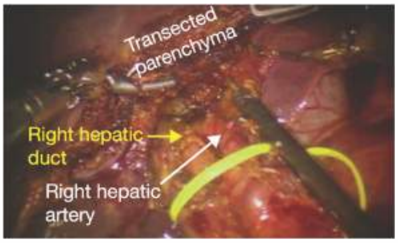

B

FIG 8 ● **A.** Examine the cut surface of the liver for bleeding and/or bile leakage. The latter is better visualized after a white sponge/pad is used to compress the liver surface. **B.** The transected surface of the liver is seen in the left upper quadrant of the picture. Note that a loose vessel loop surrounds the porta hepatis (Pringle); this can be intermittently tightened when bleeding from the cut surface is significant.

SPECIMEN RETRIEVAL

- Use sutures to mark the specimen's orientation.
- Place the specimen in an impermeable plastic bag and removed from the abdominal cavity by enlarging the right lower quadrant incision in order to insert a single site GelPort (Applied Medical, Rancho Santa Margarita, CA) for extraction.
- Note that all robotic instruments should be removed before extracting the specimen to avoid injury when pneumoperitoneum is lost.

DRAIN PLACEMENT AND CLOSURE

- A 19-mm round Blake drain is placed based on the surgeon's preference at the resection site through the R3 port and sutured to the skin using 2-0 nylon suture (**FIG 9**).
- The 12-mm camera port site is closed with a Carter-Thomason suture passer in a figure-of-eight fashion using 0 absorbable suture.
- Pneumoperitoneum is then released as the ports are removed.
- The specimen extraction/utility incision is closed using interrupted 0 absorbable suture.
- The skin is closed using 4-0 absorbable monofilament suture.

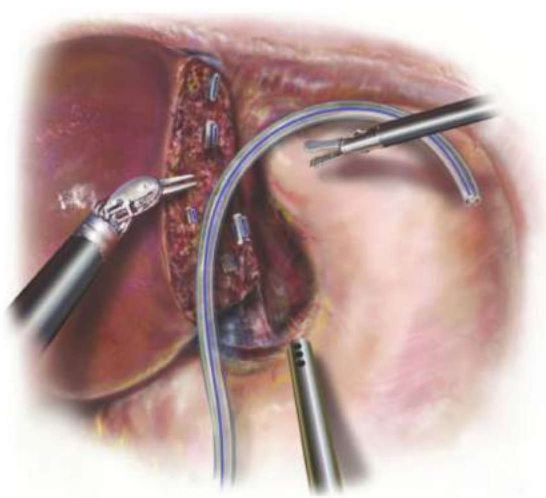

FIG 9 ● A 19-mm Blake drain is routinely used to drain the resection bed and, in the absence of a bile leak, is removed on the third or fourth postoperative day.

TECHNIQUES

CONVERSION

- Conversion should be considered for uncontrolled bleeding and failure to progress. It is recommended to place a minilaparotomy pad at the bleeding site with the administration of pressure by a laparoscopic grasper while emergent conversion occurs. This will minimize blood loss that can occur while converting to a laparotomy.

PEARLS AND PITFALLS

Port placement	▪ Keep a 5-cm distance between ports. Camera port and R1 (dissection arm) should be 5 cm to the right and left of the umbilicus and 2 in above it. This allows adequate visualization of both the hilar structures anteriorly/inferiorly and the parenchymal transection posteriorly. ▪ Robotic arms 2 (bipolar) and 3 (retractor) should be lateral and higher than the camera port and R1. ▪ Laparoscopic assistant ports in the right and left lower quadrants must be placed at a slanted angle into the fascia (rather than vertically). This allows minimal collision between the robotic arms and the assistant. It also facilitates easier stapler access to the liver hilum and parenchyma.
Liver mobilization	▪ Keeping the round ligament long facilitates its use as a handle for optimal inflow vascular dissection and parenchymal transection. ▪ Do not attempt to "overmobilize" the left triangular ligament; this may lead to injury of the left hepatic vein. ▪ Use a laparoscopic or robotic bulldog to loosely hold the two ends of the Pringle umbilical tape. In the event of needing a Pringle maneuver, the bulldog can be expeditiously "cinched down" to provide good compression of portal inflow.
Inflow control	▪ The robotic Maryland is the most optimal instrument to get around the left portal vein. It is pointed enough to dissect perivascular tissue easily but not sharp enough to readily injure the vessel. ▪ Do not grasp vascular structures with the robotic graspers. Use the periadventitial tissue to stabilize the vessel while dissecting it. Lack of tactile feedback can lead to crush injuries to the hepatic artery. ▪ A right posterior or anterior duct may insert proximally into the left hepatic duct. This may be injured if the left hepatic duct is not dissected fully.
Parenchymal transection	▪ Avoid creating valleys or pits into the liver parenchyma during transection. This makes it difficult to visualize the cut surface and to control bleeding.[8] ▪ Have an extra load of the vascular stapler available.
Vascular outflow control	▪ This is best approached within the liver. ▪ When dividing the middle hepatic vein or left hepatic vein, ensure that the tip of the stapler is seen beyond the vessel.

POSTOPERATIVE CARE

- The orogastric tube is removed at the end of the case.
- Intensive care unit (ICU) admission for major hepatectomy depends on surgeon preference.
- Subcutaneous heparin prophylaxis is started on evening of surgery.
- Clear liquids are administered on postoperative day 1.
- The Foley catheter is removed on postoperative day 1.
- Diet is advanced as tolerated.

OUTCOMES

- In experienced centers, laparoscopic liver resections are safe and feasible. In a review of 2,804 patients, of which 6.8% were left hepatectomies, the overall mortality was 0.3% and overall morbidity was 10.5%.[3] Postoperative morbidity from laparoscopic liver resection is most commonly from liver failure. A conversion rate for laparoscopy to open laparotomy was 4.1% and for laparoscopy to a hand-assisted procedure was 0.7%.
- Compared to open hepatectomies, the advantages of laparoscopic hepatectomies are less blood loss, less time with the Pringle maneuver applied, less postoperative analgesia requirements, a shorter length of stay, and fewer overall complications.[13–15]
- For patients with hepatocellular carcinoma or metastatic disease, margin status, disease-free survival, and overall survival following laparoscopic resection appear comparable to open resection.[16–20]

- Although the operative costs of a minimally invasive hepatectomy are higher than an open approach, this difference may be offset by reduced nonoperative costs due to the shorter length of stay following a minimally invasive resection.[15,21]
- A robotic-assisted approach with the da Vinci Surgical System (Intuitive Surgical, Sunnyvale, CA) alleviates some of the limitations of laparoscopic surgery such as the fixed pivot point of the instruments, a two-dimensional view, and only 4 degrees of freedom while adding tremor reduction.[5] The advantages of a robotic over a laparoscopic approach are most appreciated during suturing of bleeding parenchyma, performance of the hilar dissection, and for resections that may require intricate biliary-enteric anastomoses.
- Robotic-assisted liver resections are being increasingly performed. Early results show that it is safe and feasible with a low conversion rate, low estimated blood loss, short length of stay, and limited postoperative morbidity that may be comparable to a laparoscopic approach.[22–24]
- In a matched comparison of robotic versus laparoscopic hepatectomies at the University of Pittsburgh Medical Center, there was no significant difference in estimated blood loss, transfusion rate, R0-negative margin rate, postoperative peak bilirubin, postoperative intensive care admission rate, length of stay, and 90-day mortality. Robotic-assisted hepatectomies had a significantly higher overall operating room time (median: 342 vs. 261.5 minutes) and operative time (median: 253 vs. 199 minutes).[25] However, more robotic-assisted hepatectomies were performed in a purely minimally invasive manner, 81%, versus only 7.1% for the laparoscopic approach, with the rest of laparoscopic operations involving a hand-assisted procedure or a hybrid technique procedure. The rate of conversion to open laparotomy was similar for robotic and laparoscopic hepatectomies.

COMPLICATIONS

- Bile leak
- Hepatic insufficiency
- Close or positive margins
- Hemorrhage
- Wound infection

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Chapter 27

Robotic Liver Resection

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DEFINITION

- The use of robotic-assisted surgery for liver resections is mostly dependent on tumor location and the experience of the surgical team. Indications for the use of robotics have been reported in the Louisville Statement in 2008, which set forth the guidelines for laparoscopic liver resection. Patients with solitary lesions, 5 cm or less, and located in segments 2 to 6 were considered eligible for robotic-assisted surgery. The use of robotics should not compromise the aforementioned principles or nomenclatures.[1]
- The indication has been extended by most experienced robotic liver surgeons to include all resections, which would be considered for laparoscopic resection. The contraindications include large lesions that will prevent safe mobilization of the liver without an open incision. The space in an insufflated abdomen may not be enough to allow for manipulation of an exceedingly large tumor. The tumors that are close to major intrahepatic pedicles may also be unsafe to approach minimally invasively. Also, the sick livers with high intrahepatic portal venous pressure will lead to excessive blood loss and may not be appropriate for a minimally invasive approach.

DIFFERENTIAL DIAGNOSIS

- The differential diagnosis of a liver mass includes both benign and malignant processes. Benign processes are either cystic or solid. Malignant processes are usually solid (Table 1).

PATIENT HISTORY AND PHYSICAL FINDINGS

- The evaluation of a patient with a liver mass should include a complete history and physical exam.
- History should include questions regarding presence of abdominal pain, weight loss, alcohol use, viral hepatitis, liver disease, tattoos, blood transfusions, personal history of cancer, family history of liver, and colon cancer. History should include use of oral contraceptives for women.
- Physical exam should be directed toward findings such as presence of abdominal mass, hepatomegaly, splenomegaly, ascites, jaundice, scleral icterus, flapping tremor, and caput medusa.

Table 1: Differential Diagnosis of Liver Mass

Benign	Cystic	Pyogenic abscess
		Amebic abscess
		Hydatid cyst
		Simple cyst
	Solid	Hemangioma
		Adenoma
		Focal nodular hyperplasia
		Biliary hamartoma
Malignant		Hepatocellular carcinoma
		Cholangiocarcinoma
		Gallbladder cancer
		Metastatic colon cancer
		Metastatic neuroendocrine cancer
		Metastatic cancer of other etiologies

LABORATORY TESTS AND IMAGING

- Workup should include blood sent for the following:
  - Complete blood count
  - Platelet count
  - Blood urea nitrogen
  - Creatinine
  - Electrolytes
  - Liver enzymes
  - Albumin
  - International normalized ratio (INR)
  - Viral hepatitis screen
  - Serum ammonia level
  - Tumor markers (carcinoembryonic antigen, α-fetoprotein, cancer antigen 19-9)
- Imaging studies play a great role in the diagnoses of liver lesions and in the preoperative planning for liver resection.
- Ultrasound differentiates between solid and cystic lesions of the liver. It is usually used as a screening modality in patients with right upper quadrant pain. Its use is limited by interference secondary to presence of bowel gas, obesity, and overlying ribs.
- Contrast-enhanced, multiphasic computed tomography (CT) scans are used for diagnosis of liver lesions and preoperative planning for liver resections. These include arterial, venous, and portal phases. Their value lies in their ability to detect proximity of lesions to major arterial and portal structures and to asses for resectability.
- Volumetric analysis of functional liver remnant is used to assess feasibility of resection, and data supports its use because the remaining liver volume has been shown to predict mortality in cirrhotic patients. In general, a functional liver remnant of 20% is desired with a healthy liver and 50% with a diseased liver.
- Contrast-enhanced magnetic resonance imaging (MRI) is another imaging modality that is gaining acceptance for evaluation and characterization of liver lesions. It allows for better contrast resolution, avoidance of radiation exposure, and multiplanar imaging. The choice of CT versus MRI is institution dependent.
- Other imaging modalities used include positron emission tomography (PET) scan and CT-PET scans. PET imaging is ideal for many metastatic cancers to the liver, but it is best combined with an intravenous (IV) contrast CT scan so that anatomic relations can be made.

SURGICAL TECHNIQUE

- Patient positioning and room setup:
  - The robot is usually at the top of the operating table. The anesthesia area is on the left side of the patient's head.
  - The patient is placed in the supine position with the legs split and both arms tucked.
  - The first surgeon stands on the right side of the table while the second surgeon stands between the legs. An assistant stands on the left side of the table.
  - The patient is placed at 30-degrees reverse Trendelenburg at all times during the procedure (**FIG 1**).

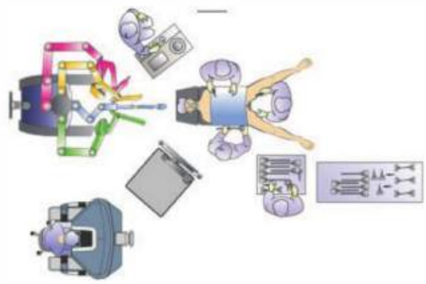


FIG 1 • Arrangement of the operating room and placement of the robot. The primary surgeon is positioned between the patient's legs during the laparoscopic portions of the procedure, with the first assistant to the patient's left. The scrub technician is to the patient's right. The anesthesiologist is positioned to the left to allow for access for the robot. (From Kim KC, ed. *Robotics in General Surgery*. New York, NY: Springer; 2014, with kind permission of Springer Science+Business Media.)

RIGHT HEPATECTOMY

- Port placement
  - Pneumoperitoneum is established through placement of a 5-mm port in the left upper quadrant. This will be exchanged at the end of port placement to become the third robotic port.
  - A 12-mm camera port is placed to the right of the umbilicus.
  - First robotic port is placed at the level of the right anterior axillary line in the midabdominal region.
  - Second robotic port is placed at the level of the midclavicular line in the midabdominal region.
  - A 12-mm laparoscopic port is placed 8 to 10 cm inferior and lateral to the camera port. This port is handled by the bedside surgeon during the robotic part of the procedure for assistance.
  - Another 5-mm assistant laparoscopic port is placed 8 to 10 cm inferior and lateral to the second robotic port (**FIG 2**).
- Step 1 (laparoscopic): The falciform and round ligaments are divided using electrocautery. This exposes the anterior surface of the liver up to the fibroareolar tissue investing the hepatic veins (**FIG 3**).
- Step 2 (laparoscopic): The patient is positioned right side up by rotating the operating table. The hepatic flexure is mobilized to inferiorly reflect the colon. The right lobe of the liver is retracted superiorly. The duodenum is reflected medially. Gerota's fascia is retracted inferiorly and the right triangular and coronary ligaments are divided up to the right hepatic vein (**FIG 4**).
- Step 3 (laparoscopic): Intraoperative ultrasound (IOUS) of the liver is then performed using the 12-mm laparoscopic port. This locates the mass in relation to the segmental anatomy of the liver and drives the planning of the resection plane.
- Step 4 (laparoscopic): The short hepatic/caudate veins that insert into the retrohepatic vena cava are divided between clips or with a coagulation device.

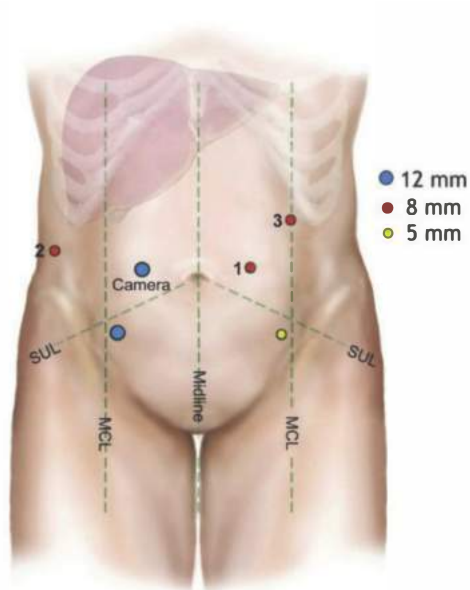


FIG 2 • Port placement for right hepatectomy. A 12-mm camera port is placed to the right of the umbilicus. The first robotic port is placed at the level of the right anterior axillary line in the midabdominal region. The second robotic port is placed at the level of the midclavicular line in the midabdominal region. The third robotic is positioned in the left upper quadrant. A 12-mm laparoscopic port is placed 8 to 10 cm inferior and lateral to the camera port. This port is handled by the bedside surgeon during the robotic part of the procedure for assistance. Another 5-mm assistant laparoscopic port is placed 8 to 10 cm inferior and lateral to the second robotic port. (From Kim KC, ed. *Robotics in General Surgery*. New York, NY: Springer; 2014, with kind permission of Springer Science+Business Media.)

TECHNIQUES

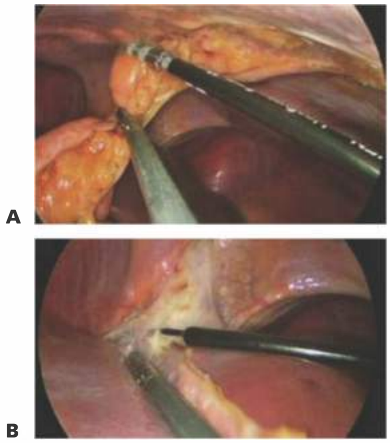


FIG 3 ● **A.** The round ligament is divided using bipolar electrocautery. **B.** The falciform ligament is divided at the level of the hepatic parenchyma up to the level of the hepatic veins.

- Step 5 (laparoscopic): The right hepatic vein is encircled with a vessel loop.
- Step 6: Docking of the robot is performed using the first, second, and third robotic ports for the respective robotic arms. The camera is aligned with the head at this time.
- Step 7: The gallbladder, if present, is retracted cephalad and blunt dissection of triangle of Calot performed so that both cystic artery and duct are identified (**FIG 5**). These are ligated after establishing the critical view. The gallbladder is not dissected off the liver bed as it is useful for retraction while dissection is performed at the level of the porta hepatis. The right hepatic artery is identified and ligated between clips and/or ties (**FIG 6**). A vascular load for the Endo GIA stapler may be used for the same purpose. The right portal vein is then dissected and identified along its full length. Another load of the vascular stapler is used to transect it (**FIG 7**). After transecting the hepatic artery and vein, the right hepatic duct is identified. This is ligated distally then transected (**FIG 8**). It is important to make sure that bile is flowing from the proximal side before ligating the structure as lymphatics and connective tissue can be misidentified as the biliary tree. After completing the dissection at the level of the porta hepatis, the gallbladder is dissected off the gallbladder bed and removed.

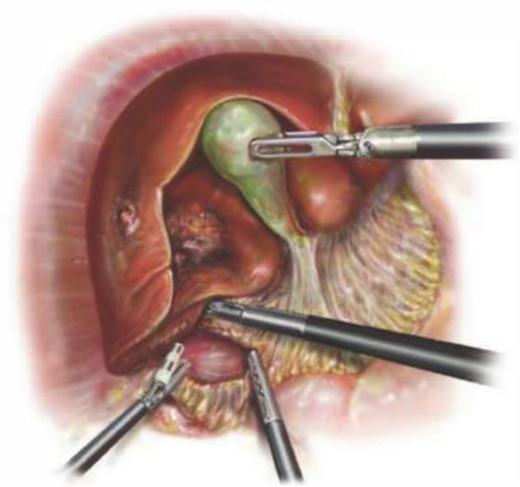
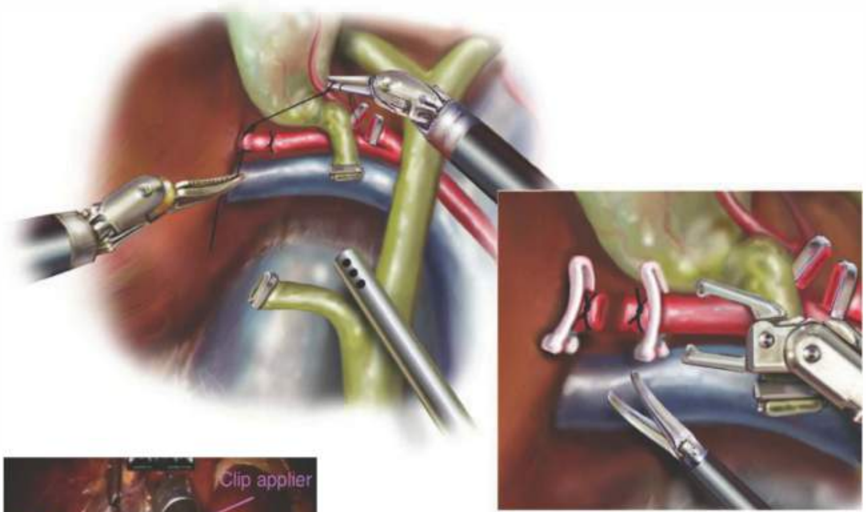


FIG 4 ● The right lobe of the liver is fully mobilized by dividing the triangular ligament. The gallbladder, if present, is a useful point of retraction. (From Kim KC, ed. *Robotics in General Surgery*. New York, NY: Springer; 2014, with kind permission of Springer Science+Business Media.)

FIG 5 ● The portal dissection is most safely initiated by identifying the cystic artery and duct (structure being clipped in the figure). These structures are bluntly dissected to their origin as a safe means to identify the right hepatic artery and hepatic duct.

- Step 8: The right hepatic vein can now be divided extrahepatically if desired, and this is preferable if this region is important for an adequate margin. Alternatively, the vein can also be divided during the parenchymal dissection (**FIG 9**).
- Step 9: After completing the aforementioned dissection, the parenchyma of the liver is transected. The liver is allowed to drop and the line of transaction is based on the demarcated ischemic liver. Hook cautery is used to divide the capsule of the liver. IOUS is performed again to ensure the planned margin. Two figure-of-eight sutures are placed on each side of the line of demarcation and retracted using the robotic arms (**FIG 10**). A heat sealing device is used for transecting the parenchyma of the liver. We use a crush technique with the PK Gyro device. Clips are applied to larger vessels and the vascular stapler for vessels too large to clip. This is continued until the right hepatic vein is identified. If the right hepatic vein has not been previously divided, a vascular load is applied across the right hepatic vein to complete the resection.
- Step 10: The specimen is retrieved using an EndoCatch bag, then removed through extension of the inferior 12-mm assistant port.
- Step 11: All laparoscopic trocar sites are closed in the regular fashion.



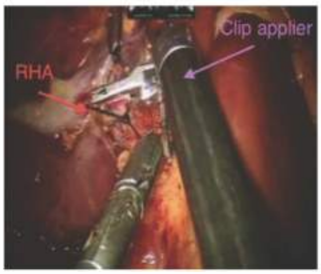
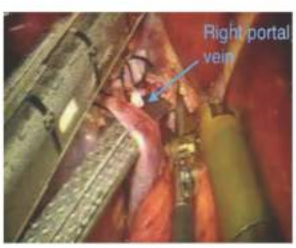


FIG 6 ● The right hepatic artery is dissected and controlled as it inserts into the liver parenchyma. It is typically posterior to the right hepatic duct and lateral and anterior to the right portal vein. It should be proximally controlled by ligation and a surgical clip. (From Kim LC, ed. *Robotics in General Surgery*. New York, NY: Springer; 2014, with kind permission of Springer Science+Business Media.)



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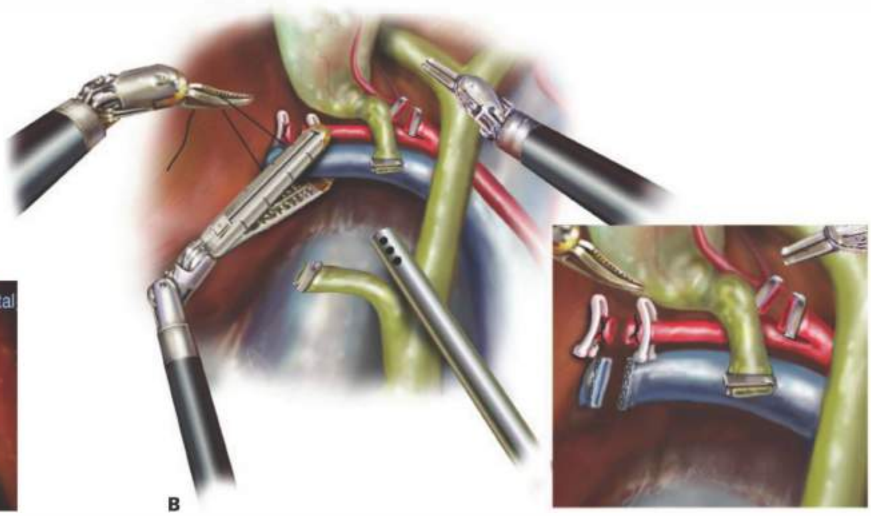

B

FIG 7 ● **A.** The right portal vein is circumferentially dissected and subsequently controlled by a vascular load of the Endo GIA stapler. Use caution during the dissection as a large branch to the caudate lobe is often present. **B.** Schematic rendition of the dissection and control of the right portal triad (part **B**: From Kim KC, ed. *Robotics in General Surgery*. New York, NY: Springer; 2014, with kind permission of Springer Science+Business Media.)

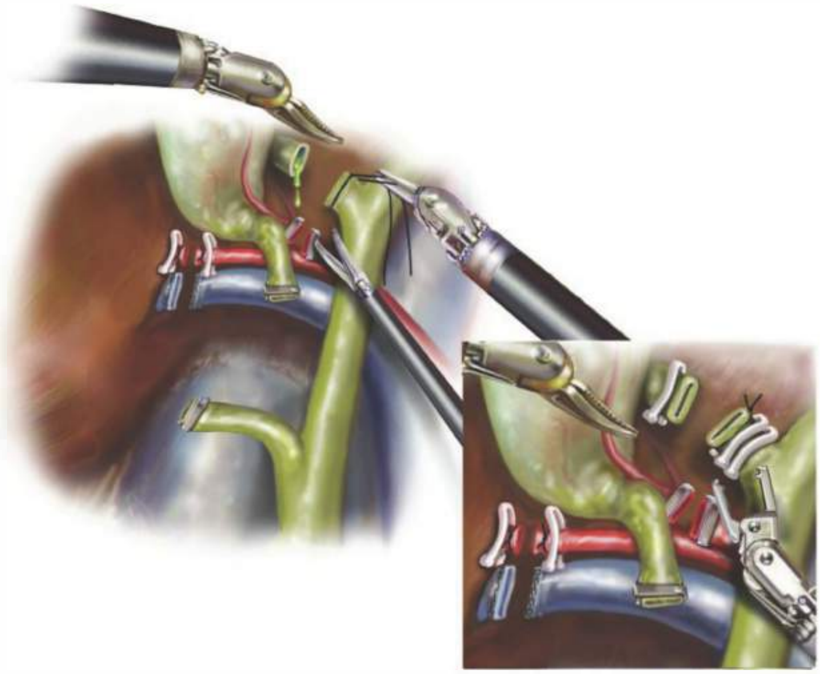

FIG 8 ● The right hepatic duct is controlled distally and divided. The authors strongly advocate identifying bile in the proximal duct to ensure a lymphatic or part of Glisson's capsule have not been inaccurately identified as the right hepatic duct. (From Kim KC, ed. *Robotics in General Surgery*. New York, NY: Springer; 2014, with kind permission of Springer Science+Business Media.)

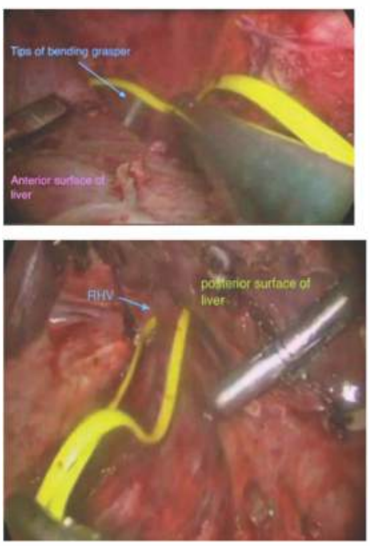

FIG 9 ● **A.** Anterior and **(B)** posterior views of the right hepatic vein after dissection.

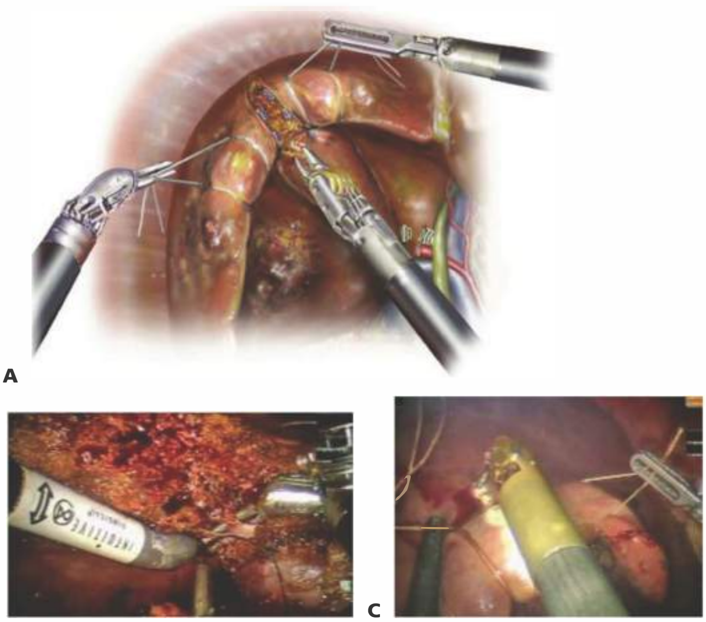

FIG 10 ● **A.** Figure-of-eight sutures on either side of the planned transaction plane are essential for elevating and separating the parenchyma to provide adequate visualization. **B.** A modified crush technique is used to identify intraparenchymal structures. Smaller structures are controlled with clips and/or cautery. (From Kim KC, ed. *Robotics in General Surgery.* New York, NY: Springer; 2014, with kind permission of Springer Science+Business Media.) **C.** Larger structures are controlled with stapler firings.

LEFT HEPATECTOMY

- Port placement
  - Pneumoperitoneum is established through placement of a 5-mm port in the left upper quadrant. This will be exchanged at the end of port placement to become the third robotic port.
  - A 12-mm camera port is placed in the supraumbilical area.
  - First robotic port is placed at the level of the right midclavicular line in the subcostal area.
  - Second robotic port is placed at the level of the left anterior axillary line.
  - A 12-mm laparoscopic port is placed 8 to 10 cm inferior and lateral to the camera port on the right. This port is handled by the bed side surgeon during the robotic part of the procedure for assistance
  - Another 5-mm laparoscopic port is placed 8 to 10 cm inferior and lateral to the camera on the left. This is also handled by the assistant (**FIG 11**).
- Step 1 (laparoscopic): The falciform and round ligaments are divided using electrocautery. This exposes the anterior surface of the liver to the hepatic veins.
- Step 2 (laparoscopic): With the patient in the left side up position, both left triangular and coronary ligaments are divided until the left hepatic vein is identified. The liver is then retracted cephalad and the gastrohepatic ligament is divided. Care is taken to identify a replaced left hepatic artery and properly control it prior to division, if present.
- Step 3 (laparoscopic): At this point, the left hepatic vein can be isolated and encircled with a vessel loop if the intention is to divide the vein extrahepatically.
- Step 4 (laparoscopic): IOUS of the liver is then performed using the 12-mm laparoscopic port. This helps confirm the presence of the mass in the planned resection specimen and its relation to the major structures in the liver. The middle hepatic vein should be preserved, unless this approach will compromise the margin.
- Step 5: Docking of the robot is performed using the first, second, and third robotic ports for the respective robotic arms. The camera is aligned with the head.

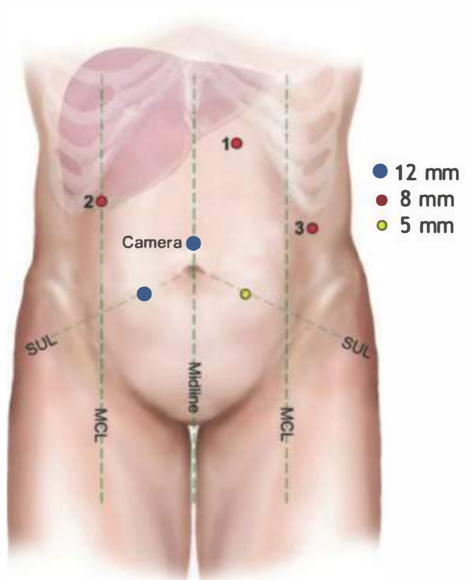

FIG 11 ● Port placement for a left hepatic lobectomy. *MCL*, midclavicular line; *SUL*, spinoumbilical line. (From Kim KC, ed. *Robotics in General Surgery*. New York, NY: Springer; 2014, with kind permission of Springer Science+Business Media.)

- Step 6: Dissection is then carried at the level of the porta hepatis. The ligamentum teres is used to retract the liver anteriorly. The left hepatic artery is identified and ligated between clips. A vascular load for the Endo GIA may be used for the same purpose, if feasible. The left portal vein is then dissected and identified along its full length. Another load of the vascular stapler is used to transect it. After transecting the hepatic artery and vein, the left hepatic duct is identified. This is ligated distally and then transected.
- Step 7: At this point, the left hepatic vein can be divided extrahepatically with a vascular stapling device.
- Step 8: After completing the aforementioned dissection, the parenchyma of the liver is transected based on the line of demarcation.

LEFT LATERAL SECTIONECTOMY

- Port placement is shown in **FIG 11**.
- Mobilization of the liver and control of the left hepatic vein proceeds as described for left hepatic lobectomy.
- The portal structures supplying segments 2 and 3 are controlled with a vascular staple load at the posterior aspect of segment 3 to the patient's right of the falciform ligament.

RIGHT POSTERIOR SECTOR RESECTIONS

- Positioning
  - The patient is positioned in the full right lateral position for posterior-lateral resections.
  - The robot is then brought in toward the left upper corner of the table.
- Port placement
  - In these cases, the ports can be placed laterally on the right side, including a robotic port through the diaphragm.
  - The camera port is at the costal margin, the left hand port is through the diaphragm, and the right hand port is along the anterior axillary line inferiorly.

- A third robotic port can be placed more medially at the midclavicular line on the right (**FIG 12**).
- Step 1 (laparoscopically): Mobilize the right lobe of the liver as aforementioned, fully exposing the anterior and lateral aspects of the right hepatic vein.
- Step 3: Docking of the robot is performed using the first, second, and third robotic ports for the respective robotic arms. The camera is aligned with the left nipple.
- Step 4: With the aid of IOUS, hook cautery is used to divide the capsule of the liver where the parenchymal transection will occur. Two figure-of-eight sutures are placed on each side of the line of demarcation and retracted using the robotic arms.
- Step 5: The parenchymal dissection is performed as previously described.
- Step 6: The robot is undocked.
- Step 7: The robotic port through the diaphragm is removed and the diaphragm is repaired with a single figure-of-eight suture.
- Step 8: A chest tube is placed to decompress the pneumothorax and then immediately removed.

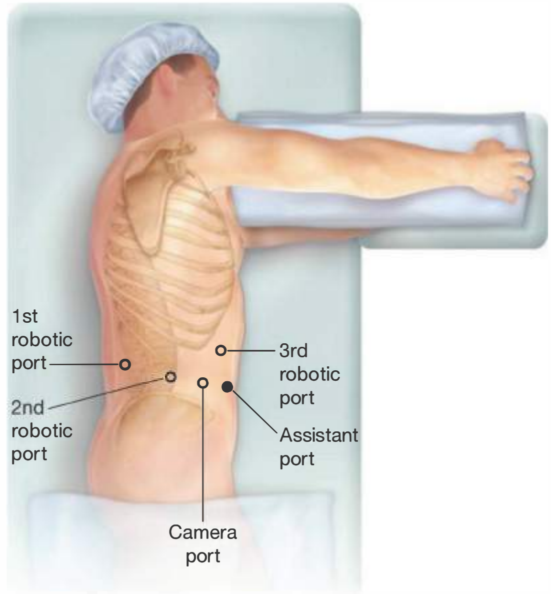

FIG 12 ● Port placement for a posterior sectionectomy.

PEARLS AND PITFALLS

Preoperative planning	■ Cirrhotic livers with significantly high intrahepatic portal pressures will be associated with significant blood loss and may be better approached as an open procedure. ■ Most resections tend to be nonanatomic with the goal to preserve parenchyma and anatomy for future resections. ■ Flexibility in port placement is important and may vary depending on the location of the lesion, the body habitus, the size of the liver, and so forth. For example, in some patients, the liver extends well below the costal margin and the ports will need to be placed below the level of the umbilicus.
Operative technique	■ A central line should be placed and the central venous pressure monitored and kept low. ■ Care should be taken to identify major hepatic veins or pedicles by ultrasound in advance of the parenchymal transection so that these are handled carefully. ■ Although air embolus is a theoretical concern, it is rare in practice. ■ A Pringle maneuver is recommended to reduce blood loss. ■ The line of parenchymal transection should be lined up with the camera and the assistant 12-mm port for stapling. ■ Obtaining adequate margins can be challenging without the ability to feel the tumor. Ultrasound needs to be used during the parenchymal transection to ensure that the margin is preserved, and the initial marking of the margin by cautery should be generous.

POSTOPERATIVE CARE

- No drain is left next to the resection bed unless a bile leak is identified.
- Orogastric tube is removed in the operating room.
- Patient is transferred to a regular floor monitored bed.
- Daily laboratories are ordered including complete blood count, blood urea nitrogen, electrolytes, liver enzymes, bilirubin, and coagulation studies.
- Clear liquids are given on postoperative day 1 and advanced as tolerated.
- Foley catheter is removed on postoperative day 1.
- Central venous catheter is removed on postoperative day 1.

OUTCOMES

- The advantages of minimally invasive surgery are well documented in the literature. These include decreased postoperative pain, early return of activity, decreased postoperative ileus, better cosmesis, and shorter hospital stays.[2]
- However, several limitations inherent to laparoscopic surgery are present. These include two-dimensional imaging, limited range of instrument motion, tremor amplification, and poor surgeon ergonomics.[3]
- The use of robotics offers multiple advantages to the operating surgeon such as improved three-dimensional imaging, near 360-degree movement of surgical instruments, along

Table 2: Comparison of Robotic and Laparoscopic Groups: Operative and Postoperative Parameters

	Robotic (n = 57)	Laparoscopic (n = 114)	*Overall P-value*
EBL, median mL	200 (50–337.5)	100 (50–350)	0.097
Transfusion rate (%)	2 (3.8)	7 (7.4)	0.372
Room time, median, min	342 (264–453)	261.5 (199.5–333)	<0.001[a]
OR time, median, min	253 (180–355)	198.5 (137.75–261.5)	0.001[a]
Complication rate (%)	11 (19.3)	29 (26)	0.34
Major complication rate (%)	1 (1.8)	1 (0.9)	0.624
Postoperative peak bilirubin	1.15 (0.7–1.7)	1.2 (0.8–1.6)	0.895
Postoperative ICU (%)	11 (19)	8 (8.5)	0.053
LOS, median, days	4.0 (3.0–5.5)	4.0 (3.0–5.0)	0.10
30-days mortality (%)	0 (0)	1 (0.9)	0.478
90-days mortality (%)	0 (0)	1 (0.9)	0.478
R0 negative margin (%)	40 (95)	98 (92)	0.44

OR, operating room; ICU, intensive care unit; LOS, length of stay; EBL, estimated blood loss.
[a] $p < 0.05$.

Table 3: Comparison of Early Robotic versus Later Robotic: Operative and Postoperative Parameters

	Early (n = 13)	Later (n = 44)	*Overall P-value*
EBL, median, mL	300 (200–600)	100 (50–300)	0.008[a]
Transfusion rate (%)	1 (7.7)	1 (1.9)	0.393
Room time, median, min	466 (349–571.5)	314.5 (257–381)	0.001[a]
OR time, median, min	381 (253–499.5)	232 (175–283)	0.001[a]
Complication rate (%)	3 (23)	9 (20)	0.84
Major complication rate (%)	1 (8)	1 (2)	0.36
Postoperative peak bilirubin	1.30 (1.10–3.65)	1.1 (0.6–1.63)	0.144
Postoperative ICU (%)	3 (23)	8 (18)	0.694
LOS, median, days	5.0 (3.5–10)	4.0 (3.0–5.0)	0.031[a]
30-days mortality (%)	0 (0)	0 (0)	1.00
90-days mortality (%)	0 (0)	0 (0)	1.00
R0 negative margin (%)	10 (77)	29 (66)	0.45

OR, operating room; ICU, intensive care unit; LOS, length of stay; EBL, estimated blood loss.
[a] $p < 0.05$.

with improved surgeon comfort and precision. Robotics also offers elimination of tremor.[4,5]

- This comes at the cost of prolonged operative times, absence of haptic feedback, higher costs, and a steep learning curve.[4,5]
- The current literature describes 19 publications that focus on robotic liver resections and provide a description of 217 cases.[6]
- Commonly reported procedures included robotic nonanatomic resections and segmentectomies (37.7%).[6]
- Right hepatectomies comprised 21.6% and left lateral sectionectomies 20.8%.[6]
- In a systemic review of the current literature, conversion rates were 4.6%. Most common reasons for conversion included confirmation of surgical margin, problems during hilar dissection, long resection planes, and obesity.[6]
- Operative times ranged between 200 and 507 minutes. Operative blood loss ranged between 50 and 600 mL with more blood loss associated with more complex procedures such as major hepatectomies.[6]
- Mean hospital stay after robotic liver resections was 5.5 to 11.7 days.[6]
- Oncologic outcomes were not well reported in the aforementioned series, although some authors believe that they are comparable to those of laparoscopic liver resections.[6]
- No surgical mortality was reported in the literature after robotic liver resections. The morbidity rates were around 20.3% on average.[6]
- In a matched series from the University of Pittsburgh comparing patients who received robotic and laparoscopic liver resections, there was no difference in estimated blood loss, hospital length of stay, morbidity, or mortality (Table 2). There was an increase in major hepatic resections performed. There was no difference in the conversion rate between the two groups (7% vs. 8.8%).[7]
- Upon comparison of early versus late experience with robotic cases, there was a significant difference in estimated blood loss (EBL), operative time, and hospital length of stay in favor of the later cases, which reflects the presence of a learning curve (Table 3).[7]

COMPLICATIONS

- Intraabdominal fluid collections
- Postoperative ileus
- Pleural effusions
- Minor wound complications
- Thromboembolic events are comparable to any major abdominal surgery.
- Hepatic failure

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Chapter 28

Central Hepatectomy

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DEFINITION

- Central hepatectomy, alternatively referred to as mesohepatectomy, central bisegmentectomy, middle lobectomy, or central trisegmentectomy, is an operation that removes segments 1, 4, 5, and 8 en bloc (or lesser resections) while leaving the left lateral and right posterior lateral segments in situ (**FIG 1**).
- It is a technically demanding operative procedure for large or deep-seated tumors located at the central part of the liver. It essentially requires two hepatic parenchymal dissections in close proximity to the hepatic veins and inferior vena cava (IVC) while preserving the portal pedicles to the remaining hepatic segments and results in two cut surfaces of the liver.
- Because it conserves more liver parenchyma, central hepatectomy should be considered (vs. extended hepatectomy) in patients with centrally located tumors and compromised liver function (**FIG 2**).

DIFFERENTIAL DIAGNOSIS

- Resection of benign neoplasms of the central liver is indicated for one or more of three indications: (1) to relieve symptoms, (2) because the diagnosis is uncertain, or (3) to prevent malignant transformation (**FIG 2**).
  - Hemangioma
  - Adenoma, angiomyolipoma (AML)
  - Complex cysts
  - Focal nodular hyperplasia (FNH)
- Liver resection remains the treatment of choice when appropriate for both primary and secondary central liver malignancies.
  - Hepatocellular cancer (HCC)
  - Metastatic cancers
    - Colorectal cancer
    - Breast cancer
    - Ovarian cancer
    - Lung cancer
    - Others
  - Sarcoma

PATIENT HISTORY AND PHYSICAL FINDINGS

- Hepatic neoplasms may present with abdominal, flank, and/or shoulder pain. Other symptoms include early satiety, weight loss, or increasing abdominal girth.
- With modern imaging, many hepatic lesions are an incidental finding in studies obtained as part of follow-up for a previously treated malignancy or for other unrelated indications.
- A history of previous hepatitis or jaundice should be solicited.
- A detailed history of alcohol consumption should be obtained.
- Symptoms of liver failure should be queried including fatigue, lethargy, encephalopathy, and increasing abdominal girth.
- The physical exam should focus on evidence of malnutrition including temporal and intrinsic hand muscle atrophy, the presence of ascites or peripheral edema, mental status changes of hepatic encephalopathy, asterixis, and telangiectasia.

IMAGING AND OTHER DIAGNOSTIC STUDIES

- All potential liver surgery patients should undergo preoperative viral serologic testing, laboratory assessment of liver function including protein and coagulation profiles, and assessment of the Child-Pugh's classification score.
- Magnetic resonance imaging (MRI) or three-dimensional computed tomography (CT) reconstruction of the liver can help identify and map the variations of the intrahepatic vascular structures and their relationship to tumors (**FIG 2**).
- CT with volumetric assessment is useful to determine if the planned hepatic remnant volume is adequate.[1]
- Alternatively, hepatic functional reserve can be determined by indocyanine green (ICG) clearance or ICG 15 minutes retention (15-R). Central hepatectomy should be considered in patients with an ICG 15-R less than 20%.[2]

SURGICAL MANAGEMENT

Preoperative Planning

- A complete medical history is essential. In particular, underlying cardiac or pulmonary comorbidities should be thoroughly evaluated prior to determining whether a patient is a candidate for liver resection.
- For malignant lesions, the evaluation for extrahepatic metastases should include a chest CT.
- The risk of postoperative hepatic failure should be determined. Central hepatectomy is performed for patients with underlying liver disease. A preoperative liver biopsy to determine the extent of disease may be warranted in high-risk patients to avoid nontherapeutic laparotomy.
- The Child-Pugh score is the most commonly employed clinical tool for selection of surgical candidates. Most patients

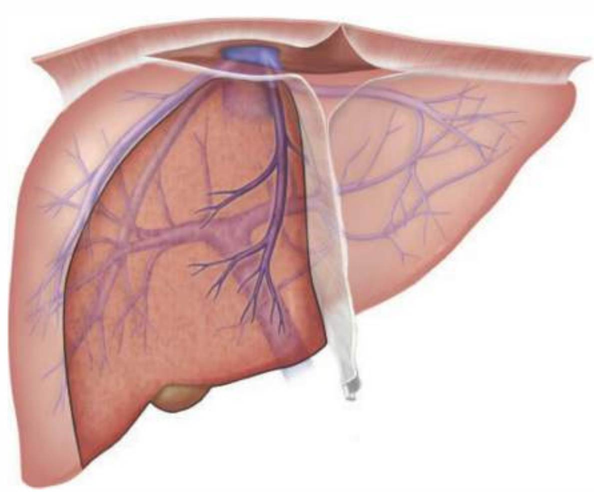


FIG 1 ● Resection area: Central hepatectomy removing part or all of the left medial sector and right anterior sector.

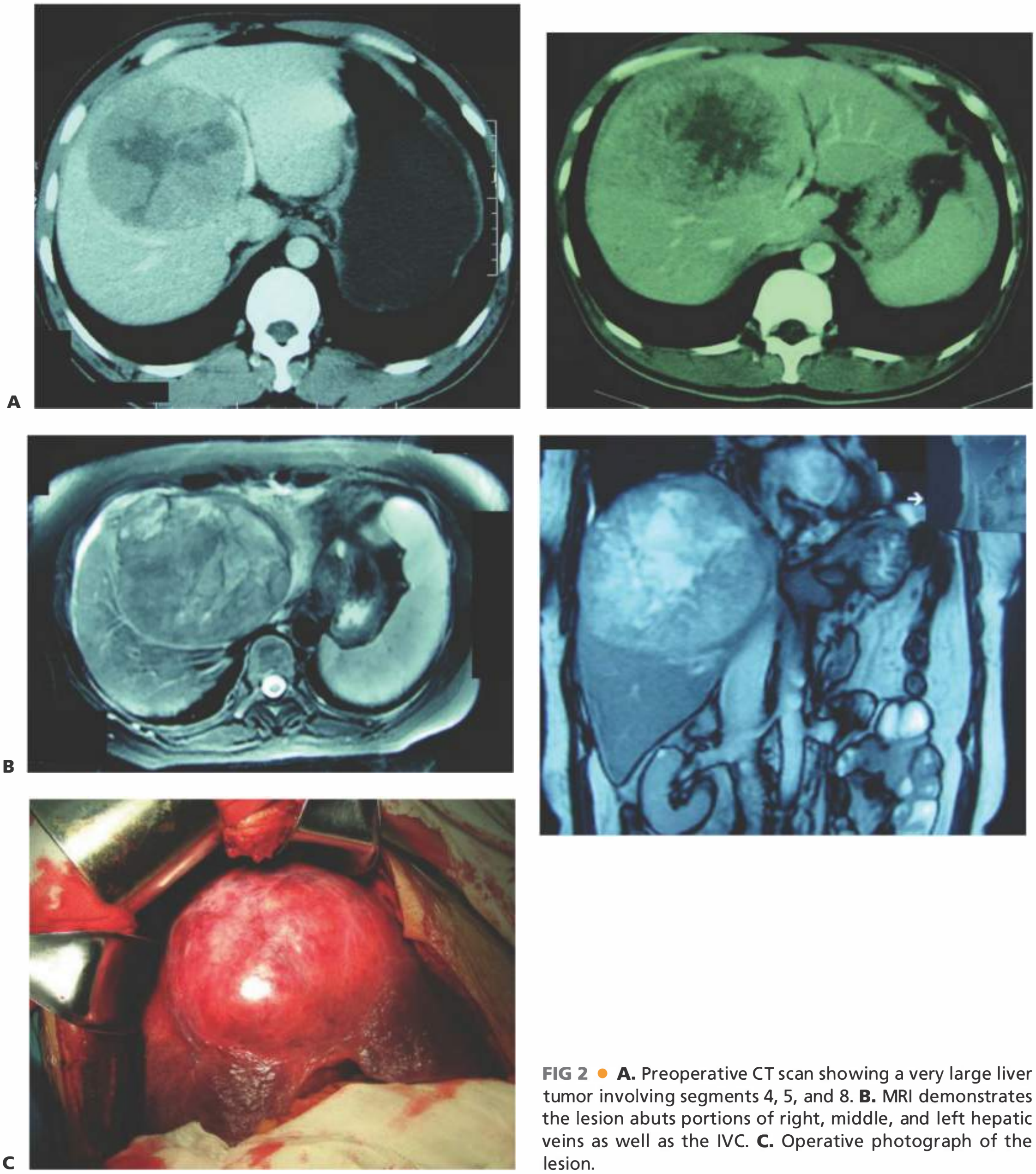


FIG 2 ● **A.** Preoperative CT scan showing a very large liver tumor involving segments 4, 5, and 8. **B.** MRI demonstrates the lesion abuts portions of right, middle, and left hepatic veins as well as the IVC. **C.** Operative photograph of the lesion.

being considered for central hepatectomy will be classified as Child-Pugh A.

- For central hepatectomy, preoperative portal vein embolization is rarely employed as it is often difficult to determine which side of the portal vein should be embolized. Although preoperative transarterial chemoembolization (TACE) has been suggested for reducing HCC tumor size and for facilitating the subsequent resection, in patients who underwent preoperative TACE, cholecystitis and dense adhesions around the liver hilum developed, thus increasing the operative complexity.

Positioning

- The patient should be positioned supine, in gentle reverse Trendelenburg, with both arms extended.
- If suprahepatic control of the IVC is planned or possible, the right arm should be tucked and the chest included in the sterile field.
- Arterial, central venous, and urethral catheters were inserted preoperatively to monitor vital signs, intravascular volume, and urine output during the operation.

- The essential principles of central hepatectomy are (1) control of inflow vessels, (2) control of outflow vessels, (3) parenchymal transection, (4) identifying and controlling potential sites of bile leak, and (5) preserving the vascular inflow and outflow of the hepatic remnant.

INCISION AND INITIAL EXPLORATION

- The abdomen is entered through a right subcostal margin or a bilateral subcostal margin incision. Most surgeons use a bilateral subcostal incision extended vertically to the xiphoid process.
- A right thoracoabdominal incision should be considered. This is particularly relevant when tumor is large and involving the dome of the liver. In this circumstance, control of the hepatic veins and the vena cava may prove very difficult. The morbidity of a thoracoabdominal incision is preferable to potentially catastrophic hemorrhage.
- The liver is bimanually palpated; hepatic metastases and the degree of cirrhosis are determined. Extrahepatic metastases and potential portal adenopathy are assessed, and specimens obtained for frozen section if indicated.
- Intraoperative ultrasonography is used to delineate the extent of the neoplasm, the relationship of the lesion to vital structures, and mark the plane of the parenchymal transection.

MOBILIZATION OF LIVER

- The round ligament is divided and the falciform ligament incised and separated from the anterior abdominal wall.
- The peritoneal reflections that form the triangular ligament are incised and the diaphragm fully mobilized from all attachments to the liver. If, in the course of mobilization, tumor is found to involve the diaphragm, the affected area of the diaphragm may be excised and subsequently repaired with pledgeted sutures.
- The suprahepatic IVC and the hepatic veins above the liver are dissected to facilitate the subsequent approach to the hepatic veins.
- The caudate lobe is fully dissected from the IVC, controlling the small hepatic veins that directly drain into the IVC with clips and/or ligatures. An accessory posterior right hepatic vein is often encountered and may require suture ligation to obtain reliable control of the vessel.

DISSECTION OF THE PORTA HEPATIS

- The classic approach involves extrahepatic control of the inflow vessels (hepatic artery and portal vein) and biliary tree.
- The sheath of the porta hepatis is opened laterally. The cystic duct and artery are ligated and divided. The gallbladder may be either removed or left attached to the liver to preserve a margin when appropriate.
- The portal vein is followed cephalad up to and above the bifurcation. There is usually a small branch that passes posteriorly from the right portal vein to the caudate lobe. Control and division of this vessel is important during middle hepatectomy.
- The right anterior branch and left medial branches of the portal vein and hepatic artery are circumferentially dissected, controlled with vessel loops, and then with vascular clamps prior to being divided and ligated (**FIGS 3** and **4**). These vessels supply the right lobe anterior segments (Couinaud's segments 5 and 8) and the left medial segment (Couinaud's segments 4a and 4b). The usual practice is to ligate the right anterior branch and left medial branch of the artery and portal vein (sometimes including hepatic duct), working from anterior to posterior.
- Typically, unless the tumor involves the middle hepatic vein close to its junction with the IVC, the middle hepatic vein is not controlled extrahepatically. It is identified, controlled, and divided during the parenchymal dissection.
- When feasible, the middle hepatic vein is extraparenchymally isolated, cross-clamped, and divided at its insertion (**FIG 5**). There are two methods for exposing the middle hepatic vein extrahepatically:
  - Method one: The left lobe is retracted anterior and cephalad, and the pars flaccida is incised to expose the caudate lobe. The superior pole of the caudate lobe is then retracted caudally and the medial wall of the IVC is exposed. The ligament of Arantius is divided to establish space between the left hepatic vein, the IVC, and the upper edge of the caudate lobe. The common venous trunk representing the confluence of the left and middle hepatic veins is then encircled with a vessel loop.
  - Method two: From an anterior approach, the fibrous tissue representing the remaining phrenohepatic ligament between the main hepatic veins (confluence of the left and middle veins, and the right hepatic vein) is dissected to develop a plane that extends posteriorly to the anterior surface of IVC. The parenchyma anterior to the left vein is incised for 1 to 2 cm to expose the anterior surface, often exposing the confluence of the left and middle hepatic veins. The middle vein is then controlled.
- The ability to dissect and define the anterior surface of the retrohepatic IVC at the level of insertion of the hepatic veins is often the final step in assuring resectability of lesions located in segment 4a.

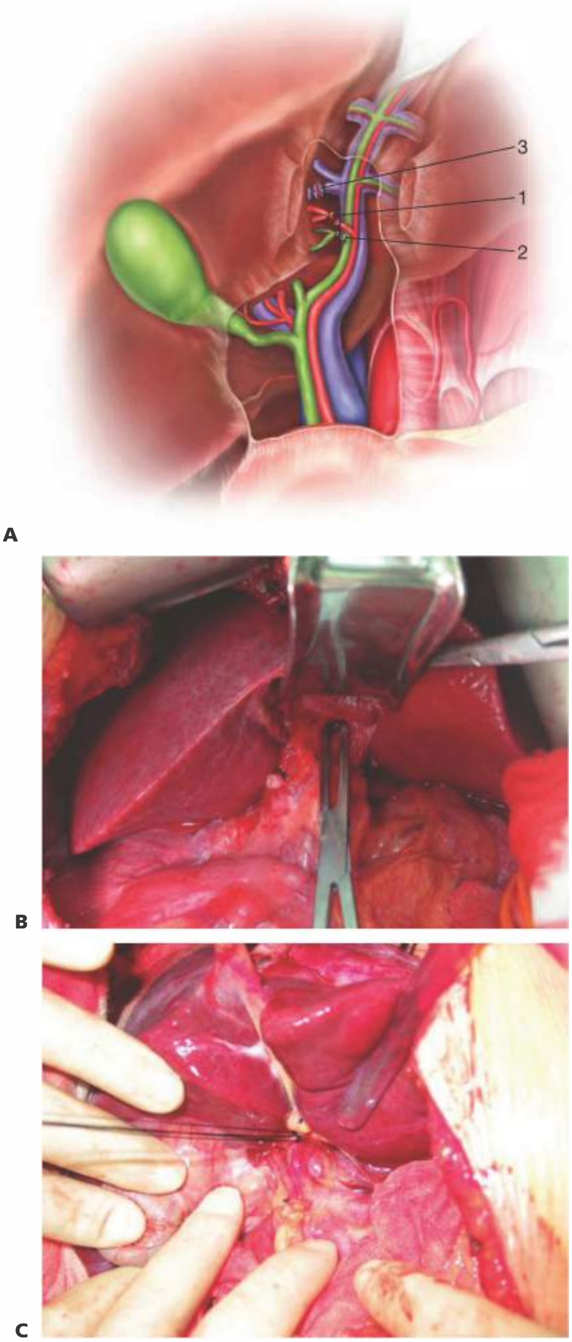


FIG 3 ● **A.** Separation and ligation of the left porta hepatis: *(1)* the left medial hepatic artery, *(2)* the left medial hepatic duct, and *(3)* the left medial portal vein. **B.** Operative photograph of exposure to the segmental branches of the portal structures to segment 4. **C.** Operative image of segment 4 portal structures after ligation and division.

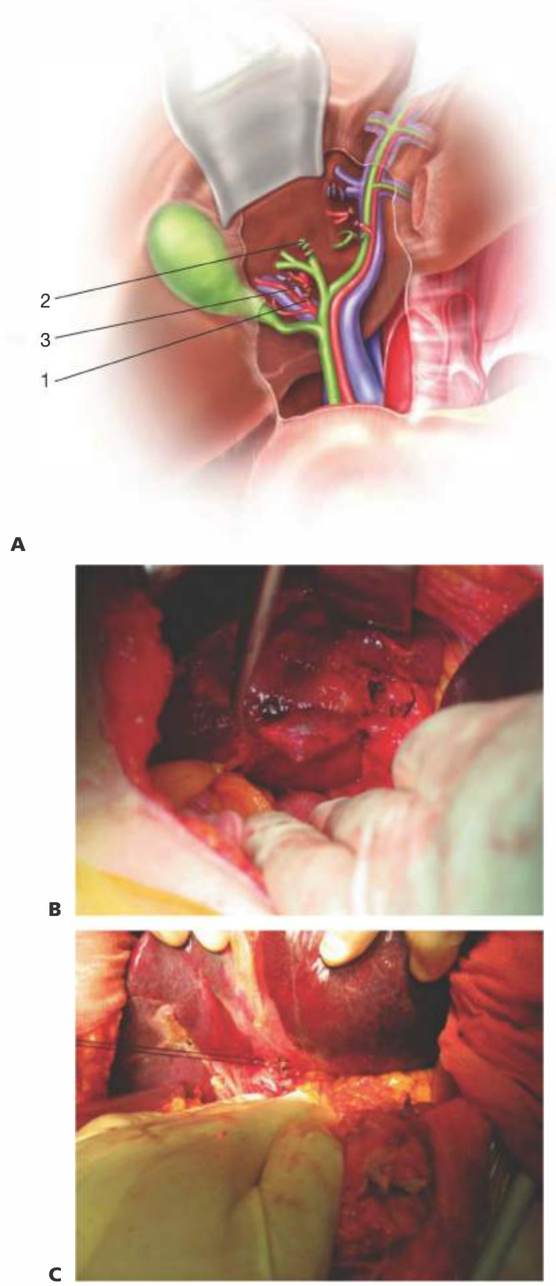


FIG 4 ● **A.** Separation and ligation of the right porta hepatis: *(1)* the anterior branch of the right hepatic artery, *(2)* the anterior branch of the right hepatic duct, and *(3)* the anterior branch of the right portal vein. **B.** Posterior retraction of the mobilized gallbladder to expose the segmental branches of the portal structures. **C.** Segment 5 branches after ligation and division.

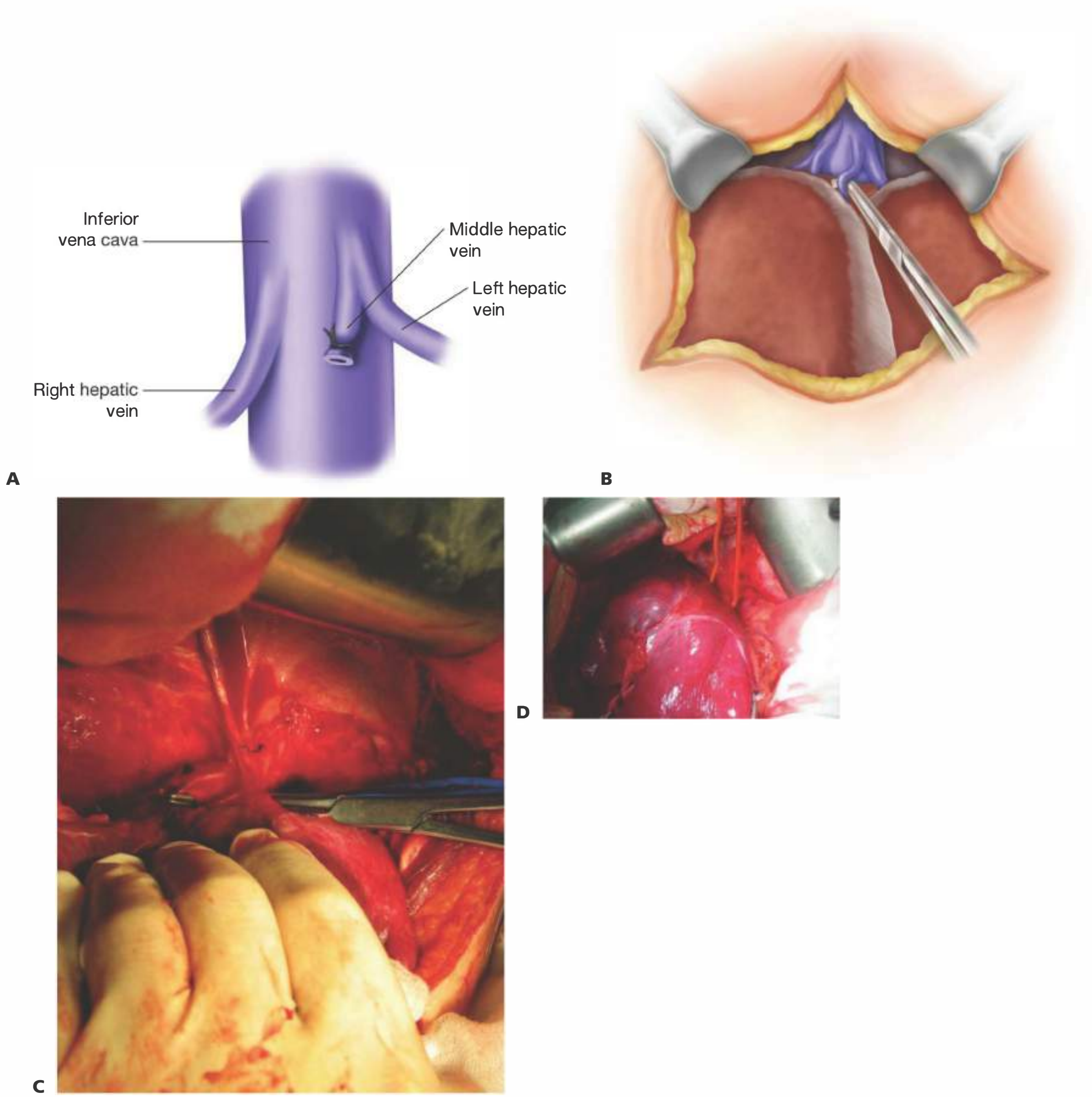


FIG 5 ● Extrahepatic control of the middle hepatic vein. **A.** Typically, there is a confluence of the middle and left hepatic veins prior to insertion into the vena cava. **B.** The confluence of the middle and left hepatic vein occasionally can be dissected extrahepatic, but often, this confluence is enveloped in hepatic parenchyma. **C.** Anterior retraction of the left lobe with posterior retraction of the caudate and vena cave (surgeon's hand) provides exposure to the left and middle hepatic veins. **D.** Anterior view of the looped confluence of the left and middle hepatic veins.

PARENCHYMAL TRANSECTION

- Many specialized instruments are available for use in the parenchymal transection, including argon beam electrocautery, bipolar electrocautery, cavitating ultrasonic aspirators, water-jet dissectors, and combinations thereof.
- The authors prefer to perform the liver parenchymal transection using finger fracture technique with hemihepatic inflow occlusion technique (cyclic clamping of the ipsilateral hepatic artery and portal vein) (**FIG 6**). Alternatively, intermittent application of Pringle's maneuver or total hepatic vascular exclusion may be employed (**FIG 7**).
- It is of paramount importance to preserve both the right and left hepatic vein. As the parenchymal transection must be performed along the course of these vessels, the most technically demanding aspect of central hepatectomy is prevention of injury to one of the hepatic veins draining the intended remnant liver. Such an injury leads to hemorrhage and the potential for air emboli. Also of concern is subsequent hepatic failure from venous congestion.
- Although transsection of the liver parenchyma should be performed as close as feasible to the lines of segmental anatomy, intraoperative ultrasound is of great value to obtain an adequate margin (ideally ≥1 cm) without undue risk to the hepatic veins.
- The first incision is made between the left medial sector (segments 4a and 4b) and left lateral sector (segments 2 and 3). The liver capsule is incised along the falciform ligament, and then the hepatic parenchyma is dissected (**FIG 8**). The vessels to the left part of segment 4 are ligated and divided to the right of the round and falciform ligaments. The full thickness of the parenchyma is sequentially divided with a combination of crushing and ligation.
- As mentioned earlier, ideally, the middle hepatic vein has been isolated, clamped, divided, and sutured outside the liver parenchyma. However, in situations where the tumor involves or is in close proximity of the root of

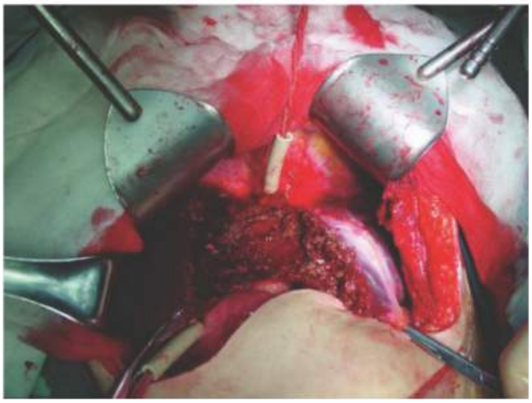
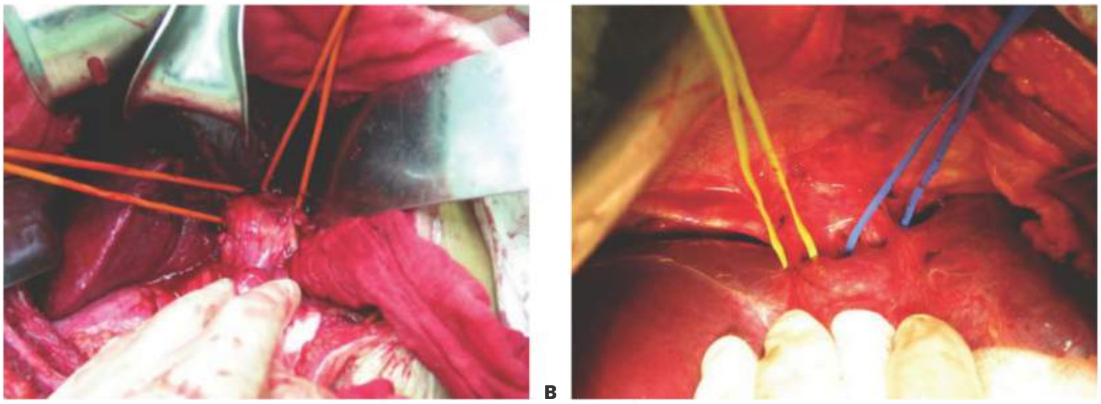


FIG 7 ● Total hepatic vascular isolation. In addition to control of portal inflow and hepatic vein outflow, occlusion of the suprahepatic IVC and infrahepatic IVC is obtained using two umbilical tapes. This intraoperative view is taken after the parenchymal dissection to facilitate visualization of the controlled IVC.

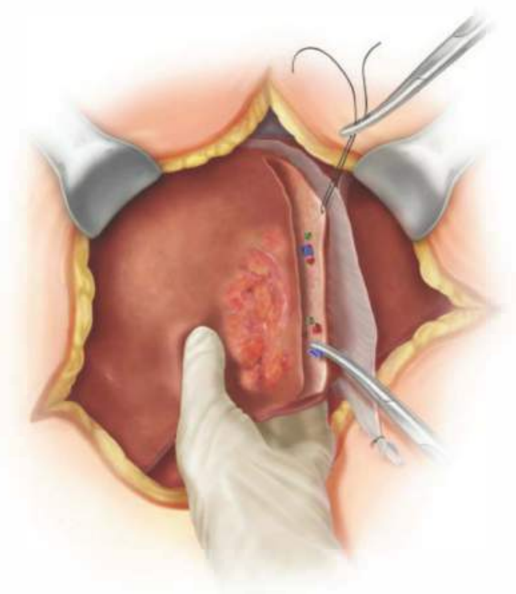


A B

FIG 6 ● The hemihepatic inflow occlusion technique. **A.** Vessel loop control of the left and right portal veins. **B.** Vessel loop control of the hepatic veins.

middle hepatic vein, the middle hepatic vein may need to be divided and ligated within the liver parenchyma (FIG 8). This can be particularly challenging as the middle hepatic vein is often compressed by tumor.

- The second incision is made between the right anterior sector (segments 5 and 8) and right posterior sector (segments 6 and 7); restated, the right resection line runs along the demarcation line between the anteromedial and posterolateral segments. The right anterior portal vein, hepatic artery, and bile duct should have already been managed extrahepatically (FIG 9). On the inferior surface of the liver, the resection line runs centrally along the hilar plate.
- The cut surfaces of the liver are then treated with a combination of electrocautery, argon beam coagulation, and thrombogenic agents.



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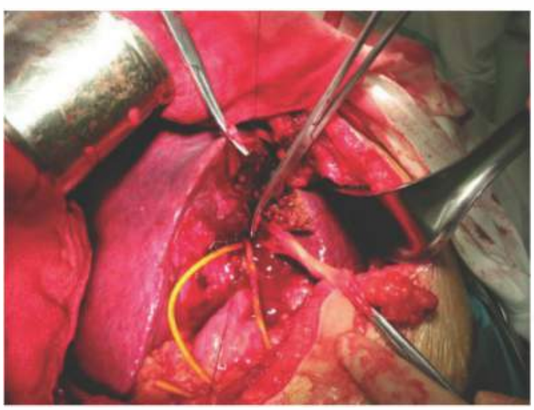

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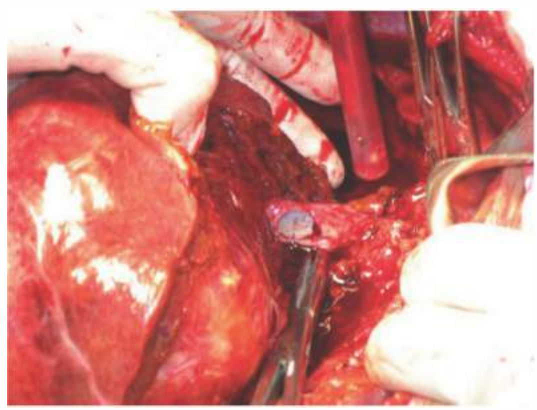


C

FIG 8 ● Parenchymal transection proceeds from the bottom to the top, from anterior to posterior. **A.** Schematic drawing of intraparenchymal control of bridging structures. **B.** Lateral retraction of the obliterated umbilical vein can guide the resection plane. **C.** Intrahepatic control of the middle hepatic vein at the confluence with the left hepatic vein.

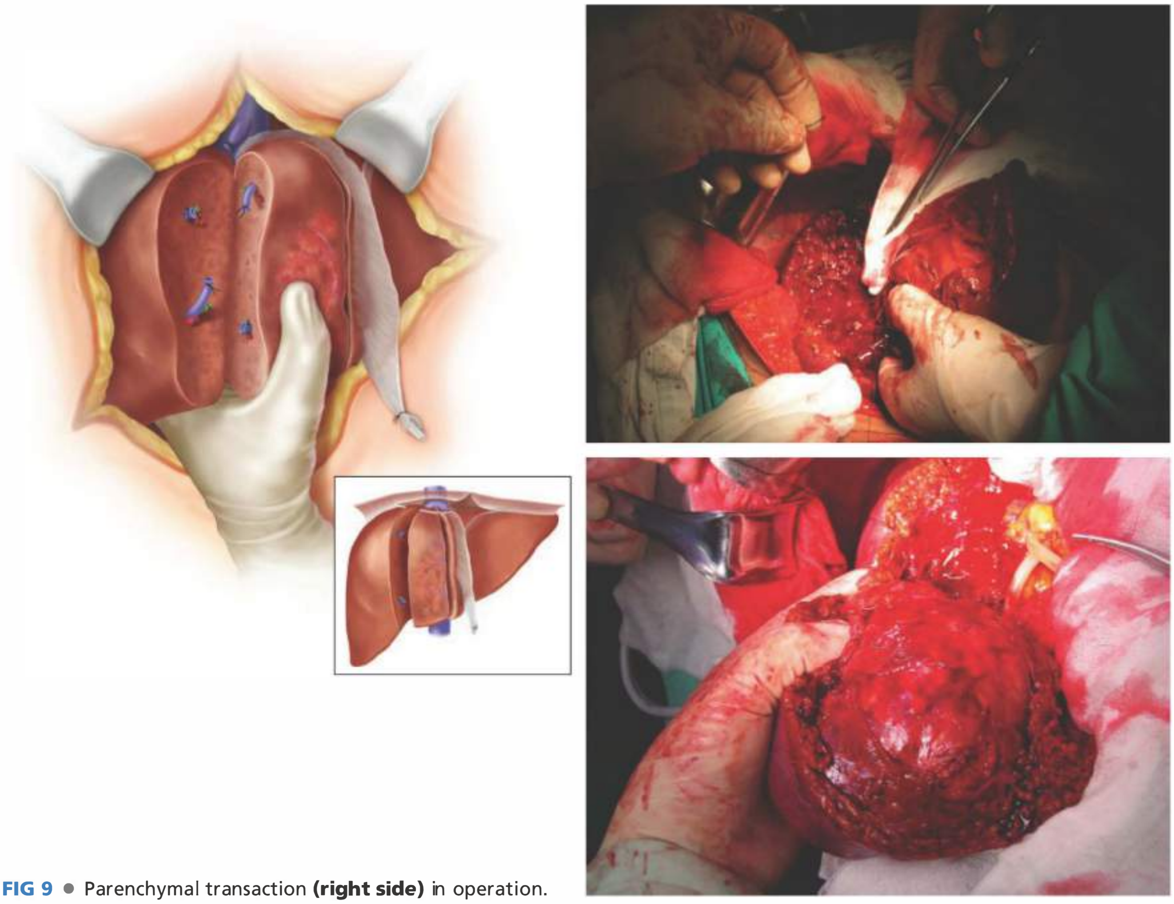


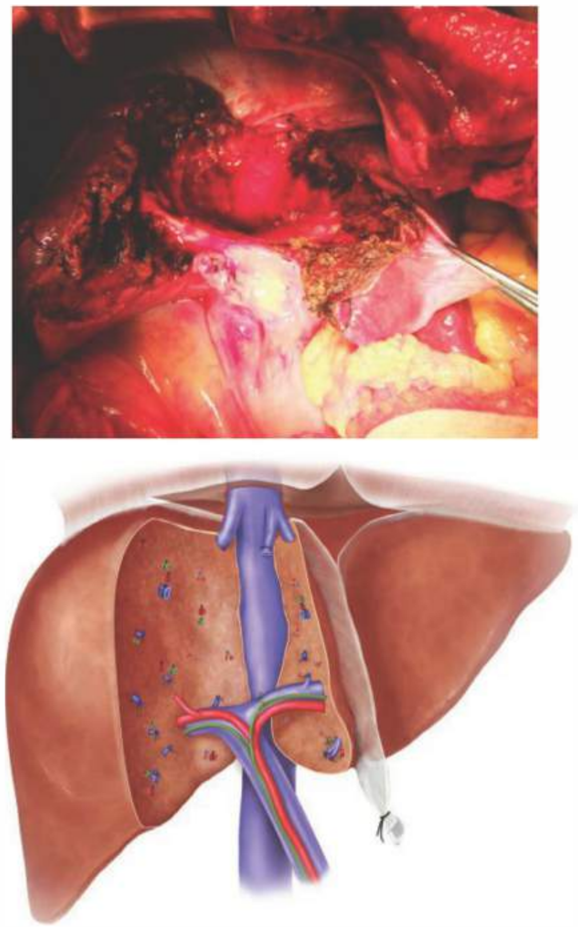
FIG 9 ● Parenchymal transaction **(right side)** in operation.

ALTERNATIVE: HEPATECTOMY WITHOUT EXTRAHEPATIC DISSECTION OF THE PORTA HEPATIS

- Hepatectomy without dissection of key structures in the porta hepatis is a simplified surgical maneuver commonly used in clinical practice at present. This approach reduces the complexity of the procedure and is associated with reduced risk of accidental injury.
- Intraoperative ultrasound is used to identify the right and left hepatic veins. Their course is marked on the anterior surface of the liver with electrocautery.
- Using ultrasound and palpation, the liver capsule is marked to achieve 1-cm margins from the lesion.
- The combination of these surface landmarks is used to plan the resection. The liver capsule is then scored along the intended resection planes.
- The hepatic tissue is separated gradually from superficial to deep tissues using a Pringle maneuver to limit inflow. The liver tissue along the right lateral edge of the round ligament on the left is incised working caudad to cephalad and anterior to posterior. Priority is given to identification of the middle hepatic vein, which is then transected and ligated at the insertion.
- The hepatic parenchyma is dissected along a plane 1 cm to the left side of the right intersegmental fissure. The right resection surface should avoid the main right portal vein and right hepatic vein.
- The hepatic capsule is then incised at the posterior and inferior edge of the tumor at the anterior aspect of the confluence of the left and right hepatic ducts confluence to create a plane of dissection between the Glisson's pedicle and the hepatic parenchyma. As this dissection is carried cephalad, the level of dissection should proceed deeper (posterior) into the liver. During this portion of the dissection, care must be taken to not inadvertently enter the IVC.
- All portal branches should be ligated carefully to prevent hemorrhage and formation of biliary fistula.
- To avoid damage to the bile ducts with this technique, the use of a bile duct dilator advanced into the parenchyma from a ductotomy in the common bile duct can help avoid damage to the bile duct during the hepatectomy. Postoperative T-tube drainage is then used as a mitigation strategy against biliary fistula.

MANAGEMENT AND DRAINAGE OF THE HEPATIC WOUND

- After removal of the tumor, the hepatic wound has two raw surfaces. These must be carefully inspected for hemostasis (**FIG 10**). After further examination to assure that there is no biliary fistula, the cut surfaces of the hepatic remnants are appositionally sutured face-to-face, as long as the porta hepatis is not excessively compressed by this maneuver as this can lead to kinking and associated obstruction of portal structures (**FIG 11**).
- Similarly, obstruction of the hepatic outflow vessels due to compression of the hepatic veins may cause swelling and congestion of the liver. This is often apparent intraoperatively; the liver becomes purple and the edges become firm and blunted.
- This face-to-face suturing is not compulsory and should not be performed if it produces excessive tension or is at risk of causing hepatic ischemia or congestion. In such cases, the wound surface can be kept open and covered with a piece of isolated or pedicled greater omentum, or the wound surface can be treated with hemostatic spray gel or other hemostatic materials.
- The authors routinely place two drains under the right diaphragm and in Morrison's pouch.



A

B

FIG 10 ● Uncovered (bare) cut surfaces of the residual liver. **A.** The operative field after the removal of segments 4, 5, and 8. Division of the right anterior branches and left medial branches of portal vein leads to full exposure, anteriorly and medially, of the preserved branches to segments 2, 3, 6, and 7. The vena cava is apparent above the bifurcation of the portal vein. **B.** Schematic visualization of the resection bed.

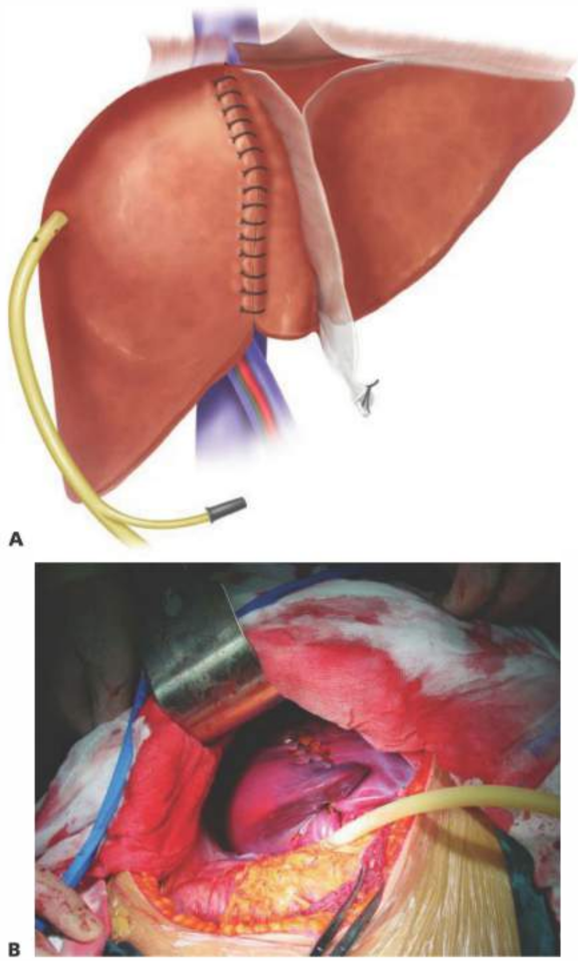


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FIG 11 ● **A.** Schematic and operative image **(B)** of the liver parenchyma after it has been reapproximated using multiple sutures through the liver capsule. The authors believe that this maneuver reduces the risk of postoperative hemorrhage or bile leak.

PEARLS AND PITFALLS

Patient selection	■ Patients should have intrinsic liver disease or a marginal hepatic remnant to be considered for central hepatectomy.
Preoperative assessment	■ Use ICG clearance or CT volumetry to determine the adequacy of the intended hepatic remnant.
Surgical technique	■ Intraoperative ultrasound is essential to guide localization of vascular anatomy and plan resection planes for adequate margins. ■ Control of the middle hepatic vein at its insertion is paramount. ■ Inflow occlusion reduces blood loss. ■ Intrahepatic control of segmental branches of the portal structures is associated with fewer iatrogenic injuries.
Complications	■ Bile leak is more common given the larger cut surface area. ■ Liver failure is of greater concern as the indication for the procedure is intrinsic liver disease that precludes extended lobectomy.
Outcomes	■ Survival is comparable to that of patients that are candidates for extended lobectomy (**FIG 12**).

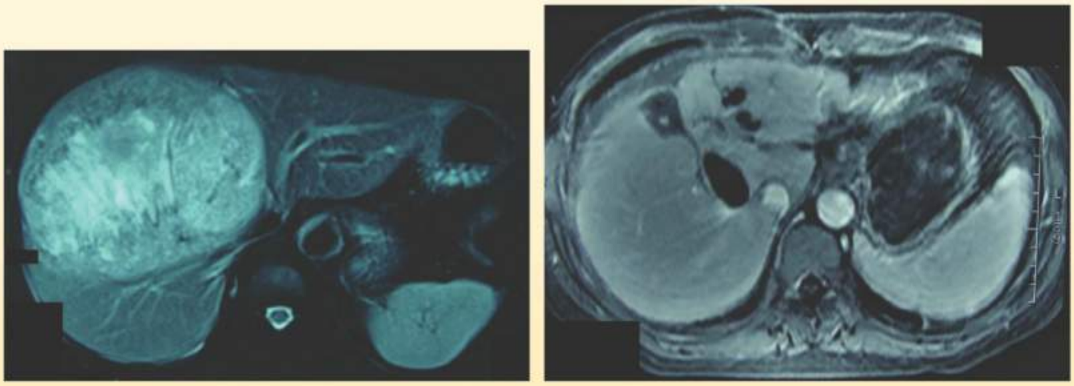

FIG 12 ● MRIs preoperatively and 3 months after central hepatectomy.

POSTOPERATIVE CARE

- The focus of postoperative care in cirrhotic patients is on management of aberrant hepatic synthetic and detoxification functions and portal hypertension. In most patients who undergo hepatic resection, transient hepatic insufficiency develops postoperatively, with hyperbilirubinemia, ascites formation, hypoalbuminemia, edema, and worsening of the baseline coagulopathy.
- Serum levels of aspartate aminotransferase (AST), alkaline phosphatase (ALP), total and direct bilirubin, partial thrombin time (PTT), electrolyte levels, and blood count are checked on the postoperative first, third, and seventh day, or prior to discharge. Serum bilirubin typically is elevated but should peak by postoperative day 2 and then return to normal levels within 1 week. A continued rise in the bilirubin is ominous for insufficient hepatic reserve.
- Sodium intake should be minimized.
- The regenerating liver requires phosphorus supplementation.
- Spironolactone is started in all cirrhotic patients as soon as oral diet is resumed and furosemide is added as needed to control ascites and/or peripheral edema.
- Postoperative pain control is best achieved with patient-controlled analgesia (PCA). Because of the decreased clearance of liver-metabolized drugs after a major hepatectomy, selection and dosing of pain medications should be adjusted accordingly.
- An oral diet can be resumed as early as postoperative day 3.
- The surgical drain can be removed on postoperative day 3 unless it is controlling a bile leak.
- If an unexplained fever occurs or the bilirubin level rises when other hepatic function parameters are normal, an intraabdominal bile collection may be present and a CT scan should be obtained. Percutaneous drain placement usually brings about resolution of such collections after a few days; reoperation is rarely necessary.

OUTCOMES

- Mehrabi et al.[3] reported 48 consecutive patients with centrally located liver tumors that underwent central hepatectomy. Postoperative surgical complications were seen in 18.8% of patients. The 3-year disease-free survival rate was 47.9%.
- As for oncologic outcomes, overall 1-, 3-, and 5-year disease-free survival rates range from 53% to 82%, 30% to 50%, and 17% to 30%, respectively.[4,5]
- Three retrospective studies have compared central hepatectomy to lobar or extended hepatectomy and found no difference in perioperative morbidity and mortality or mean postoperative hospital stay.[6–10] Wu et al.[11] found that central hepatectomy required a significantly longer inflow occlusion time for liver parenchymal transection

than did extended hepatectomies. Patients who underwent extended hepatectomy had worse 1-, 3-, and 6-year disease-free survival rates, but this did not reach statistical significance.

COMPLICATIONS

- Liver failure—The major advantage of a central hepatectomy is preservation of functional liver parenchyma.
- Hemorrhage—Extraparenchymal exposure of the hepatic veins with the possibility of clamping them in association with the Pringle maneuver, and the maintenance of a low central venous pressure during central hepatectomy, can substantially reduce operative hemorrhage.
- The most frequent causes of perioperative death are liver failure and hemorrhage.
- Bile leak—Central hepatectomy is an independent risk factor for bile leak; there are two transection planes and extensive dissection of the hepatic hilum.
- Hepatic venous outflow obstruction
- Ascites

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Chapter 29

Vena Cava Resection during Hepatectomy

Aijun Li   Mengchao Wu

DEFINITION

- Hepatic neoplasms involving the inferior vena cava (IVC) have usually been considered unresectable because of the high surgical risk of massive bleeding and air embolism. However, aggressive surgical approaches for hepatic tumors involving the IVC have recently been reported to have been performed safely and have been shown to alter the natural history of the disease.[1–28]

DIFFERENTIAL DIAGNOSIS

- Intrahepatic cholangiocarcinoma(ICC)[29]
- Hepatocellular carcinoma (HCC)
- Renal cell carcinoma
- Metastatic disease

MEDICAL HISTORY AND PHYSICAL EXAM

- By far, the most frequent indication for IVC resection en bloc with hepatectomy is HCC. As cirrhosis is the major risk for HCC and also the major risk factor for postoperative liver failure, great attention must be paid to history, symptoms, and signs associated with underlying liver disease. In general, hepatectomy that also requires IVC resection is only performed in patients without intrinsic liver disease.
- History
  - Hepatitis
  - Alcohol consumption
- Symptoms
  - Fatigue
  - Encephalopathy
  - Rapid weight gain
- Signs
  - Ascites
  - Asterixis
  - Abdominal or thoracic telangiectasia
  - Cachexia
  - Morbid obesity (steatohepatitis)
  - Extensive pedal edema (IVC compression)
- A thorough evaluation of potential pulmonary and cardiovascular disease must be performed. Patients with significant comorbidities are not candidates for major hepatectomy with en bloc IVC resection.

IMAGING AND OTHER LABORATORY STUDIES

- Ultrasonography (US). US is often the initial diagnostic imaging modality employed but is inadequate to fully evaluate hepatic lesions and IVC involvement.
- Contrast-enhanced computed tomography (CT). In addition to providing information regarding the number, size, and location of lesions, CT is an effective tool to estimate the remnant liver volume (RLV).
- Magnetic resonance imaging (MRI) examination. MRI is valuable for characterizing lesions and defining vasculature. It is particularly helpful in diagnosing the extent of tumor thrombus (TT) within the IVC. Magnetic resonance angiography (MRA) is useful for identifying the major hepatic veins and the IVC and clarifying their relations to any tumor masses.
- Each of these modalities may reveal IVC compression or TT within IVC.
- Patients that are suspected of having malignant invasion of the IVC wall on preoperative radiologic studies should also have echocardiography to assess for extension into the right heart. Such extension is not prohibitive of resection but mandates an operative approach that provides access to the chest, thus increasing morbidity while hope for a surgical cure is fleeting.
- In addition to routine laboratories, all patients must undergo a careful preoperative assessment of liver function and potential underlying disease.
  - Liver function tests
  - Hepatitis serologies
  - Coagulation studies
  - Platelet count

SURGICAL MANAGEMENT

Preoperative Planning

- Preoperative ipsilateral portal vein embolization to create hypertrophy of the planned liver remnant may prevent postoperative hepatic failure after extended major hepatectomy.
- Low-volume resuscitation minimizes blood loss but exaggerates potential hemodynamic instability with clamping of the IVC.
- Venovenous bypass (VVB) with total hepatic vascular exclusion (THVE) facilitates resection of primary and metastatic hepatic neoplasms that invade the vena cava.[21,22] Given the prior pearl, be prepared to use VVB when IVC invasion is suspected (**FIG 1**). Preoperative communication and coordination with perfusion and anesthesia teammates is vital to success in this regard.

Anatomic Considerations

- *Characteristics of the posterior hepatic IVC.* The posterior hepatic IVC extends from the renal veins to the confluence of the right atrium (RA). This is further divided anatomically into the inner segment of the pericardium (intrapericardial IVC), the suprahepatic IVC below the diaphragm, the retrohepatic IVC, and the lower segment of the subhepatic renal vein. The IVC is thick-walled, tenacious, elastic, and not particularly susceptible to invasion. The hepatic veins are thin-walled but rapidly develop thicker walls as they insert into the IVC. Thus, the proximal portions of the hepatic veins are at greatest risk for injury during the operation.

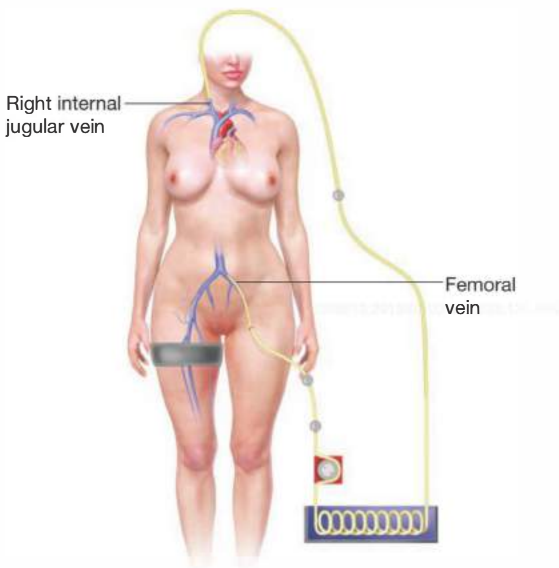

FIG 1 ● Schematic of a VVB circuit. The left femoral and right internal jugular veins are cannulated percutaneously. The patient is heparinized and the cannulae connected to a closed circuit containing a roller pump and a heat exchanger. Blood is drawn from the femoral site and infused into the jugular site.

Such injury invariably results in intraoperative hemorrhage and/or air embolism.

- *Characteristics of tumors that involve the IVC*. Most liver cancers near the IVC originate from hepatic segments 1, 4, 5, and/or 8, or in the paracaval portion of the caudate (referred to by some as segment 9).
    - *Caudate tumors*: Anatomically, the hepatic caudate lobe is divided into the left hepatic caudate lobe (Spigelian lobe, caudate lobe proper, segment 1) and right hepatic caudate lobe (dorsal sector). The right hepatic caudate lobe can be further divided into the paracaval portion (segment 9) and the caudate process (segment 10).[23–26] Caudal tumors may either extend anteriorly and thus invade the portal vein and/or the bile duct, resulting in obstructive jaundice, or extend posteriorly and thus invade the IVC. Generally, about one-fourth of caudate tumors involve the IVC.[27,28]
    - *Tumors arising near the root of the hepatic veins*: These tumors typically compress the anterior IVC between the mid and right hepatic veins or between the mid and left hepatic veins. Because the hepatic veins have no valves, are thin-walled, and fixed in the hepatic parenchyma, they are unable to retract upon injury and air embolism is liable to occur. To avoid air embolism and massive hemorrhage, the operative strategy should plan to isolate the hepatic veins extrahepatically and occlude them in advance.[17–19] The risk in resecting tumors that are near the confluence of the hepatic veins with the IVC is not rupturing the IVC but injuring the thin wall of the hepatic veins.
- *Characteristics of inferior vena cava tumor thrombus (IVCTT)*: IVCTT often spreads from the hepatic veins or hepatic short veins.[30–33] IVCTT is clinically classified into three types (**FIG 2**): (1) the posterior liver type (type I), where TT is located in the IVC behind the liver and below the surface of the diaphragm; (2) the superior liver type (type II), where TT extends into the IVC above the surface of the diaphragm but outside the atrium; and (3) the intracardiac type, where TT surpasses the surface of the diaphragm and enters the RA. The operative plan for patients with IVCTT completely depends on this classification of the IVCTT.

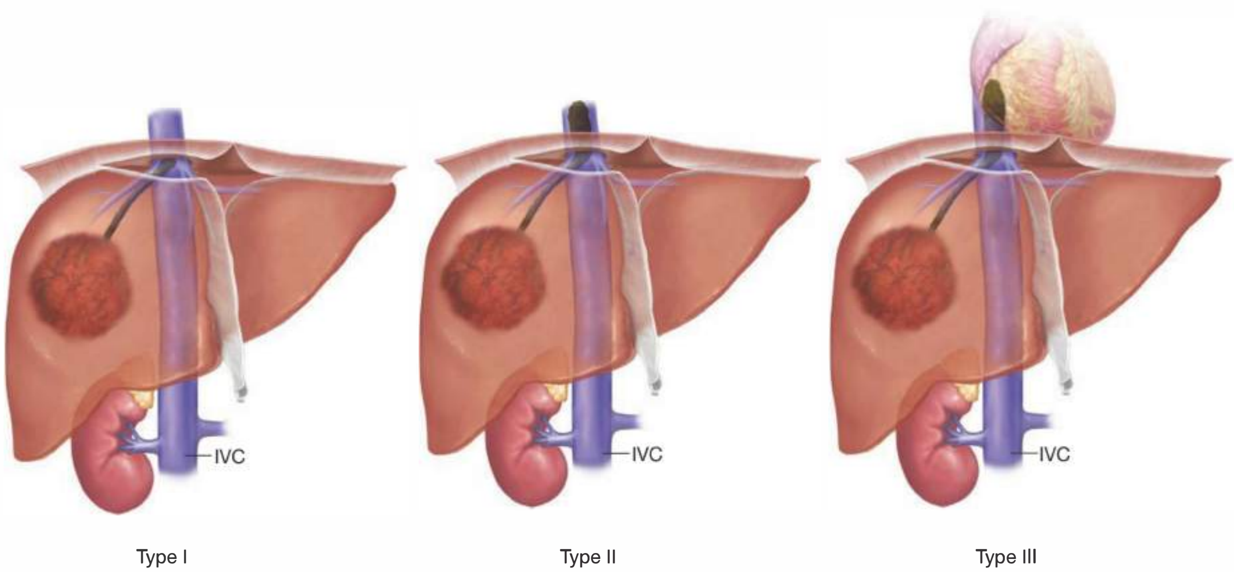

FIG 2 ● **A.** The posterior liver type (type I), where thrombus is located in the IVC behind the liver and below the surface of the diaphragm. **B.** The superior liver type (type II), where thrombus extends into the IVC above the surface of the diaphragm but remains outside the atrium. **C.** The intracardiac type, where thrombus surpasses the surface of the diaphragm and enters the RA.

Surgical Positioning

- The patient is positioned supine with both arms tucked (access to the chest may be required).
- The patient is prepped from chin to midthigh. The chest should be covered with sterile drapes, if sternotomy is not anticipated, to optimize maintenance of normothermia.
- The authors advocate placement of central lines in the left jugular vein and left femoral vein. These are the access points for VVB should it be required.

Incision

- A right subcostal incision with midline extension to the xiphoid process provides excellent exposure and facilitates extension should a sternotomy prove indicated.
- A fixed retractor is used that is capable of providing adequate exposure. The authors use a Thompson retractor.

HEPATIC NEOPLASM INVASION OF THE INFERIOR VENA CAVA WALL WITHOUT TUMOR THROMBUS

- The liver is fully mobilized.
- An umbilical tape is placed around the hepatoduodenal ligament and vessel loops are placed around the right hepatic vein as well as the confluence of the left and middle hepatic veins. Occasionally, lesion location will preclude this control of both veins. The authors advocate being prepared to perform THVE, and associated VVB if indicated, in this setting.
- Next, assess for IVC invasion versus compression. The underlying pathology will be somewhat predictive of encountering true invasion. HCC most typically will compress, but not invade the IVC (**FIG 3**). ICC or metastatic adenocarcinomas are more prone to truly invade the IVC.
- Dissect, control, and divide short hepatic veins working in a caudal to cranial fashion. When the IVC is invaded by a hepatic tumor, the wall becomes pale and stiff. More often than not, there is usually a plane between the tumor and the IVC for separation. Careful identification of this plane may completely avoid injury or need for resection into the IVC.

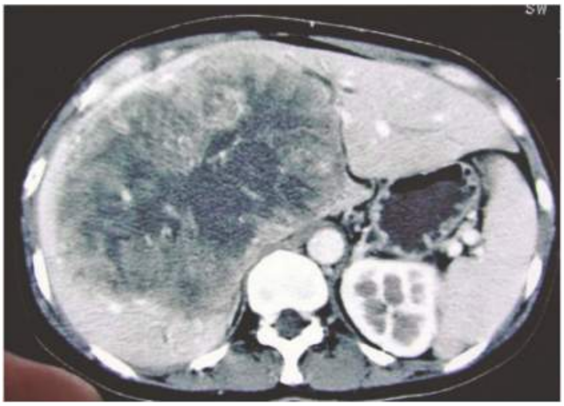

FIG 3 ● Preoperative CT scan showing a very large liver tumor located at segments 4 to 8 with infiltration into the caudate lobe. The IVC is not clearly identified and invasion of the IVC versus compression cannot be determined. Surgical exploration revealed the IVC was not involved. A right trisegmentectomy was performed.

- Sometimes, after tumors are stripped from the IVC or the IVC outer membranes are compromised by sharp dissection technique, the thinned IVC wall should be repaired with polypropylene 5-0 sutures ideally placed in the transverse axis to prevent narrowing of the lumen.
- If the IVC can be fully dissected, resection proceeds as described in other chapters.
- If the IVC is invaded, the next step is to determine if the segment is short enough to facilitate IVC resection with control using a side-biting vascular clamp such as a Satinsky clamp (**FIG 4**). This clamp is most easily placed after the parenchymal transection when the resection specimen can be retracted to elevate the final area of attachment on the IVC. You may not be able to determine the cranial extent of involvement until the liver has been divided.
- Prior to beginning the parenchymal dissection, get control of the suprahepatic and infrahepatic vena cava by circumferentially dissecting them and placing umbilical tapes (**FIG 5**). Identify and set aside the appropriate vascular clamps you will require should THVE prove indicated. A test clamp of the suprahepatic vena cava should be performed to determine the need for VVB, if THVE is required.
- Hepatic transection proceeds from superficial to deep tissues with the portal trial clamped. The left index finger should be placed up against the lateral wall of the IVC, and the left thumb is put on the medial/anterior aspect of the IVC. This maneuver provides proprioception for the operative surgeon during the transection.
- To facilitate vascular control for subsequent repair, clamp the IVC with a large Satinsky clamp to provide a margin for sharp resection of the involved segment of the IVC (**FIGS 6** and **7**).
- If the segment of IVC involvement proves to be more extensive, proceed with THVE to remove the tumor and repair the IVC.
- Sharply excise the lesion with a venous margin that ideally is greater than 0.5 cm.
- Alternatively, the resection can be performed in two steps: to resect and remove the main tumor first, then to clamp the affected part on the IVC wall with Satinsky forceps, cut off the remnant tumor, and finally repair the IVC.
- Assess whether a patch will be required versus primary repair.
    - Simple, longitudinal closure with 5-0 polypropylene is acceptable unless it results in narrowing of the IVC lumen greater than 25%.

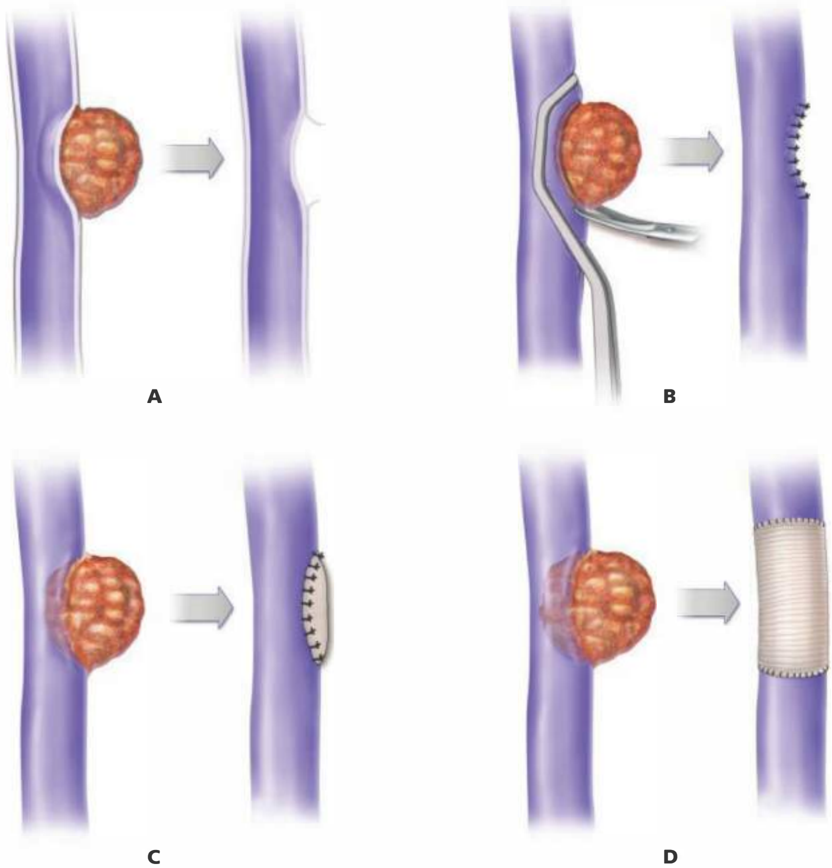

FIG 4 ● **A.** The IVC is not infiltrated, but the IVC was compressed and flat. The tumor is stripped from the IVC, or the IVC outer membranes are sheared by scissors. **B.** The IVC is partially involved but can be resected under side clamping and then primarily closed with direct longitudinal suturing (result should lead to less than a 25% narrowing of the IVC). **C.** When the IVC is extensively involved (>50% of the diameter), the IVC is resected and reconstructed using a patch (bovine pericardium). **D.** If the defect is large or the IVC is occluded, circumferential excision and primary anastomosis is warranted. An interposition graft should only be used only when a long segment of IVC (>3-cm length) is resected.

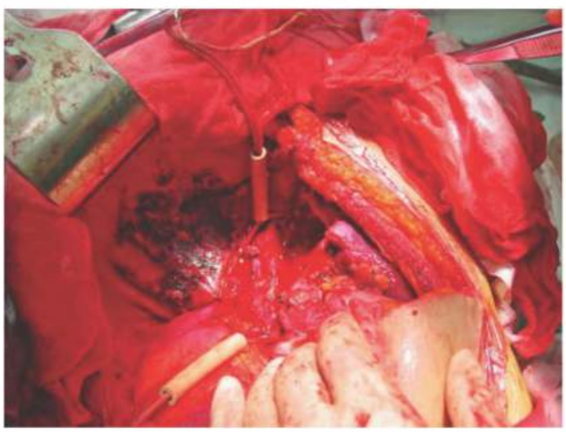

FIG 5 ● Occlusion of the suprahepatic IVC and infrahepatic IVC using two umbilical tape clamps (total hepatic vascular exclusion). This postresection image (to improve visualization of the placement of the umbilical tapes) was taken after a right trisegmentectomy was performed.

FIG 6 ● Preoperative CT scan showing a liver tumor located at the caudate lobe with probable invasion of the IVC.

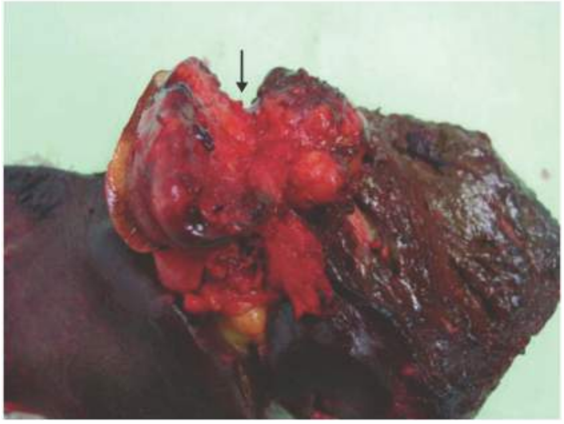

FIG 7 ● Macroscopic findings of resected specimen. A 4 × 5 × 5 cm IVC infiltrating-type tumor occupied the caudate lobe parenchyma sitting astride the IVC. The *black arrow* indicates the course of the IVC. This lesion was resected using a side-biting vascular clamp. The resultant defect in the IVC required a patch repair.

- Alternatively, if the resection exceeds about half of the circumference, a patch of autologous vein or bovine pericardium can be sewn circumferentially with running 5-0 polypropylene.
- Reported vein grafts for patch repair include saphenous vein, superficial femoral vein, or left renal vein.

- If the IVC is either extensively infiltrated or completely obstructed, the IVC should be resected and reconstructed using a graft. During segmental resection, vascular clamps should be placed at both proximal and distal sides of the involved part of the IVC. Umbilical tapes will not provide adequate hemostasis.
- Defects shorter than 3 cm can often be primarily reapproximated with 5-0 polypropylene.
- If the defect is longer than 3 cm or primary anastomosis is under undue tension, an interposition graft is warranted.
- Unfortunately, autologous vein grafts are too small to replace the IVC. The favored material for an IVC interposition graft is stented polytetrafluoroethylene (ePTFE).[14, 34–46] These conduits are available in varying sizes and are inserted using 5-0 polypropylene running suture.

HEPATIC NEOPLASM WITH INFERIOR VENA CAVA TUMOR THROMBUS

- Surgery selection depends on the level at which TT enters the IVC (**FIG 2**).
- In surgical manipulation of HCC with TT, it is critical to avoid squeezing the hepatic veins and the IVC in the process of dissecting the tumor, which may result in TT pulmonary embolism. However, "no-touch" technique is almost impossible in the process of dissecting a large tumor mass, and therefore, it is difficult to prevent TT from falling off completely.
  - One option to minimize this risk is to implant a device near the IVCTT proximal to the heart before tumor dissection so as to prevent TT fall off. B. Braun's Tempofilter II temporary IVC filter is a device designed for this purpose.[33]
  - The filter is implanted under local anesthesia via the right cervical vein 1 day before surgery or in the morning of surgery and fixed in the IVC by means of the delivery rod. It can be withdrawn easily after surgery.
  - The device can be fixed securely as long as there is a more than 2-cm distance between the TT and the right atrial orifice.
- For type I tumors
  - Explore the location and size of the tumor and location of the IVC first; completely mobilize the liver and expose the IVC above and below the liver.
  - The levels for vascular exclusion are at the suprahepatic IVC and infrahepatic IVC (between the adrenal vein and renal vein). Pass umbilical tapes at these levels.
  - Use care to minimize manipulation of the involved hepatic vein—tumor embolus is possible.
  - Transect the liver parenchyma under Pringle occlusion first, leaving only the affected hepatic vein in continuity with the specimen and the IVC.
  - Clamp the IVC.
  - Open the hepatic veins and the IVC under direct vision (open the IVC below the liver longitudinally); resect and remove TT under direct vision.
    - As most tumor thrombi are not attached to the wall, they can be removed or dissected from the IVC under direct vision.
    - In some cases where TT is attached to the wall or invade the IVC wall and cannot be removed completely, partial IVC resection plus repair can be performed.
    - In cases where TT has infiltrated the venous wall, adhered with it severely, and obstructed the IVC completely, resect the involved partial IVC together with TT.
    - In cases where complete removal of TT is impossible, IVC replacement can be considered. As the location of type I IVCTT is relatively low, venous TT can be removed surgically by using the standard radical hepatectomy and THVE.
  - To restore venous return, control the IVC with a side-biting vascular clamp and release the occluding clamps.
  - Irrigate the IVC and suture the luminal wall.
- In type II tumors, TT has surpassed the level of the diaphragm, thus the TT has to be removed by opening the diaphragm and the pericardium so that the level of

FIG 8 ● The CT of the case described revealed a large hepatic tumor with TT through the right hepatic vein to the IVC. The patient underwent a combined right hepatic and TT resection.

vascular isolation of the suprahepatic IVC is above the diaphragm but below the RA (**FIGS 8** and **9**).

- In type Ⅱ TT, subdiaphragmatic occlusion of the IVC is not appropriate, as it may cause TT rupture and fall off, resulting in cardiac tamponade, acute pulmonary embolism, and other serious complications.
- Dissect the infrahepatic IVC first and fully mobilize the liver.
- Open the diaphragm anterior to the suprahepatic IVC and enter the mediastinum to expose the right auricle (**FIG 10**).
- Control the suprahepatic IVC from within the pericardial space. Place an umbilical tape (**FIG 11**).

FIG 9 ● Coronal view of an MRI of the same patient demonstrating TT extending into the supraphrenic IVC *(black arrow)*, above the surface of the diaphragm but outside the atrium.

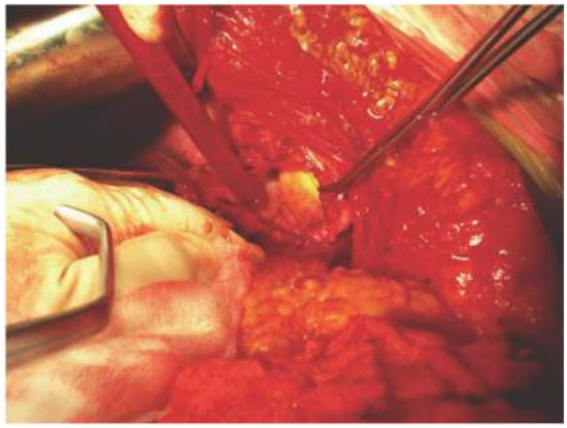

FIG 10 ● Exposure of the suprahepatic IVC above diaphragm. Note the white pericardium.

- Occlude the first portal (Pringle occlusion) and then the infrahepatic IVC.
- Occlude the right auricle with Satinsky forceps (**FIG 12**).
- Open the IVC longitudinally and resect the TT together with the tumor under direct vision.
- Before resuming blood flow, the residual TT and clots should be washed out with the help of the blood pressure still existing in the IVC for the sake of avoiding pulmonary embolism caused by air and blood clots.
- Close the IVC defect with running 5-0 polypropylene (**FIG 13**).
- Reversely, release the Satinsky forceps, and then the IVC below the liver, and the first portal occlusion (Pringle occlusion).
- Repair the pericardium and the diaphragm (**FIG 14**).
- **FIG 15** demonstrates the resected specimen with extension of TT that has been removed.

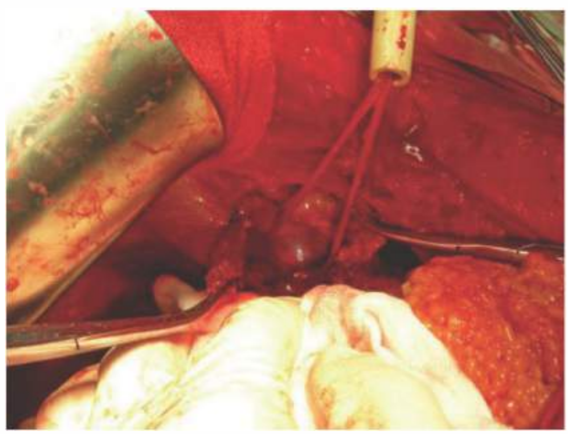

FIG 11 ● The suprahepatic IVC is circumferentially dissected within the pericardial space, above the diaphragm, and an umbilical tape passed.

FIG 12 ● The right atrial appendage was occluded with a Satinsky clamp.

- Type III TT can extend to the RA (**FIG 16**), and therefore, TT removal has to be performed under direct vision using extracorporeal circulation (under cardiopulmonary bypass).[31,32]
- Georgen et al.[31] describe an original finger-assisted thoracoabdominal approach for resection of HCC with thrombus extending into the RA, assisted by transesophageal echocardiography (TEE), which avoids the need for extracorporal bypass. There are three prerequisites for this procedure:
  - There are no adhesions to the venous wall of macroscopic thrombus in patients with HCC.
  - Complete mobilization of the liver allows caudal retraction of the liver and en bloc retraction of the tumor and the thrombus out of the RA.
  - After application of a vascular clamp on the suprahepatic portion of the IVC above the thrombus, a routine hepatic vascular exclusion can be performed to remove the tumor and the thrombus.

FIG 13 ● The IVC wall is closed using polypropylene 5-0 suture.

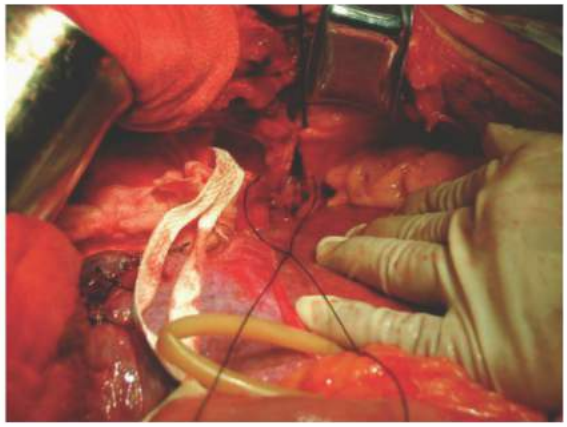

FIG 14 ● The diaphragm is repaired using interrupted sutures.

FIG 15 ● Liver tumor together with thrombus gross pathology. *Arrow* indicated TT in the right hepatic vein; TT of IVC *(right)*.

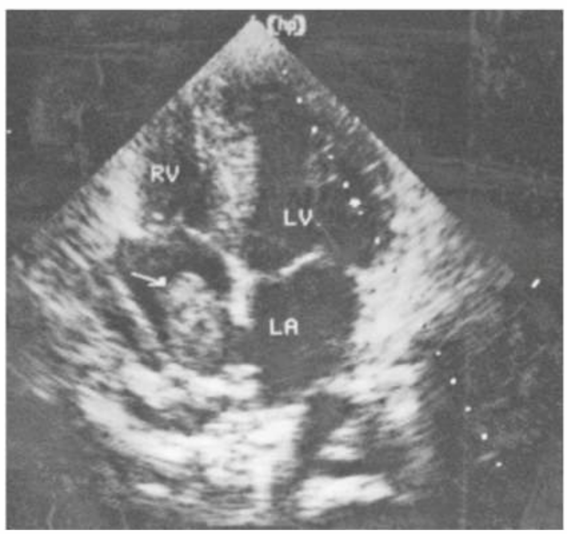

FIG 16 ● Echocardiography revealing TT *(white arrow)* extending into the RA.

POSTOPERATIVE MANAGEMENT

- Liver function, electrolyte levels, blood count, and prothrombin time (PT) are checked after the operation and then daily until discharge.
- Postoperative pain control is best achieved with patient-controlled analgesia (PCA). Because of the decreased clearance of liver-metabolized drugs after a hepatectomy, selection and dosing of pain medications should be adjusted accordingly.
- Phosphate supplementation is empirically provided as liver regeneration will consume large amounts of phosphate.
- An oral diet can be resumed as early as postoperative day 3.
- Fever, tachycardia, or hyperbilirubinemia when other hepatic function parameters are normal are signs that an intraabdominal bile collection may be present, and a CT scan should be obtained. Percutaneous drain placement usually brings about resolution of such collections after a few days; reoperation is rarely necessary.
- The focus of postoperative care in cirrhotic patients is on management of cirrhosis and portal hypertension. In most such patients who undergo hepatic resection, transient hepatic insufficiency develops postoperatively with hyperbilirubinemia, ascites formation, hypoalbuminemia, edema, and worsening of the baseline coagulopathy.

COMPLICATIONS

- Bleeding (hepatic wound surfaces, intraperitoneal, and gastrointestinal bleeding)
- Hepatic failure, renal failure
- Bile leak
- Subphrenic abscess
- Hepatic venous outflow obstruction
- The hepatic wound surfaces infection
- Pneumothorax, pleural effusion

OUTCOMES

- The reported 5-year survival for HCC invading the main trunk of the portal vein and the IVC is 20%,[34] and this was better than that of patients that received transarterial chemoembolization (TACE) alone.
- Arii et al.[35] reported IVC resection with reconstruction using ePTFE led to a 50% survival at 29 months. Patency of the graft was maintained for the long term without infectious complications. One-year, 3-year, and 5-year survival rates were 63.6%, 38.2%, and 25.5%, respectively.
- Azoulay et al.[36] reported their experience with concomitant hepatic and IVC resection in 22 patients with various liver tumors. Actuarial 1-, 3-, and 5-year survival rates were 81.8%, 38.3%, and 38.3%, respectively.
- Recent data[7,31,32,47–50] reported a 5-year survival rate of 20% to 30% and a median survival of 9.8 to 28 months, showing that patients who underwent complete resection of the tumor together with associated TT survived a long time.
- It is now generally accepted that the prognosis is good in HCC patients who received radical resection of the tumor together with dissection of the IVCTT as long as there is no local or distal metastasis.

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Chapter 30

Right Hepatic Trisegmentectomy

Ivan R. Zendejas

DEFINITION

- Removal of all the liver located to the right of the falciform ligament; the left lateral segment represents the functional remnant. By the segmental anatomy of the liver (**FIG 1**), this represents the resection of the three liver segments located to the right of the falciform ligament including the middle segment (4A and 4B), the right anterior segment (5 and 8), and the right posterior segment (6 and 7).
- The resection may also include the caudate lobe and all the biliary ducts to the right of the umbilical fissure. This is most frequently indicated in hilar cholangiocarcinoma patients.

DIFFERENTIAL DIAGNOSIS

- Cholangiocarcinoma
- Metastatic carcinoma
- Hepatocellular carcinoma
- Gallbladder cancer
- Liver trauma

PATIENT HISTORY AND PHYSICAL FINDINGS

- Attention must be given to the potential for underlying liver disease. The intended hepatic remnant following right trisegmentectomy is inadequate.

IMAGING AND OTHER DIAGNOSTIC STUDIES

- Triphasic, contrast-enhanced abdominal computed tomography (CT) scan
  - Its main value is to identify the vascular structures involved, anatomic variations in the hilar vasculature, and margins to be preserved at the time of surgery (**FIG 2**).

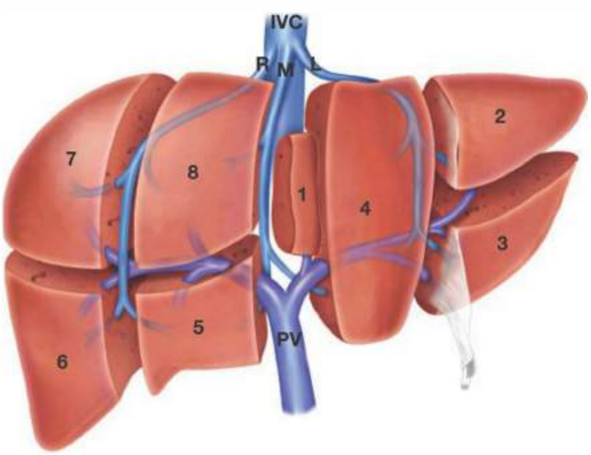

FIG 1 ● Anatomy of a right trisegmentectomy. Segments 7 and 8 are routinely removed. Segment 1 is selectively included in the resection, depending on the indication and ability to obtain a negative resection margin.

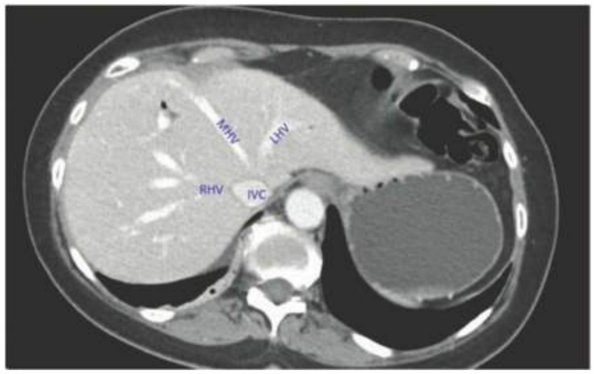

FIG 2 ● Anatomy of the hepatic veins. The transection plane for a right trisegmentectomy is between the middle hepatic vein (MHV) and left hepatic vein (LHV).

  - Examples of CT scans from patients with hepatocellular carcinoma involving the right side and middle segments (**FIG 3**) and a right dominant hilar cholangiocarcinoma are shown (**FIG 4**).
- Abdominal magnetic resonance imaging (MRI) with contrast and delayed liver phase
  - Equivalent to a contrast CT scan; slightly better at defining parenchyma abnormalities and in differential diagnosis
- Intraoperative ultrasound (IOUS)
  - Essential tool and skill needed during liver surgery. IOUS helps define margins, identify smaller lesions (<1 cm), and visualize the portal pedicles and hepatic veins (**FIGS 5** and **6**).

SURGICAL MANAGEMENT

Preoperative Planning

- The volume of the intended remnant liver should to be calculated with preoperative imaging and considered against the patient body weight. The author favors 3-D reconstruction of a CT scan with software rendition of the remnant volume (**FIG 7**).

FIG 3 ● Hepatocellular carcinoma involving the right and middle sectors.

FIG 4 ● Right dominant hilar cholangiocarcinoma. Note the dilated bile ducts in segment 4, to the right of the falciform ligament, suggesting the obstruction is distal to their confluence with the other ducts draining the left lobe.

FIG 6 ● IOUS of a hepatic neoplasm. The hypoechoic lesion is at the top of the image. The interface with normal parenchyma is readily apparent.

- The functional capacity of the remnant liver should be estimated.
- Portal vein (PV) embolization of the right lobe (and occasionally segment 4) is often indicated.
- If PV embolization is performed, CT scan volumetrics are repeated 3 to 4 weeks postembolization to assess for adequate hypertrophy of the planned liver remnant.
- Low-volume intraoperative resuscitation reduces blood loss. This approach requires preoperative communication with the preoperative nursing staff and anesthesiologist.
- Regional anesthesia approaches, such as epidural catheters, reduce pain scores and respiratory complications.
- Preoperative steroid (100 mg intravenous [IV] methylprednisolone) is associated with reduced peaks of liver injury test values but not improved outcomes.

Positioning

- The patient is placed in a supine position. Tucking the right arm is optional, depending on the retractor to be used.
- The patient is prepped from the nipples to the pubis on both sides.
- The authors routinely place an arterial line and central venous line.

FIG 5 ● Hepatic vein confluence under IOUS. Fluid-filled structures appear *black*. Doppler color facilitates identification of cystic lesions from vascular structures. In this image, the left hepatic vein is highlighted by the Doppler signal *(blue)* and the right hepatic vein is highlighted *red* as they insert into the inferior vena cava (IVC). The middle hepatic vein in this patient does not fuse with the left hepatic vein prior to IVC insertion and is seen above the IVC without Doppler enhancement.

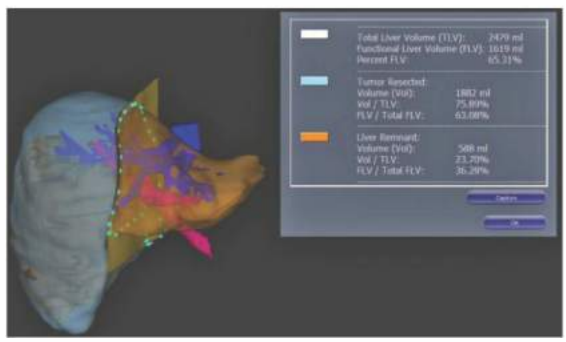

FIG 7 ● Tridimensional reconstructions showing the volume of the liver remnant. This particular software package provides the volume and percent of the total volume (table insert).

INCISION

- A number of options are possible (**FIG 8**) for appropriate exposure to perform a right trisegmentectomy.
- Bilateral, subcostal incision with upper midline extension (A + B + C)
- A right-sided, hockey stick–type incision (A + C)
- In children, a flat bilateral incision can be used (A + B).
- Removal of the xiphoid process is optional in order to get a better exposure of the suprahepatic abdominal vena cava.

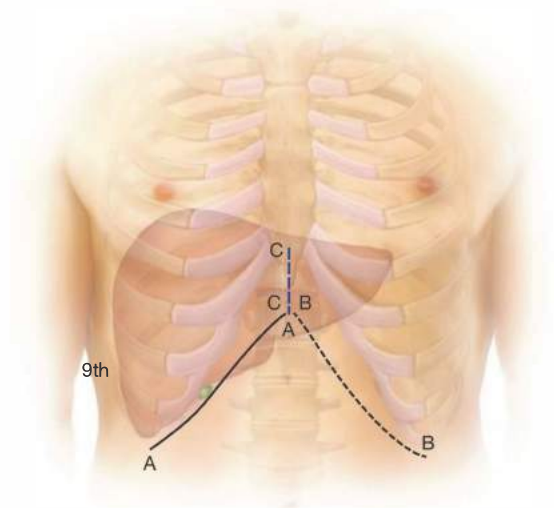

FIG 8 ● Types of incision for a right trisegmentectomy. The authors favor a right subcostal incision with midline extension to the xiphoid process.

EXPOSURE

- A Thompson retractor facilitates the application of adequate tension of the costal margin to provide exposure to the hepatic veins and suprahepatic vena cava.

HILAR PALPATION

- Bimanual palpation of the hilar structures through the foramen of Winslow quickly defines the arterial anatomy (**FIG 9**). A pulse felt posterior to the PV is a sure sign of a replaced right hepatic artery originating from the superior mesenteric artery. The gastrohepatic ligament is inspected for the presence of a replaced/accessory left hepatic artery supplying the left lateral segment. The best place to palpate the left hepatic artery is the umbilical fissure at the base of the liver. The arterial supply of the left lateral segment has to be clearly identified and preserved for a successful outcome.
- Nodal disease can be palpated and fixation of portal structures can estimate tumor extension.

FIG 9 ● Palpation of the porta hepatis facilitates definition of the arterial anatomy, the presence of involved lymph nodes, and pedicle encasement due to tumor extension.

LIVER MOBILIZATION

- The round ligament is ligated. The falciform ligament is taken down to the level of the hepatic veins. The gastrohepatic ligament is opened with careful attention to preserve the occasional replaced/accessory left hepatic artery. At this point, mobilization of the right lobe is performed (IOUS may be occasionally performed prior to mobilization depending on the tumor size and mobility of the liver) (**FIG 10**). The right lobe is mobilized by taking down the right coronary and triangular ligaments and lifting up the right lobe from the bare area with attention to the adrenal gland and the right side of the vena cava. The short caudate veins are isolated and controlled with ligatures, clips, and/or vascular stapler loads.

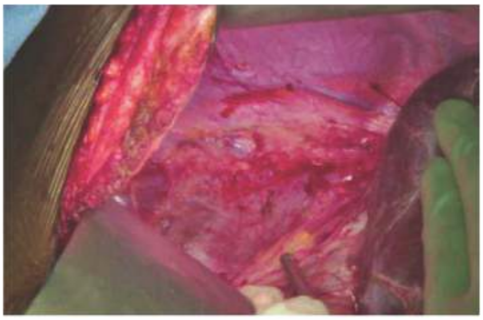

FIG 10 ● Mobilization of the right lobe. The liver is being manually retracted to the midline, revealing the exposed diaphragm after division of the triangular ligament.

HILAR DISSECTION

- The cystic duct and cystic artery are dissected, ligated, and divided. The right hepatic artery is identified on the right side of the bile duct, ligated, and divided (**FIG 11**). There are so many variations in the arterial anatomy that the left hepatic artery flow has to be felt by doing a test clamp on the right side. The lymphatic and nerve tissue in the porta hepatis will be cleared, and the right PV branches will then be visualized. Alternatively, the right PV can be identified by following the main PV situated laterally and posteriorly in the portal pedicle. The right PV is encircled with a vessel loop. If the vein is long, then it can be stapled using a vascular load. If it is short, then it will be divided in between clamps and then sutured with continuous 6-0 Prolene. After the inflow is occluded, the area of demarcation will be seen on the right lobe of the liver from the gallbladder fossa to the vena cava area.
- The common hepatic duct divides high up on the hilum and, in fact, the division may be within the substance of the liver and only visualized after incising the hilar plate (**FIG 12**). The right branch of the duct will be identified at the base of the liver and, once encircled, it will be ligated and divided. Before the division of the right duct is completed, a definite duct that passes into the left side has to be demonstrated (**FIG 13**).
- At this point, the retractor is adjusted to expose the area of the umbilical fissure (**FIG 14**). The fissure may need to be exposed by transecting the parenchymal bridges that occasionally join the medial and lateral segments. The transverse portion of the umbilical fissure is identified at the base of segment 4B. Except for a few posterior caudate branches, there are no other significant branches in this portion of the PV. If the caudate lobe

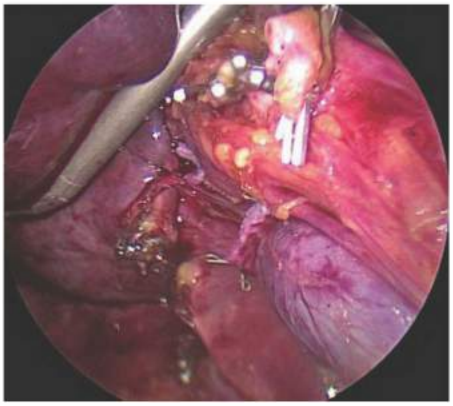

FIG 11 ● Ligation/stapling of the right-sided structures. The right PV has been divided with a linear stapler, and the right hepatic artery and hepatic ducts have been divided between surgical clips.

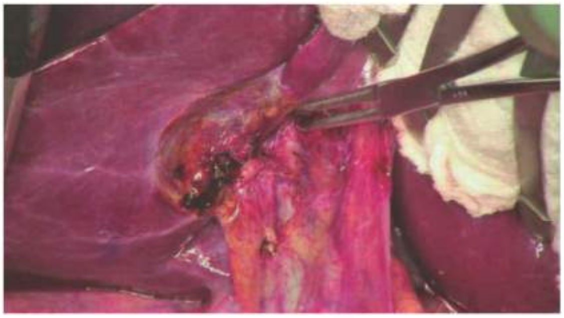

FIG 12 ● Dissection of the hilar plate. The bifurcation of the hepatic duct can be within the parenchyma of the liver. Glisson's capsule has been incised anterior to the hepatic duct in this example (tip of the surgical instrument).

FIG 13 ● Clear identification of the left bile duct. By elevating the hilar plate, the left hepatic duct is then clearly identified (tip of the forceps).

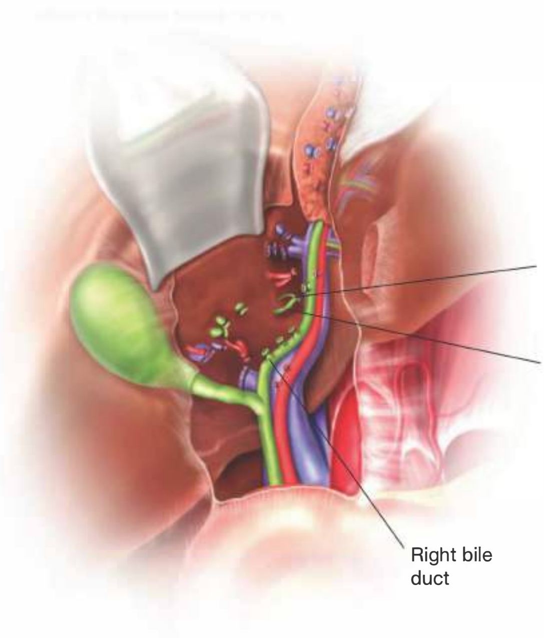

FIG 14 ● Dissection of segments 4A and 4B branches. Dissection is carried medial to the left hepatic duct. The dissection plane must be to the right of the falciform ligament to prevent injury to the structures essential to segments 2 and 3.

is to be removed, then these branches are ligated and divided. A replaced or accessory left hepatic artery will be identified at the base of the umbilical fissure. If present, this variant is an advantage by minimizing the risk of de-arterializing the remaining liver. The dissection is then carried out along the right side of the umbilical fissure, ligating all the medial branches to segments 4A and 4B. This can be done via the Glissonian approach (ligating and dividing them individually) or during the parenchymal transection.

HEPATIC VEINS DISSECTION

- With the right lobe of the liver fully mobilized to the left side of the vena cava, all the retrohepatic veins are ligated and divided including the right adrenal vein, right caudate vein, and several small posterior hepatic veins. The origin of the right hepatic vein is identified, encircled, and divided with a vascular stapler or between clamps, depending on the vessel length and proximity to the tumor (**FIG 15**). After this step, the only patent veins will be the middle and left hepatic veins. The middle vein will be divided during the parenchymal transection as this is typically the safest approach (injury of the left hepatic vein is catastrophic). Alternatively, when an adequate margin is at risk or the anatomy is favorable, the middle vein can be individually encircled by an anterior approach dissecting the tight space between the left and middle vein. A right angle can be used to find this groove, pointing it inferiorly. The left lateral segment is elevated to the right and the ligamentum venosus is divided. The left hepatic vein is identified and the dissection will be carried out on its back wall in a plane just anterior to the vena cava. With careful dissection, the left hepatic vein can be encircled as well as the middle vein. Once again, it is critical to leave the origin of the left hepatic vein intact to secure an adequate function of the remnant.

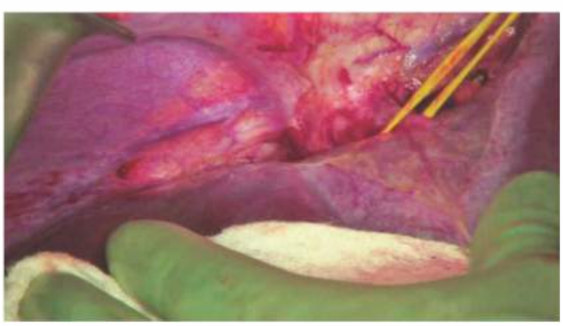

FIG 15 ● Left/middle hepatic vein isolation. The insertion of the middle hepatic vein into the left hepatic vein is most frequently within the parenchyma of the liver. Thus, it is safest to control and divide the middle vein during the parenchymal transection.

LIVER TRANSECTION

- The transection line for right trisegmentectomy is just to the right of the falciform ligament anteriorly, the umbilical fissure or the round ligament inferiorly, and the anterior surface of the vena cava posteriorly (FIG 16). A hanging maneuver using a long Penrose drain or an umbilical tape passed behind the substance of the liver can facilitate proprioception of the transection plane. The parenchyma can be divided with a combination of techniques including fragmentation, stapler, or precoagulation. Regardless of the method used, the small portal triads and hepatic vein branches should be clipped or ligated. As the transection continued, the middle hepatic vein will be divided as well. The cut surface of a right trisegmentectomy transection plane is generally small and relatively hemostatic (FIG 17). Hemostasis on the surface can be achieved with a combination energy devices and chemical products.

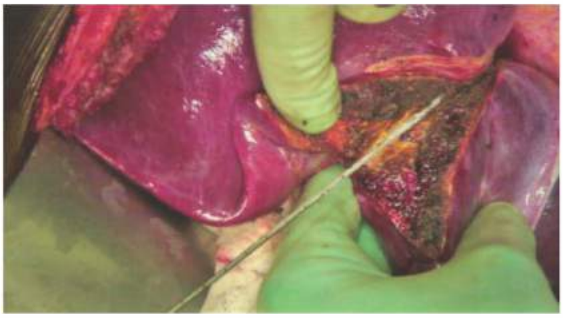

FIG 16 ● Parenchymal transection. The authors prefer a combination of cautery, clips, and ligatures to perform the transection. The use of a microwave probe is demonstrated in this example.

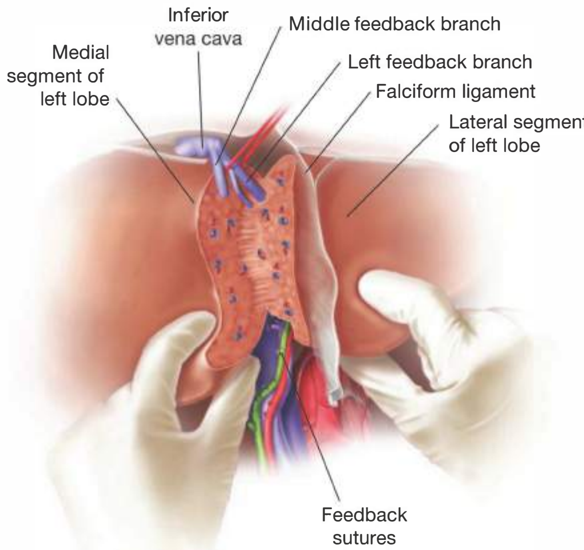

FIG 17 ● Completion of the parenchymal transection with preservation of the left hepatic vein.

CLOSURE

- The use of a drain is optional. The parenchyma and biliary pedicles are inspected for leaks and sutured as needed.
- The left lateral segment is attached to the anterior abdominal wall with a nonabsorbable suture to prevent potential torsion and the associated catastrophic compromise of vascular inflow or outflow.
- The abdominal wall is then closed in a single- or double-layer fashion with absorbable suture. Skin is then closed with subcuticular sutures or staples.

PEARLS AND PITFALLS

Preoperative planning	■ Right trisegmentectomy with caudate lobectomy is indicated for advanced hilar cholangiocarcinoma with involvement of the right-sided bile ducts. Only when the bile duct is divided at the left side of the umbilical fissure can significant negative margins be achieved. Performance of an R0 resection is essential for a good outcome. ■ Assessment of the planned liver remnant by volumetrics or other functional assessment is critical for trisegmentectomy patients. ■ PV embolization should be considered for all potential trisegmentectomy patients.
Intraoperative monitoring	■ Temperature: It is imperative to maintain adequate core temperature to avoid the mortal triad of hypothermia, acidosis, and coagulopathy. The core temperature can be measured with an esophageal probe; Foley catheter with thermometer of a PA catheter, if deemed necessary. ■ Hemodynamic monitoring includes central line for central venous pressure (CVP) and an arterial line to assure an adequate perfusion in real time.
Operative technique	■ The division of the intrahepatic bile duct is critical in the treatment of hilar cholangiocarcinoma because the tumor originates from and extends along the bile duct intramurally or superficially. ■ The blood supply and duct drainage of segment 4 originate within the umbilical fissure and feed back toward the right side buried in liver substance. These structures should be ligated and divided within the liver substance just to the right of the falciform ligament without entering the umbilical fissure, avoiding injury to the blood supply and drainage of the left lateral segment.

POSTOPERATIVE CARE

- Standard postliver resection precautions including minimal use of central nervous system (CNS) depressants to avoid aspiration
- Maintain a low CVP as long as the urine output is adequate.
- Monitor and correct international normalized ratio (INR), platelets, fibrinogen, and thromboelastogram, if needed, to prevent bleeding.
- Venous thromboembolism occurs in these patients. Prophylaxis is indicated.

OUTCOMES

- The 5-year survival for a margin-negative resection, regardless of underlying histology, is approximately 25%.

COMPLICATIONS

- Liver failure
- Hemostasis
- Bile leak
- Intraabdominal abscess
- Respiratory complications

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Chapter 31 Left Hepatic Trisectionectomy

Jason A. Castellanos Kamran Idrees

DEFINITION

- First described by Starzl et al.[1] in 1982, this procedure entails a standard left hepatic hepatectomy (segments 2, 3, and 4) as well as resection of the right anterior sector (segments 5 and 8) (FIG 1).
- This operation is performed in a patient with a primary hepatic tumor or metastases involving the left liver invading across the middle hepatic vein toward the right hemiliver and/or portions of segments 5 and 8. Additionally, patients with hilar cholangiocarcinoma may require this procedure in order to obtain tumor-free margins.

PATIENT HISTORY AND PHYSICAL FINDINGS

- Careful evaluation of the patient is required to ensure that the future liver remnant provides adequate liver function after resection. This should include assessment of liver function and exclusion of cirrhosis in addition to volumetric evaluation of the expected remnant liver volume on cross-sectional imaging.
- It is imperative to rule out portal hypertension or chronic liver disease, as a majority of the liver will be resected during this procedure.
- Details regarding prior therapy should be obtained.

IMAGING AND OTHER DIAGNOSTIC STUDIES

- Obtain either a liver-devoted magnetic resonance imaging (MRI) or contrast-enhanced, triphasic computerized tomography (CT) scan of the abdomen to identify tumor/s and its relationship to hilar structures and hepatic veins, anatomic variations of hilar vasculature, and assess for radiographic signs of cirrhosis (FIG 2).
- Identify tumor and assess margins for possibility of R0 resection as well as volumetric assessment of future liver remnant.
- For metastatic disease, perform a complete staging evaluation as appropriate for the particular primary neoplasm.
- Intraoperative ultrasound is essential to define margins; exclude presence of disease in the planned liver remnant and visualize hepatic inflow and outflow.

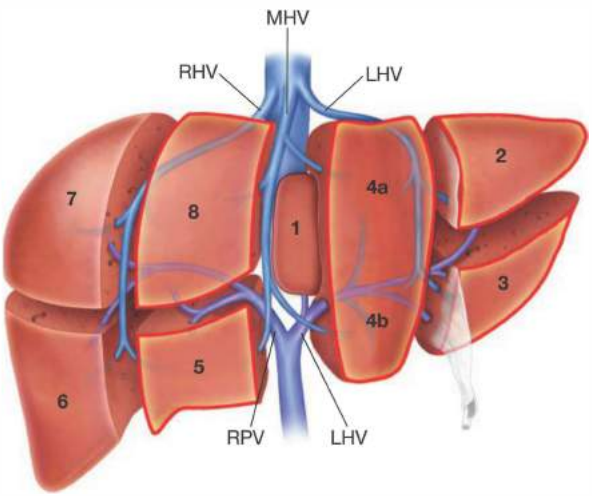


FIG 1 ● Liver anatomy for left trisectionectomy. Segments outlined in *red* signify the resection margin. RHV, right hepatic vein; MHV, middle hepatic vein; LHV, left hepatic vein; RPV, right portal vein.

SURGICAL MANAGEMENT

Preoperative Planning

- Assessment of the future liver remnant volume should be calculated with preoperative imaging to ensure adequate liver function after resection—greater than 20% in patients with normal liver function, greater than 30% for patients with evidence of liver disease (nonalcoholic fatty liver disease, chemotherapy-associated steatohepatitis, etc.), and greater than 40% in cirrhotic patients.[2,3] If the remnant liver volume is deemed to be too small, then portal vein embolization may be used as an adjunct therapy to hypertrophy the future liver remnant prior to hepatectomy.

Positioning

- The patient should be placed in the supine position with the right arm tucked and prepped from the nipples to the pubis bilaterally.

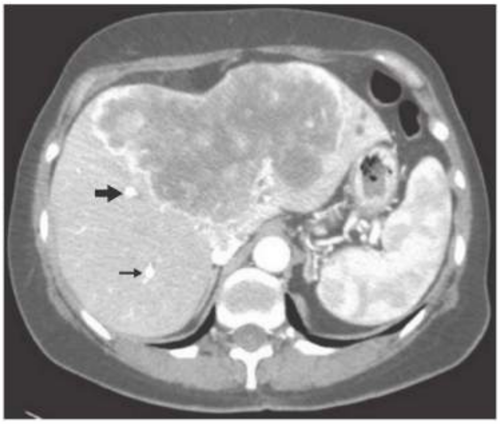


FIG 2 ● Triple-phase CT scan (portal venous phase) of a cholangiocarcinoma involving segments 1, 2, 3, 4, 5, and 8. The right anterior *(thick arrow)* and posterior *(thin arrow)* pedicles are visible. This patient underwent left trisectionectomy with excision of the caudate lobe, which resulted in R0 excision of the tumor and a favorable outcome.

DIAGNOSTIC LAPAROSCOPY

- Our practice is to perform an initial diagnostic laparoscopy to ensure that there is no evidence of peritoneal disease.
- A supraumbilical incision is made through the skin and subcutaneous tissue using the Hasson technique and a trocar is introduced into the abdomen, which is then insufflated to a pressure of 15 cm H_2O.
- The abdomen is explored including the hilum of the liver to assess for metastatic disease and periportal adenopathy. If there are no contraindications to operation, we then proceed to incision.

INCISION

- A bilateral subcostal incision is made, with superior extension in the midline to the xiphoid process, and a self-retaining retractor is placed. Another option is a midline incision to just above the umbilicus with a rightward extension (**FIG 3**).
- The xiphoid process may be excised in order to enhance exposure of the confluence of the hepatic veins into the suprahepatic inferior vena cava (IVC).
- The abdomen is inspected again for evidence of distant metastases that would contraindicate proceeding with operation.

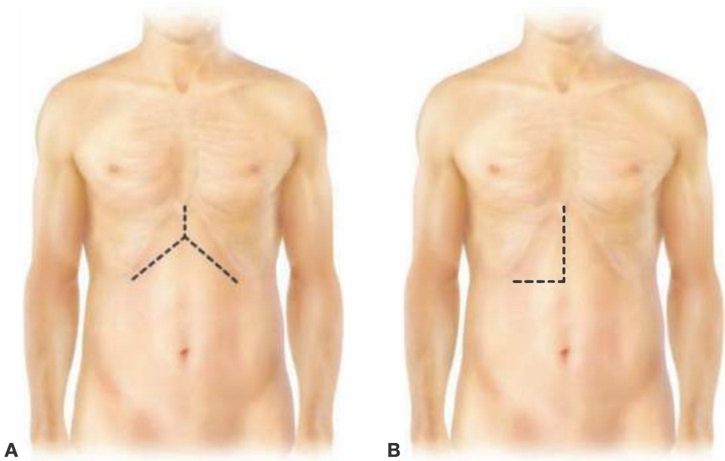


FIG 3 ● Incisions for left trisectionectomy include **(A)** bilateral subcostal incision and **(B)** long midline incision with rightward extension.

INSPECTION OF THE HILUM, CHOLECYSTECTOMY

- The hilar structures are palpated in order to define any anatomic variations (e.g., a posterior pulsation indicates a replaced/accessory right hepatic artery originating from the superior mesenteric artery).
- The cystic duct and cystic artery are identified and ligated, and a cholecystectomy is performed (**FIG 4**).

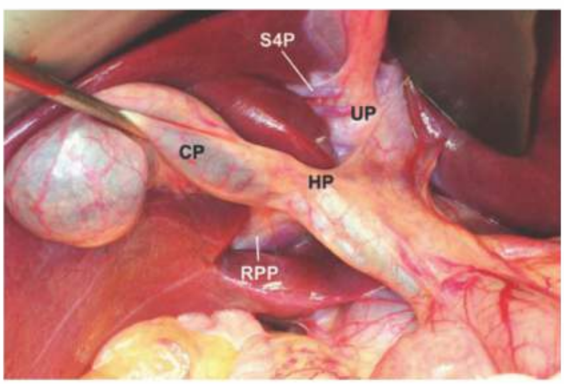


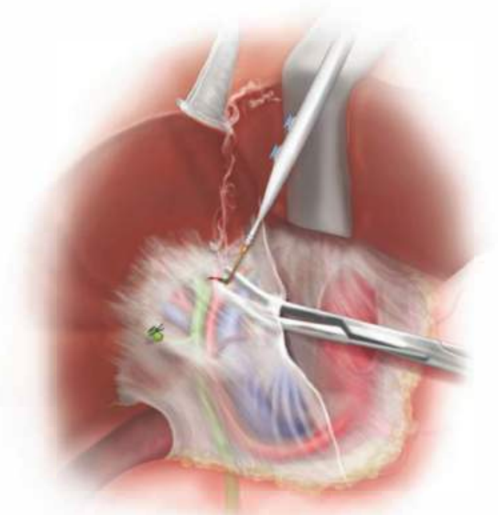
FIG 4 ● Surface anatomy of the plate system showing the cystic plate (CP) covered by the gallbladder, the hilar plate (HP), and the umbilical plate (UP). S4P, segment 4 pedicle; RPP, right posterior pedicle. (From Fischer JF, ed. *Mastery of Surgery*. 6th ed. Philadelphia, PA: Lippincott Williams & Wilkins; 2012.)

MOBILIZATION OF THE LIVER

- The round ligament is ligated and divided, and the falciform, left triangular and coronary ligaments are divided to the level of the hepatic veins. The right coronary and triangular ligaments are transected, exposing the bare area of the liver.
- Intraoperative ultrasound is used at this point to identify the right hepatic vein to plan the line of transection and ensure resectability of the tumor as well as rule out any disease in the future liver remnant.
- After palpation, to identify a potential replaced or accessory left hepatic artery, the gastrohepatic ligament is divided. An aberrant left hepatic artery may be ligated at this time, as segments 2, 3, and 4 will be resected.
- Mobilization of the right liver is also required in order to facilitate parenchymal dissection along the right hepatic vein. Short hepatic veins are ligated and divided off of IVC. The hepatocaval ligament is then ligated or divided with a vascular stapler.

HILAR DISSECTION

- The hepatoduodenal ligament is opened and the common bile duct, proper hepatic artery, and portal vein are visualized after lymphatic and nerve tissues are cleared (**FIG 5**).
- A Rummel tourniquet is placed around the porta hepatis prior to further dissection to facilitate the Pringle maneuver, if needed.
- The left hemiliver is lifted and retracted toward the right to expose the left hilar branches of the portal triad. A vessel loop is placed around the left portal vein, left hepatic



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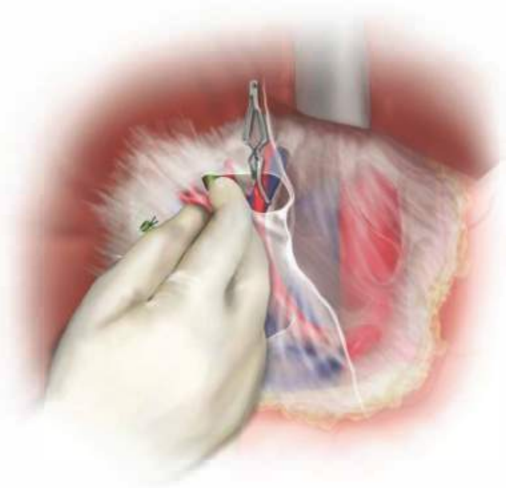

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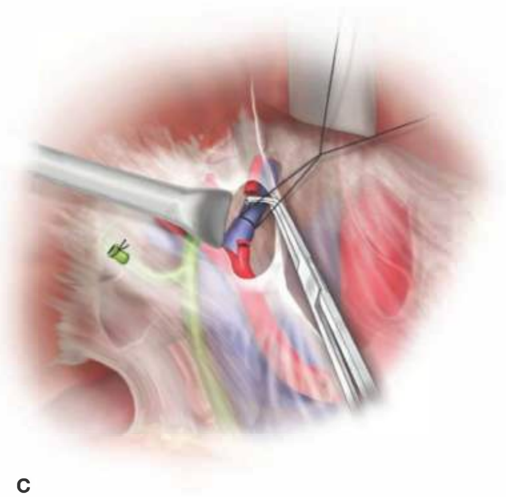


C

FIG 5 ● Dissection of the hilum and left pedicle. The hepatoduodenal ligament is opened **(A)**, followed by identification of the left hepatic artery **(B)**. Clamping of the artery with a bulldog clamp allows for assessment of blood flow to the right liver. The left hepatic artery and vein are ligated **(C)**, either with suture ligation or with vascular staplers.

artery, and left hepatic duct to isolate them for ligation. Dissection may be aided by using the caudal stump of Arantius' ligament as an anatomic guide toward the left portal vein.

- Ligation of the structures may be performed from an anterior to posterior or posterior to anterior approach; we prefer to begin ligation with the posterior structures. The left portal vein is ligated and divided first, leaving a distance of at least 5 mm to prevent stenosis of the right portal vein. Next, the left hepatic artery and left hepatic duct are ligated and divided. If the caudate lobe will be resected as well, then the left hilar structures should be ligated as close as possible to their origin.
- Next, the right anterior pedicle is identified with careful dissection in the right portal sheath. Identification of this pedicle can be aided by use of ultrasound, which can determine the location and depth (typically 1 to 2 cm from the inferior surface) of the pedicles. There are three options that the surgeon may use to approach this structure, depending on the ease of dissection, the extent of tumor involvement of the right portal sheath, and surgeon preference: extrahepatic, intrahepatic, or delayed dissection and ligation. If the anatomy is clear and the tumor does not impair dissection, then the right anterior pedicle may be dissected in the right portal sheath and individual structures of right anterior pedicle selectively ligated (extrahepatic) or right anterior pedicle is transected en bloc with a vascular stapler (intrahepatic pedicle ligation) while the right posterior pedicle is preserved. If the tumor involves the portal sheath, then the pedicle may be ligated during tissue transection instead (delayed) (**FIG 6**).
- Machado et al.[4] describe an intrahepatic approach to isolating and ligating this structure. A small anterior

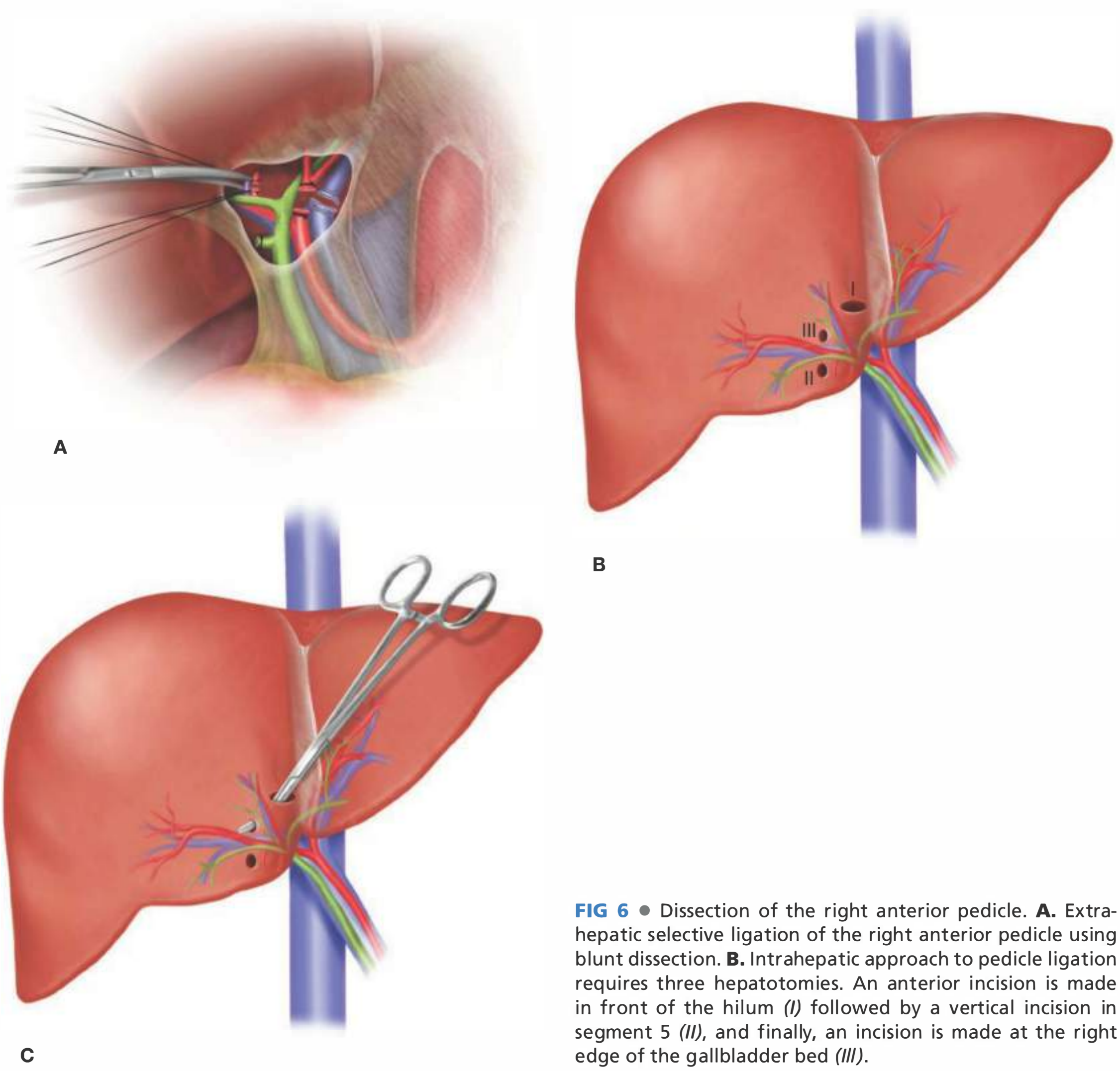


FIG 6 ● Dissection of the right anterior pedicle. **A.** Extrahepatic selective ligation of the right anterior pedicle using blunt dissection. **B.** Intrahepatic approach to pedicle ligation requires three hepatotomies. An anterior incision is made in front of the hilum *(I)* followed by a vertical incision in segment 5 *(II)*, and finally, an incision is made at the right edge of the gallbladder bed *(III)*.

incision is made in front of the hilum, and the parenchyma is bluntly dissected until the anterior aspect of the pedicle is identified. Another small incision is made perpendicular to the hilum at the junction of segments 1 and 5. The right main sheath is then isolated with the use of a large curved clamp inserted between these two incisions, and a vessel loop is placed. A third incision is made on the right side of the gallbladder fossa and a curved clamp used to dissect between this and the first incision, thus isolating the right anterior pedicle.[4]

- It is important to note that the blood supply to segment 7 may come from the right anterior pedicle, and so this must be kept in mind prior to transection in order to ensure adequate blood supply to the remnant liver. Clamping the pedicle prior to transection enables assessment of this relationship if it is not clear on preoperative imaging.
- We ligate these structures using Endo GIA staplers with a vascular load, but if the vessel is too short for this technique, then suture ligation followed by oversewing the distal stump with a continuous 6-0 Prolene may be performed. Our practice is to delay ligation of the right anterior hepatic duct until parenchymal dissection due to the possibility of anatomic variation.
- After ligation of the vessels feeding the left and anterior right liver, the area that will be resected will become demarcated by cyanosis.

DISSECTION OF THE MIDDLE AND LEFT HEPATIC VEINS

- The anterior aspect of the left and middle hepatic veins is exposed by dissection of the falciform left triangular and coronary ligaments as described earlier. The junction of the veins is dissected apart with a blunt right angle and the left phrenic vein is identified, ligated, and divided at its insertion in the left hepatic vein (**FIG 7**).
- With the left lateral section retracted upward, the lesser omentum is divided up to the diaphragm. Arantius' ligament (ligamentum venosum), which runs from the left branch of the portal vein to the left hepatic vein, is then ligated and divided.
- The cephalad stump of Arantius' ligament is grasped and used to guide dissection toward the IVC. The ligament will broaden close to the IVC, at which point dissection is stopped and the ligament is retracted cephalad and leftward to create tension that will enable visualization of an avascular plane between the left and middle hepatic veins.[5]
- A vessel loop is then placed around the confluence of the middle and left hepatic veins. The hepatic veins may be ligated at this time if the confluence of the middle and left hepatic vein is already isolated. However, if vascular control cannot be achieved because of tumor proximity, our practice is to first divide the parenchyma and then ligate these vessels. Premature attempts to ligate these vessels may be dangerous as there are posterior tributaries that are difficult to control prior to transection of the parenchyma.
- If the caudate lobe will be resected, then the low hepatic veins that drain the caudate should be ligated and divided prior to transection of the parenchyma.

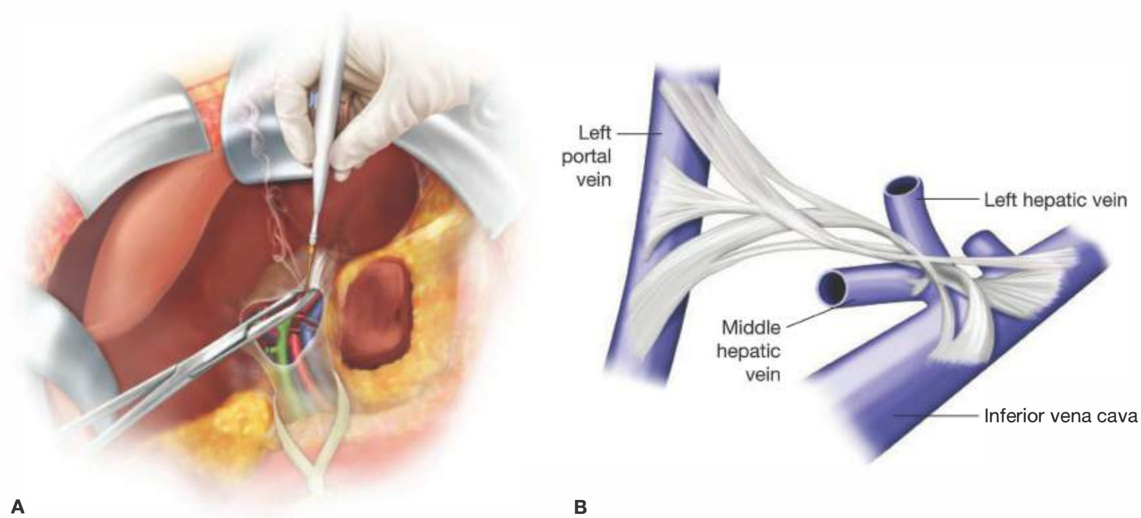
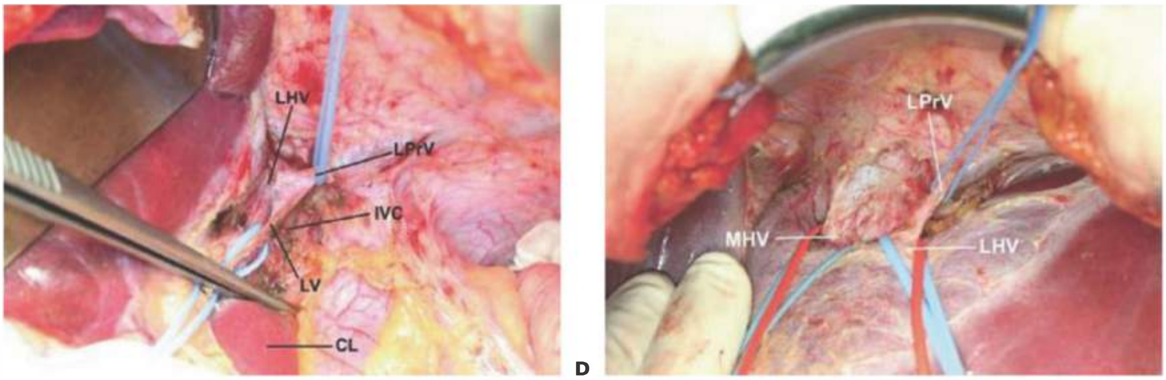


FIG 7 ● Dissection of the left and middle hepatic veins. **A.** Dissection of Arantius' ligament to expose the left and middle hepatic veins. **B.** Arantius' ligament inserts onto the left and middle hepatic veins as demonstrated in this schematic. *(continued)*

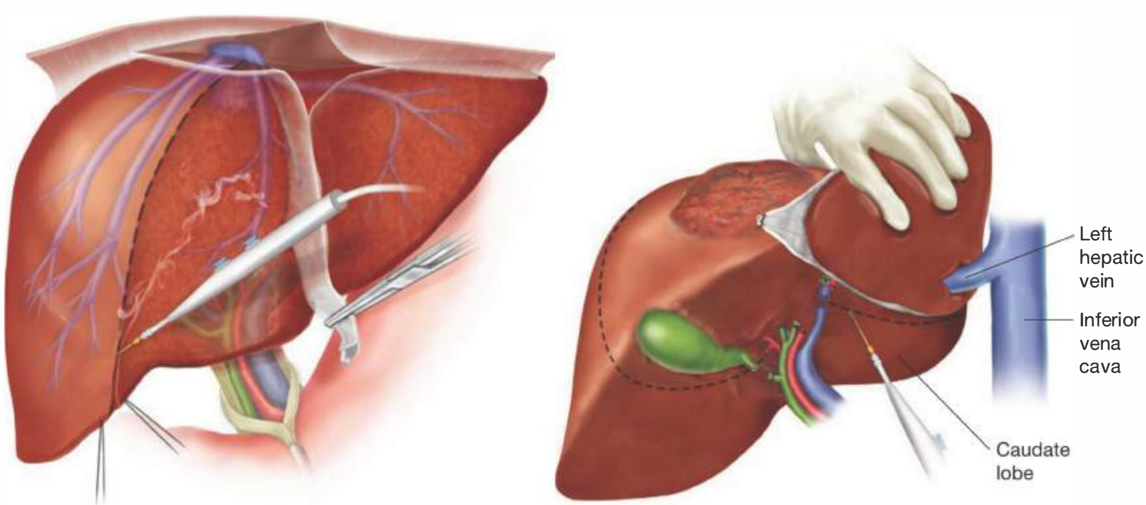


C D

FIG 7 ● *(continued)* **C.** Isolation of ligamentum venosum (LV) at its junction with the left hepatic vein (LHV). **D.** Operative photo showing extrahepatic isolation of the left and middle hepatic veins together with their common trunk. Division of the left phrenic vein allows an extra length of the left hepatic vein to be isolated. LPrV, left phrenic vein; IVC, inferior vena cava; CL, caudate lobe; MHV, middle hepatic vein; LHV, left hepatic vein.

TRANSECTION OF THE LIVER PARENCHYMA

- 2-0 chromic stay sutures are placed at the inferior margin of the liver, one on the ischemic left side and one on the normally perfused right side.
- The surgeon should communicate with the anesthesia team at the beginning of the case to ensure a low central venous pressure (CVP) (<3 mmHg).
- The transection line is scored on the liver capsule following the ischemic demarcation. Resection of the entire specimen can be accomplished en bloc, but if the right anterior pedicle dissection is difficult, then resection of the left lobe initially may facilitate dissection of the right anterior pedicle (**FIG 8**).
- The liver is then divided from the inferior margin following the line of ischemic demarcation. Ultrasound can be used prior to this to ensure that the course of the right hepatic vein is known throughout the liver. Various techniques may be used to transect the liver including stapling, electrosurgery, fragmentation, ultrasonic dissection, radiofrequency energy device dissection, and water-jet dissection (**FIG 9**).



A B

FIG 8 ● Anterior (**A**) and posterior (**B**) lines of transection.

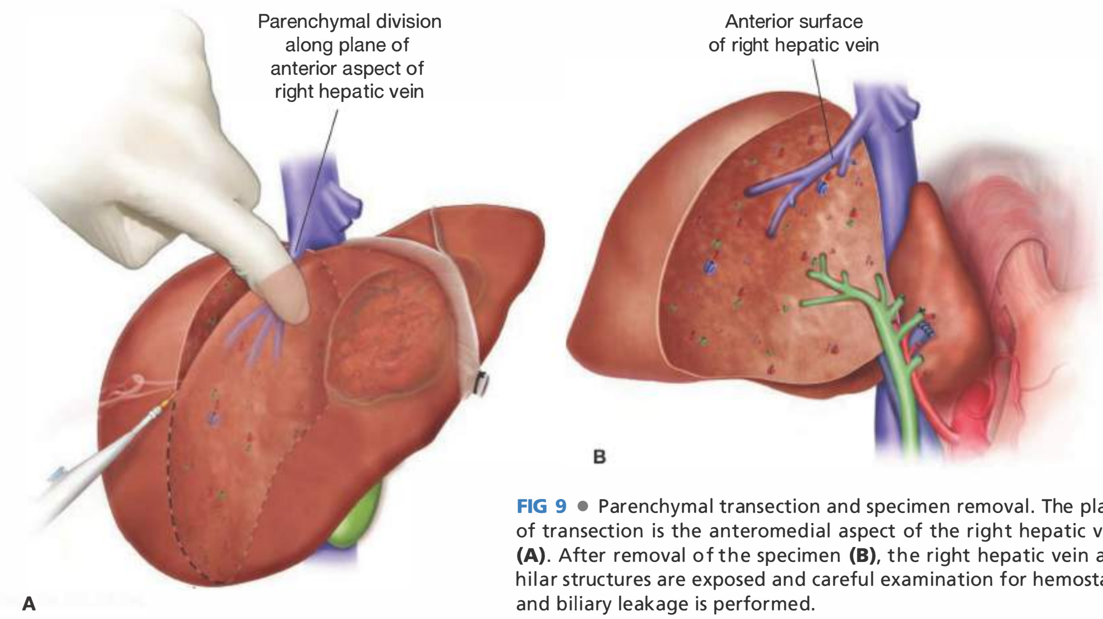


FIG 9 ● Parenchymal transection and specimen removal. The plane of transection is the anteromedial aspect of the right hepatic vein **(A)**. After removal of the specimen **(B)**, the right hepatic vein and hilar structures are exposed and careful examination for hemostasis and biliary leakage is performed.

- If the right anterior pedicle cannot be ligated prior to transection of the parenchyma, then the line of transection should be marked 1 cm to the left of the course of the right hepatic vein.
- When transection is complete, the left and middle hepatic veins are ligated and divided and the specimen is removed from the operative field.
- The remnant liver is examined for hemostasis, which is controlled with argon beam coagulation and placement of Surgicel, and biliary leakage, which is controlled with clips or suture ligation.

CLOSURE

- Placement of a drain is optional and largely dependent on the clinical scenario. We place drains if there is evidence of biliary leakage or if any biliary reconstruction was performed.
- The incision is then closed in the standard fashion with absorbable suture, and the skin is closed with staples or subcuticular sutures.

PEARLS AND PITFALLS

Operative indications	■ Tumor involving the left liver and right anterior section (segments 5 and 8) ■ No evidence of peritoneal spread or other metastatic disease
Preoperative assessment	■ Ensure normal liver function prior to considering operation. ■ Assess the volume of future liver remnant preoperatively to decrease the likelihood of postoperative liver failure.
Isolation of the right anterior pedicle	■ Ultrasound may be used to help identify structures. ■ Dissection may be either intrahepatic, extrahepatic, or delayed until transection. ■ If tumor involves the hilum, then dissection and ligation of the right anterior pedicle should be performed during parenchymal transection. ■ Ensure that the blood supply to segment 7 is not compromised prior to dividing the right anterior pedicle.

POSTOPERATIVE CARE

- Initial postoperative care may occur on a monitored surgical floor or surgical intensive care unit, depending on the course of the operation and the patient's comorbidities.
- Careful attention is paid to hemodynamic parameters, urine output, respiratory status, body temperature, and signs of postoperative liver failure.
- Postoperative resuscitation with colloid (e.g., albumin) instead of crystalloid fluids is preferred in order to maintain a lower CVP, as an elevated CVP and fluid overload cause congestion of the liver remnant and may impair its function.
- Hepatic function and coagulation labs should be followed in addition to blood count and electrolyte panels. Special attention should be placed on monitoring postoperative phosphorus levels. Coagulopathy and anemia should be corrected per institutional protocol.
- Diet is advanced as tolerated and depending on the need for respiratory support. Early ambulation should be encouraged.

OUTCOMES

- Left hepatic trisectionectomy is an extensive procedure and it is rarely performed. There is no large series of outcomes describing the morbidity or mortality of this procedure. In carefully selected patients in expert hands, however, this procedure can be performed safely and with good oncologic results.

COMPLICATIONS

- Postoperative liver failure
- Hemorrhage—perioperative or postoperative
- Bile leak
- Intraabdominal abscess
- Respiratory failure or pneumonia

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Chapter 32

Endoscopic Ultrasonography of the Pancreas

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DEFINITION

- Endoscopic ultrasonography (EUS or echoendoscopy or endosonography) is an endoscopic procedure using a high-frequency ultrasound transducer integrated into an endoscope.
- The echoendoscope is an oblique-viewing endoscope. It has an ultrasound transducer located at its tip, which emits high-frequency acoustic waves to the surrounding tissues. This action permits the acquisition of unique views of the gut wall, the surrounding organs, and blood vessels.

BACKGROUND

- EUS was first introduced by Dr. Eugene DiMagno in the 1980s. Initial echoendoscopes were radial, which scan perpendicular to the axis of the endoscope and provide 360-degree images similar to computed tomography (CT). In 1991, a convex linear-array echoendoscope was introduced. These linear echoendoscopes scan parallel to the longitudinal axis of the endoscope and enable fine needle aspiration (FNA) and various therapeutic interventions.
- Over the past two decades, EUS has evolved to become an indispensible tool for the evaluation of the pancreas. EUS is useful for the detection, diagnosis, staging, and treatment of multiple pancreatic disorders including solid pancreatic masses, pancreatic cystic lesions, and acute and chronic pancreatitis.
- Currently, two types of echoendoscopes are available: radial sector and linear-array transducers. Radial and linear EUS provides high-resolution images of the gut lumen, the adjacent organs, the lymph nodes, and the vascular structures. They are also equipped with color Doppler, which allows for accurate identification of vascular structures and aids in vascular staging of pancreatic tumors.
- EUS is a safe procedure. Complications are rare and typically related to therapeutic efforts. EUS-FNA complications include bleeding (0% to 1.3%), perforation (0% to 0.4%), infection (0.3%), and pancreatitis (1% to 2%).[1,2] The risk of bacteremia is low, and prophylactic antibiotics are not recommended except prior to EUS-guided FNA of pancreatic cystic lesions. The risk of tumor seeding is significantly lower as compared to percutaneous approaches with only four case reports so far.[2]

PANCREATIC DISORDERS AND ENDOSCOPIC ULTRASONOGRAPHY FINDINGS

- Pancreatic tumors typically appear as irregularly shaped hypoechoic or heterogeneous areas within the normal echo texture of the pancreas. In cases of pancreatic cancer, tumor extension into the adjacent vasculature (portal; splenic and superior mesenteric veins; and celiac, splenic, and superior mesenteric arteries), the common bile duct, and the duodenum can be identified. Additionally, ascites, celiac and peripancreatic lymph nodes, and metastatic disease to the liver can be seen.
- Pancreatic cysts are divided into nonneoplastic and neoplastic cysts. EUS findings should be interpreted in the context of the clinical impression, morphologic EUS criteria, and results of the cystic fluid analysis to determine the origin of the cyst and guidance of further management. Morphologic features associated with an increased risk for malignancy are an irregular or thickened cyst wall, the presence of mural nodules or a solid mass within the cyst, a cyst size over 3 cm, or an increase in cyst size during follow-up.
- EUS can help identify causes of pancreatitis, including gallbladder and bile duct stones and sludge (microlithiasis), pancreatic duct stones, pancreatic cysts (pseudocysts and cystic neoplasms), ampullary neoplasms, pancreas divisum, changes of chronic pancreatitis, and pancreatic masses.
- EUS is sensitive to subtle changes associated with chronic pancreatitis. It shows fine parenchymal details such as early fibrosis, calcifications, and pancreatic ductal changes. The diagnosis of chronic pancreatitis by EUS depends on the presence or absence of multiple EUS criteria of chronic pancreatitis (Rosemont classification),[3] which includes parenchymal features of echogenic foci, focal regions of increased echogenicity (strands), lobularity, cyst formation, and ductal EUS features (increased echogenicity of the main pancreatic duct wall, main pancreatic duct calculi, irregular contour of the main pancreatic duct, dilation of the main pancreatic duct, and side branch dilation).

OTHER DIAGNOSTIC STUDIES

- In the 1980s, EUS was developed to overcome the limitations of transabdominal ultrasonography (US) and CT scan imaging of the pancreas.
- EUS provides high-resolution images of the pancreatic duct, as well as the parenchyma, and complements the ductal images seen in endoscopic retrograde cholangiopancreatography (ERCP).
- EUS is considered one of the most sensitive imaging modalities to detect pancreatic tumors and has the additional advantage of acquiring tissue samples by FNA with linear endosonography. The sensitivity of EUS ranges from 93% to 100%, whereas for CT, it ranges from 53% to 92%.[4]
- Compared to US- or CT-guided FNA, EUS-FNA has been proven to be the safest technique with comparable accuracy (76% of EUS vs. 81% of US/CT).[5] The sensitivity of EUS-FNA for diagnosing pancreatic cancer is greater than 90% with a specificity of greater than 95%.[4]

MANAGEMENT

Preoperative Planning

- A recent complete blood count, basic electrolytes, and coagulation studies are indicated prior to EUS. The patient should hold anticoagulants and antiplatelet agents or use bridge therapy with heparin before EUS-guided FNA.

- Patients are normally instructed to fast after midnight, the night before the procedure.
- Prophylactic antibiotics are recommended only for EUS-guided FNA of cystic lesions.[6]
- The procedure is generally performed under conscious sedation or monitored anesthesia care based on presence of associated medical comorbidities.

Positioning

- EUS of the pancreas is usually performed with the patient in the left lateral decubitus position, similar to that for performing an esophagogastroduodenoscopy (EGD).
- If drainage of pancreatic fluid collections is planned, a prone position is preferred to facilitate better fluoroscopic visualization without interference from bony structures; this positioning also fosters the concomitant performance of ERCP if indicated.

ESOPHAGEAL INTUBATION

- The echoendoscope has an oblique endoscopic view, and therefore, pharyngeal intubation is typically blind or with partial views. The echoendoscope is inserted into the pharynx with downward deflection of the tip, which is then straightened using the up-down wheel once the pharynx is reached. The esophagus is intubated with a slight clockwise torque. Care needs to be taken so as not to forcefully intubate the esophagus because of the risk of perforation if any anatomic variant is present.

STOMACH STATION

- This is the station for examination of the body and tail of the pancreas.
- The echoendoscope is positioned distal to the gastroesophageal (GE) junction, and the aorta is located.
  - Radial echoendoscopy: The aorta is seen as a circular anechoic structure with a positive Doppler signal. The balloon is inflated and keeping the aorta at the 6 o'clock position, and the echoendoscope is passively advanced. The diaphragmatic crura are seen as hypoechoic structures that wrap around the aorta. With further advancement, the crura disappear and the celiac trunk emerges from the aorta at 12 o'clock position and soon bifurcates into the hepatic and splenic arteries, which looks like a "whale's tail." Advancement of the echoendoscope from this position leads to the pancreas body with its characteristic salt-and-pepper appearance. Deep to the pancreas is the classic anechoic Doppler-positive club head (golf club sign), which signifies the splenoportal confluence (**FIG 1**). Clockwise torque and gradual withdrawal of the scope is performed to image the body up to the tail of the pancreas. Initially, the left kidney is seen below the pancreas as an oval structure with a hypoechoic cortex and a hyperechoic medulla. Next, the spleen is seen as a hypoechoic structure to the right of the screen, and the splenic artery and vein are seen entering the hilum of the spleen. This completes the exam up to the tail of the pancreas (**FIG 2**). From this region, the maneuvers are reversed and counterclockwise torque and gradual advancement of the scope is performed to image the pancreas up to the neck.
  - Linear echoendoscopy: The approach is similar to that described earlier with the radial echoendoscope. The echoendoscope is positioned at the GE junction and the scope is rotated in a clockwise manner to locate the aorta, which is a linear structure that slopes downward from the right to the left of the screen. The diaphragmatic crura are again noted and the celiac artery is seen arising from the

FIG 1 ● Radial EUS view of pancreatic body (splenoportal vein confluence is highlighted by the *white arrow*; "golf club sign").

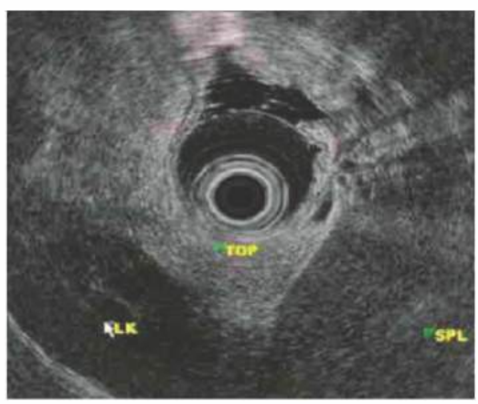


FIG 2 ● Radial EUS view of pancreatic tail. *TOP*, tail of pancreas; *SPL*, spleen; *LK*, left kidney.

aorta as soon as the crura disappear (FIG 3). The celiac artery is traced until it splits into the hepatic and splenic artery. The superior mesenteric artery is seen emerging from the aorta distal to the takeoff of the celiac artery. Advancement of the scope beyond the celiac bifurcation with a gentle down on the up-down wheel (tip up of the echoendoscope) leads to the pancreas. The pancreas is then traced to the tail and the splenic hilum by gentle clockwise rotation and withdrawal. The maneuvers are then reversed to trace the pancreas up to the neck. Unlike the radial endoscope where advancement and withdrawal is mostly passive, constant slow clockwise and counterclockwise torque is essential when examining with a linear endosonoscope.

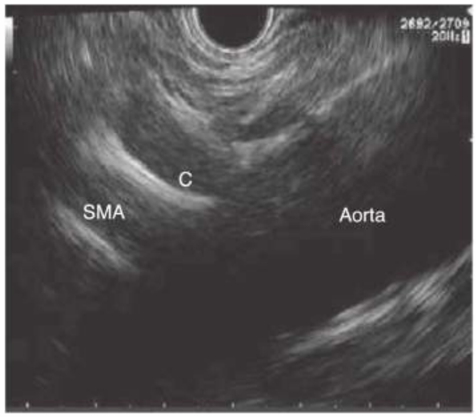


FIG 3 ● Linear EUS imaging of aorta at the level of the celiac artery takeoff. The vessels appear dark given their efficient transmission of ultrasonic waves. *C*, celiac artery; *SMA*, superior mesenteric artery.

DUODENUM STATION (BULB, AMPULLA, AND DISTAL DUODENUM)

- The head of the pancreas is examined from the bulb, the ampullary region, and from the duodenum distal to the ampulla (FIG 4).
  - Radial echoendoscopy: The scope is gently advanced through the stomach and the pylorus is visualized endoscopically. The scope is then advanced through the pylorus with the tip up, that is, big wheel pushed toward the endoscopist ("setting sun sign"). The balloon on the echoendoscope is inflated in the duodenal bulb and endosonographic visualization is commenced. The liver is positioned at 11 o'clock, which places the pancreas at 6 o'clock position. The portal vein is seen as a large tubular structure coursing downward from the top left to the bottom right of the screen. The duodenal falloff represents the muscularis propria of the duodenum and is a hypoechoic line coursing down from the transducer. The bile duct is a tubular anechoic structure coursing from the liver to the duodenal falloff and is located between the portal vein and the transducer. The scope is pushed in with a clockwise torque to trace the bile duct to the ampulla. Counterclockwise torque and withdrawal of the scope enables visualization of the bile duct up to the hilum (bifurcation). The pancreatic duct may or may not be seen in the same plane as the portal vein, bile duct, and the duodenal falloff and gentle upward or downward deflection may be needed to achieve adequate imaging of the pancreatic duct. The next position for visualization of the head of the pancreas is at the level of the ampulla. The echoendoscope is passed into the second part of the duodenum and then is withdrawn into a short position akin to when performing an ERCP. The major papilla is visualized and the balloon is inflated. The major papilla is positioned such that upward deflection of the scope should bring the scope near the papilla. The pancreas appears crescent-shaped in this position. As the transducer is moved back and forth, the bile and pancreatic duct appear to course through the duodenal wall with the bile duct appearing in a cross-sectional configuration above the pancreatic duct. Duodenal motility can be reduced with intravenous administration of glucagon and water infused into the duodenal lumen, if detailed views of the ampulla are required. The uncinate process is next visualized by advancing the scope just distal to the papilla (FIG 5). The big wheel is pushed toward the endoscopist with the tip thus maximally up and the right-left wheel locked in the right position. Gentle counterclockwise torque and withdrawal brings the aorta in

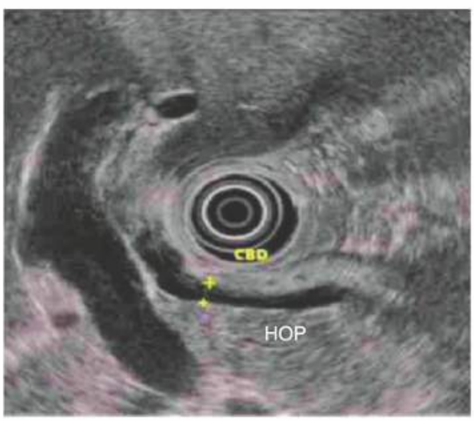


FIG 4 ● Radial EUS view of pancreatic head. *CBD*, common bile duct; *HOP*, head of pancreas.

FIG 5 ● Radial EUS view of the uncinate process. The superior mesenteric artery (SMA) is not easily visualized by EUS.

view. This may appear in a longitudinal configuration, becoming oval and finally round. The inferior vena cava may be seen superior to the aorta or may be compressed by the transducer. The pancreas is visualized to the right of the aorta.

- Linear echoendoscope: Apical imaging for the linear scope follows the same pattern as the radial scope. The scope is advanced through the stomach into the duodenal bulb. The apex of the bulb is identified with a gentle downward deflection of the tip of the scope. With the scope at the apex of the duodenal bulb, slight counterclockwise torque and upward deflection brings the portal vein in view. The bile duct is seen coursing between the transducer and the portal vein and can be traced by torquing the scope in both the directions. The pancreatic duct is also seen coursing below the bile duct and may need upward or downward deflection of the tip of the scope or torquing of the scope to visualize completely. Balloon inflation is not as necessary with a linear scope as it is with a radial scope. Visualization of the ampulla follows the same principles as the radial scope. The papilla is visualized endoscopically, the scope is kept perpendicular to the papilla and imaging is commenced. The papilla is oriented at 6 o'clock position and the bile and pancreatic ducts are visualized in their linear configuration. Gentle torquing and slow withdrawal is performed till the portal confluence is seen. Next, the uncinate process of the pancreas is seen by passing the echoendoscope distal to the ampulla and shortening to achieve a straight position. The aorta is located by gentle torquing of the scope. Once the aorta is localized, the scope is torqued clockwise to locate the pancreas and then withdrawn with gentle torquing in both directions till the portal confluence is again visualized.

ENDOSCOPIC ULTRASONOGRAPHY–GUIDED FINE NEEDLE ASPIRATION

- EUS-guided FNA uses a linear-array echoendoscope, which provides real-time ultrasound imaging of the needle in the target area. The needle device consists of the needle, its sheath, a stylet within the needle, and the handle of the device. Needles are available in various sizes: typically, 19 gauge, 22 gauge, and 25 gauge. A 22-gauge or 25-gauge needle is preferred when accessing lesions from within the duodenum as acute angulation and looping of the scope may make it technically challenging to advance the larger 19-gauge needle out of the scope. An aspiration syringe is typically used along with the needle device and is usually provided in the same package.
    - The lesion of interest is imaged by the linear echoendoscope. The distance between the echoendoscope and the lesion should be minimized with the aid of the up/down and sometimes the left-right wheels of the echoendoscope.
    - Color Doppler imaging is performed to ensure that (1) the lesion of interest is not vascular and (2) there are no intervening vessels in the path of the FNA needle.
    - The needle device is passed through the channel of the echoendoscope and the handle is then Luer-locked. The sheath is slowly advanced out of the scope and the position is confirmed endoscopically.
    - It is helpful to measure the distance from the sheath tip to the middle of the lesion using the on-screen calipers to give an idea about the approximate depth of needle insertion.
    - The needle is then advanced under real-time ultrasound guidance to the middle of the lesion. Once the needle is in the lesion, the stylet is removed from the system. The aspiration syringe is attached to the needle device and suction is applied.
    - If a cystic lesion is being aspirated, the suction syringe is removed and the needle is withdrawn into the sheath at the end of the aspiration of cyst contents. The entire system is then removed and the fluid analyzed. For practical purposes and ease of availability, cyst fluid is typically analyzed for cytology, carcinoembryonic antigen (CEA), and amylase levels.
- If a solid mass is being aspirated, quick and forceful to-and-fro movements are performed with or without suction, and the needle path is fanned inside the lesion to maximize the yield for cytology. After a few strokes, suction is stopped, the needle is withdrawn into the sheath, and the entire system is removed. The material within the needle device is then sent for cytologic evaluation. Presence of a cytologist during the procedure is recommended to get an on-site, immediate cytologic evaluation and thereby limit the number of passes of the FNA needle and maximize the diagnostic yield of FNA.

ENDOSCOPIC ULTRASONOGRAPHY IN THE EVALUATION OF BENIGN PANCREATIC DISEASES

- The normal pancreas has a homogenous, diffusely speckled pattern with a smooth contour. The pancreatic duct located within the pancreatic parenchyma is typically thin, smooth, anechoic, and does not have a positive Doppler signal. It decreases in size from the head to the tail. A normal duct measures 3, 2, and 1 mm in the head, body, and tail of pancreas, respectively. EUS exam for evaluation of benign pancreatic diseases is performed as described earlier.

Acute Pancreatitis

- Findings seen in chronic pancreatitis, with the exception of calcifications, can be seen in acute pancreatitis (cysts, ductal irregularity and dilation, stranding, etc.). Therefore, it is recommended to wait for 4 to 6 weeks before performing EUS of the pancreas after an acute attack of pancreatitis.
  - The pancreas may appear normal or diffusely enlarged with a normal or diffusely low echo pattern in edematous pancreatitis. In some circumstances, it may be possible to differentiate edematous pancreatitis from necrotizing pancreatitis, which may appear as a focal hypoechoic mass with or without echogenic strands.[7]

Chronic Pancreatitis

- EUS features of chronic pancreatitis are divided into major and minor criteria for parenchymal and ductal features based on the Rosemont criteria.[3] Major criteria include hyperchoic foci with shadowing, lobularity with honeycombing, and main pancreatic duct calculi. Minor criteria include cysts, nonshadowing foci, lobularity with noncontiguous lobules, dilated main duct or side branches, irregular duct contour, hyperechoic duct walls, or echogenic strands.

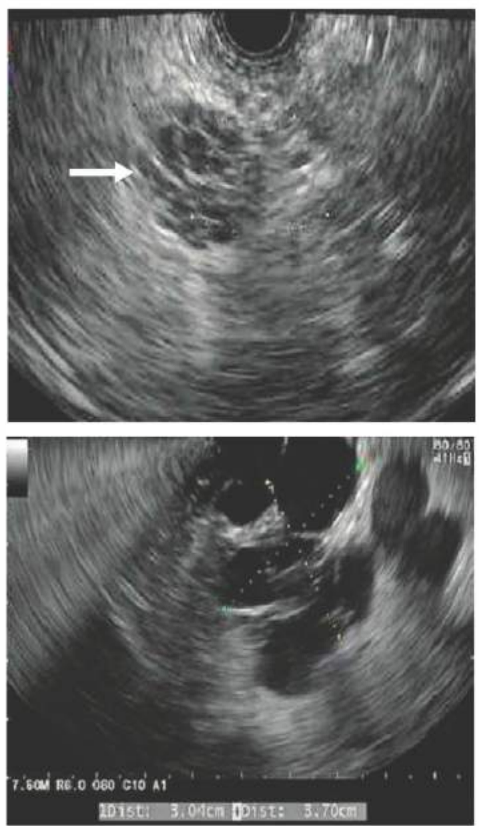
Autoimmune Pancreatitis

- The pancreas in autoimmune disease may appear either normal or enlarged and sausage-shaped. Occasionally, a hypoechoic mass may be seen and may be difficult to differentiate from adenocarcinoma. Hyperechoic strands or lobularity can also be seen,[8] and as such, core biopsy or FNA of pancreatic parenchyma or biopsy of the ampulla may be needed for a definitive diagnosis.

ENDOSCOPIC ULTRASONOGRAPHY IN THE EVALUATION OF PANCREATIC CYSTIC LESIONS

Cystic Neoplasms of the Pancreas

- Cystic neoplasms of the pancreas (FIG 6A–C) can be divided into neoplastic (serous and mucinous cysts, intraductal papillary mucinous neoplasms [IPMN], or solid pseudopapillary neoplasms with cystic degeneration) or nonneoplastic pancreatic cysts (true cysts, retentions cysts, pseudocysts, or lymphoepithelial cysts). Differentiation between the two is essential because nonneoplastic cysts can be safely monitored and treated only if they become symptomatic. Neoplastic cysts, especially those with higher malignant potential, should be considered for resection. EUS can help in examination of the cyst with regard to size, shape, morphologic features, communication with pancreatic duct, and invasion into adjacent structures. It can help evaluate the cyst wall (nodule, thickness) as well as intracystic structures such as debris or septations. The technique for EUS-guided FNA is as described earlier. If a cyst has multiple components, the largest component is targeted first. If there is an intramural nodule (cyst with higher malignant potential), needle aspiration of cyst fluid as well as sampling the nodule are targeted separately. CEA level of more than 192 ng/mL is thought to be a useful but less sensitive marker of a mucinous lesion.[9]



A

B

FIG 6 ● EUS imaging of pancreatic cystic lesions. **A.** Serous cyst (lesion is marked by *white arrow*), mucinous cyst **(B)**, and pseudocyst **(C)**. *(continued)*

C

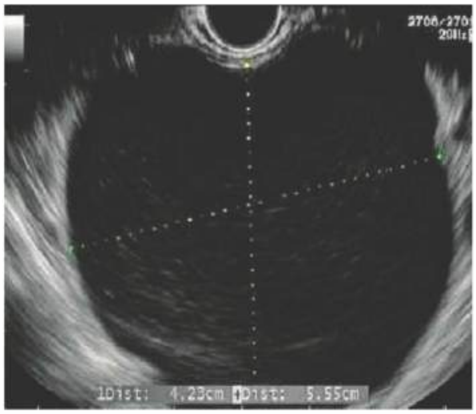


FIG 6 ● *(continued).*

ENDOSCOPIC ULTRASONOGRAPHY IN THE EVALUATION OF PANCREATIC MASSES

- EUS is useful in evaluation of pancreatic masses (**FIG 7**) by providing cytologic confirmation as well as staging of disease. Pancreatic mass lesions can be differentiated into those that are malignant (adenocarcinoma, lymphoma, other rare neoplasm) or those that are benign (chronic pancreatitis or autoimmune pancreatitis). Differentiation between the malignant and the benign mass lesions can be difficult, and occasionally, surgical resection may be the only definitive modality for diagnosis and treatment. FNA of mass lesions of the pancreas is performed as mentioned earlier (**FIG 8**). The number of passes to obtain a cytologic diagnosis is controversial, but about seven passes is considered an optimal number of passes for mass lesions of the pancreas.[10] Having an on-site cytologist is essential. The trajectory of the needle path during FNA should be altered with each stroke so as to fan the lesion and maximize yield. Suction can be used during FNA to hold the tissue against the needle during passes. However, a previous study by Wallace[11] found that suction actually makes the specimen bloodier and does not improve diagnostic accuracy, although this study was primarily done to evaluate aspiration techniques in malignant lymphadenopathy. Although evaluating a mass in the pancreas, attention should be focused on the location of the lesion, the size of the lesion, and its proximity to nearby vascular structures. If abnormal lymph nodes are seen, these should be targeted first. It is helpful to use different needle systems for FNA of pancreatic masses and suspected metastatic lesions to decrease the risk of seeding.

FIG 7 ● EUS imaging of pancreatic mass.

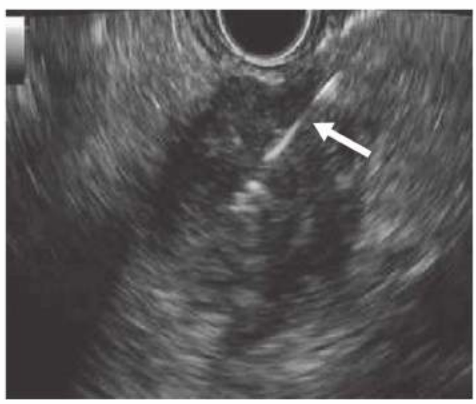


FIG 8 ● FNA of pancreatic mass. The linear, white line *(arrow)* is actually the needle, centered in the hypoechoic mass with irregular borders.

INTERVENTIONAL ENDOSCOPIC ULTRASONOGRAPHY IN PANCREATIC DISORDERS

Fine Needle Injection Therapy for Locally Advanced Pancreatic Tumors

- Endoscopic ultrasonography–guided fine needle injection (EUS-FNI) therapy of antitumor agents has been previously documented.[12,13] Recently, TNFerade, when delivered by EUS-FNI, has shown promise for locally advanced pancreatic cancer.[14] Delivery of TNFerade did not interfere with subsequent surgical resection. The technique for performing EUS-FNI is same as for an FNA.[15]
  - The tumor is localized by the linear echoendoscope, and a 22-gauge needle is advanced through the tumor using Doppler to ensure that blood vessels are not punctured.
  - The needle is slowly withdrawn and the drug is simultaneously injected, slowly, into the tumor.
  - Without complete withdrawal of the needle from the tumor, the needle is then redirected at a different angle and the process repeated, thereby spreading the injectate in a fanned manner. Typically, the volume of TNFerade injectant is 2 mL.[14]

Pancreatic Duct Drainage

- ERCP is usually the first-line therapy for relief of an obstructed pancreatic duct, but when ERCP is unsuccessful, surgery is often indicated. Recently, EUS-guided pancreatic duct drainage has been advocated when ERCP is not feasible.
  - EUS-guided drainage can be performed either via the translumenal approach (stomach or duodenum) or via a transpapillary approach.
  - The pancreatic duct is identified from either the stomach or the duodenal bulb and a 19-gauge needle is used to puncture it. Contrast is injected to delineate the duct.
  - A guidewire is advanced into the pancreatic duct in an antegrade fashion and allowed to coil into the duodenum via the papillary orifice.
  - The transmural tract is then dilated initially with an ERCP cannula or balloon or graduated dilator.
  - A 5- to 7-Fr stent with a length long enough to extend from the stomach or duodenum into the main pancreatic duct and then via the papilla into the duodenum is deployed.
  - In cases where a transpapillary rendezvous approach is undertaken, the guidewire is advanced into the duodenum as mentioned earlier and the echoendoscope is exchanged for a duodenoscope. Cannulation of the pancreatic duct is performed either alongside the guidewire or the guidewire is withdrawn into the endoscope and accessories passed over the guidewire to aid in cannulation and performing the endoscopic retrograde pancreatography (ERP).

Celiac Plexus Block and Neurolysis

- Pain in chronic pancreatitis or pancreatic carcinoma is typically mediated by sympathetic visceral afferent fibers that relay via the celiac plexus to the splanchnic nerves and enter the spinal cord from T5–T9.[16] The celiac plexus is composed of ganglia located anterolateral to the aorta at the level of the celiac trunk. Celiac plexus neurolysis (CPN) is the ablation of the celiac plexus with alcohol, whereas celiac plexus block (CPB) refers to the temporary inhibition of pain impulses through the celiac plexus with the aid of steroids and an anesthetic such as bupivacaine. The technique for CPN and CPB is the same.
  - Procedure is performed with the patient sedated in the left lateral position.
  - Intravenous saline may be administered intra- or postprocedurally to decrease the risk of hypotension.
  - Broad-spectrum antibiotics such as ciprofloxacin are recommended, especially if steroids are injected, as there have been case reports of peripancreatic abscesses after CPB.[17]
  - Using the linear echoendoscope, the aorta is localized at the GE junction and followed to the origin of the celiac artery and the bifurcation of the splenic and hepatic artery with counterclockwise rotation. The celiac ganglia are identified as small hypoechoic structures located just anterior to and above the celiac artery origin.
  - A 22-gauge or a 19-gauge needle or a dedicated 20-gauge spray needle (EUS-20-CPN, Cook Endoscopy, Winston Salem, NC) with multiple holes can be used. The CPN needle allows solutions to be dispersed over a wider area with less force. The stylet is withdrawn and the needle is flushed with saline to remove air and the gastric wall is punctured with the tip of the needle slightly anterior and above the origin of the celiac artery. Aspiration is performed to ensure that a blood vessel has not been punctured.
  - A 0.25% (5 mL) bupivacaine is injected first, followed by 20 mL of absolute alcohol if CPN is performed or 0.25% (20 mL) bupivacaine followed by 80-mg (4 mL) triamcinolone if CPB is performed.[18] The needle is then flushed with 3 mL of saline to ensure complete drug delivery.
  - Patient is observed for 2 to 4 hours for hypotension, fever, or abdominal pain, which usually is transient and treated with supportive measures.

Fiducial Placements

- Fiducials are inert radiologic markers that are implanted into the target lesion for localizing or tracking during radiation therapy of pancreatic cancers. A minimum of 1 or 2 fiducials are required. These can be placed either within the lesion or within 1 cm of the lesion of interest. Fiducials can be delivered with 19-gauge or 22-gauge needle.[19]
- Standard fiducials are cylindrical gold seeds, measuring 3 to 5 mm in length and 0.8 to 1.2 mm in diameter. Sterile bone wax can be used to hold and separate preloaded

gold fiducials within the 19-gauge needle. The new smaller, longer fiducial markers are 10 mm in length and 0.35 mm in diameter. They are preloaded on a needle carrier delivery device for use with a 22-gauge needle, which allows for optimal placement.[20] The process for fiducial implantation is similar to performing FNA. Our group has recently reported early data on EUS-guided fiducial placement with a new multifiducial delivery needle.[21]

- The lesion of interest is located by the linear scope.
- The needle device is advanced through the channel of the echoendoscope and locked in place. The needle is then advanced into the area of interest, ensuring lack of vascular structures in the path of the needle. The stylet of the needle is advanced to maximal insertion, thus pushing the fiducial out of the needle and into the area of interest.

PEARLS AND PITFALLS

ADEQUATE TRAINING AND TECHNICAL EXPERTISE BEFORE PERFORMING ENDOSONOGRAPHY CANNOT BE OVEREMPHASIZED.	
EUS of pancreas (general principles)	▪ A station-based approach is important because complete imaging of the pancreas can only be obtained from specific stations: stomach, duodenal bulb, opposite the ampulla, and distal to the ampulla. ▪ If endosonographic orientation is lost during the exam or if usual landmarks are difficult to find, one could either return to the starting point for that station or examine other stations and then come back to the difficult station. ▪ Gentle clockwise and counterclockwise torque is needed to achieve complete imaging with the linear scope.
EUS with FNA	▪ Passage of needle is easier when the scope is in a straight position and with minimal use of the elevator. ▪ The needle should be placed in the center of the cyst during aspiration. If fluid is not obtained, the needle should be repositioned inside the cyst without complete withdrawal or replaced with a larger diameter needle to allow aspiration of thick cyst contents. ▪ If there is a mass associated with a cyst, samples from both the solid and cystic components should be obtained. ▪ A fanning technique during FNA of solid lesions is preferred to maximize cytologic yield. ▪ If the aspirated specimen is less than desired, suction can be applied during aspiration. Alternatively, if the aspirate is bloody, suction should be avoided.
Celiac plexus interventions	▪ If ganglia are not clearly seen: The entire solution can be injected just above and anterior to the celiac trunk. ▪ If no resistance is encountered during injection: The needle may still be in stomach or a vascular puncture should be considered.
Pancreatic duct drainage	▪ The duct should be sufficiently dilated to allow EUS-guided needle puncture and intervention.

POSTOPERATIVE CARE

- After the EUS procedure is completed, the patient is monitored in the recovery room until sedative medications have worn off (about 30 to 45 minutes) and discharge criteria are met.
- The patient should not drive a vehicle or operate heavy machinery after receiving sedative medication. Therefore, a responsible person is needed to drive the patient home after the exam.
- Antibiotics are usually prescribed for 3 to 5 days after EUS-guided FNA of cystic lesions.[6]

COMPLICATIONS

- Patients undergoing EUS by experienced endosonographers are not at an increased risk for perforation compared with standard endoscopy.
- Most complications of EUS are associated with performing FNA and therapeutic interventions. Patients undergoing EUS-FNA of the pancreas have a 1% to 2% risk of pancreatitis. Clinically significant bleeding and bile peritonitis are rare complications of EUS-FNA.

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Chapter 33

Pancreaticoduodenectomy: Resection

George VanBuren, II William E. Fisher

DEFINITION

- Pancreaticoduodenectomy (Whipple procedure) is defined as resection of the pancreatic head, uncinate process, gallbladder, distal bile duct, duodenum, and gastric antrum.
- Pylorus-preserving pancreaticoduodenectomy (pylorus-preserving Whipple procedure) is the same operation with preservation of the gastric antrum, pylorus, and a cuff of proximal duodenum.
- Complete excision of pancreatic head tumors with negative margins maximizes local-regional control and is the standard of care for malignancies of the pancreatic head, ampulla of Vater, duodenum, or distal bile duct.

DIFFERENTIAL DIAGNOSIS

- Pancreatic ductal adenocarcinoma
- Pancreatic neuroendocrine tumor
- Pancreatic cystic neoplasm
- Cancer of the ampulla of Vater
- Distal cholangiocarcinoma
- Duodenal adenocarcinoma
- Biliary stricture
- Chronic pancreatitis

PATIENT HISTORY AND PHYSICAL FINDINGS

- A thorough history and physical exam should be performed prior to treatment.
- Critical history: weight loss greater than 10%, new-onset diabetes, jaundice, vague abdominal pain in mid-epigastrium, pain penetrating to the back (indicates possible celiac involvement), diarrhea (indicating exocrine insufficiency)
- History related to biliary obstruction: jaundice, fever, chills, pruritus, acholic stools, dark urine
- Risk factors for pancreatic cancer: smoking, chronic pancreatitis, diabetes, age 65 years or older, African American race, obesity, male gender, family history of pancreatic cancer, family history of other malignancy (i.e., BRCA2 malignancies)[1]
- Physical exam: scleral icterus, jaundice, signs of malnutrition, cachexia, temporal wasting
- Ominous signs: A palpable abdominal tumor or ascites may indicate metastatic disease. Left supraclavicular lymphadenopathy (Virchow's lymph node) is indicative of metastatic disease.
- In addition to a history and physical relating to pancreatic cancer, an overall assessment of the patient's functional status should be performed to assure the patient is a candidate for major surgery.
  - If the patient's performance status is poor (Eastern Conference Oncology Group [ECOG] score greater than 2 or Karnofsky score of less than 60), he or she should be considered physiologically borderline resectable.[2]
  - The patient's cardiopulmonary status should also be assessed with an assessment of their exercise tolerance and activity level.
  - Physical exam should look for other sources of chronic disease including carotid bruit, jugular venous distension, rales, wheezing, heart murmur, or clubbing of fingers.

IMAGING AND OTHER DIAGNOSTIC STUDIES

- "Pancreatic protocol" computed tomography (CT) scan of the chest, abdomen, and pelvis is required for all patients. Pancreatic protocol is a triphasic thin (≤5 mm), multislice CT scan with an arterial, venous, and delayed phase in conjunction with sagittal and coronal views. Water is used to opacify the stomach. A properly performed CT scan is perhaps the most critical portion of the preoperative assessment to determine if the patient is a candidate for surgery. The purpose of the CT scan is to detect any metastatic disease and to assess the relationship of the low-density tumor to the surrounding vasculature. Particular attention is paid to the relationship of the tumor to the portal vein (PV), superior mesenteric vein (SMV), superior mesenteric artery (SMA), hepatic artery, and celiac axis. In addition, a CT will aid in identification of aberrant anatomy of the hepatic artery, which is present in 20% of cases and must be noted prior to surgery.
- CT scan of chest is done to evaluate for pulmonary metastasis.
- Based on imaging, there are well-defined consensus criteria from the American Hepato-Pancreato-Biliary Association for resectable, borderline resectable, locally advanced, and metastatic diseases. These criteria have been adopted by the National Comprehensive Cancer Network (NCCN).[3]
  - Resectable tumors demonstrate the following:
    - No distant metastases; no radiographic evidence of SMV and PV abutment, distortion, tumor thrombus, or venous encasement; clear fat planes around the celiac axis, hepatic artery, and SMA (**FIG 1**)

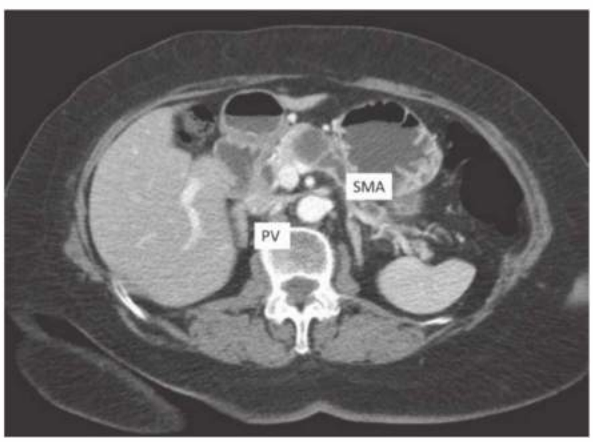


FIG 1 ● CT of a resectable pancreatic cancer. *PV*, portal vein; *SMA*, superior mesenteric artery.

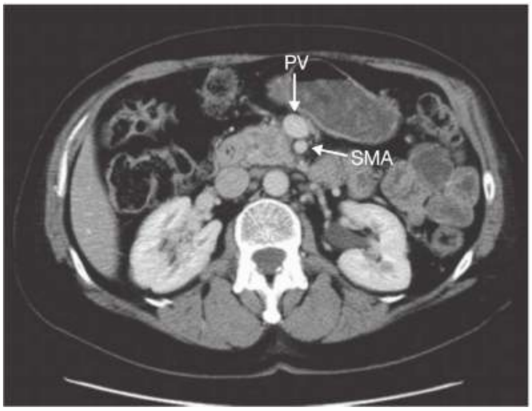


FIG 2 ● CT of a borderline resectable pancreatic cancer. There is a loss of the "fat plane" between the SMV/PV confluence. *PV*, portal vein; *SMA*, superior mesenteric artery.

- Borderline resectable tumors demonstrate the following:
  - No distant metastases; venous involvement of the SMV/PV demonstrating tumor abutment with or without impingement and narrowing of the lumen, encasement of the SMV/PV but without encasement of the nearby arteries, or short segment venous occlusion resulting from either tumor thrombus or encasement but with suitable vessel proximal and distal to the area of vessel involvement, allowing for safe resection and reconstruction; gastroduodenal artery (GDA) encasement up to the hepatic artery with either short segment encasement or direct abutment of the hepatic artery, without extension to the celiac axis; tumor abutment of the SMA not to exceed 180 degrees of the circumference of the vessel wall (**FIG 2**)
- Locally advanced tumors demonstrate the following:
  - No distant metastases; unreconstructable SMV/ PV occlusion; greater than 180 degree encasement of SMA, celiac axis, or aortic invasion; metastasis to lymph nodes beyond the field of resection (**FIG 3**)
- Endoscopic ultrasound (EUS). This is an important step in the assessment of many, but not all, pancreatic masses and cystic lesions. EUS is performed to obtain a tissue diagnosis of a solid mass, which will be required if neoadjuvant chemotherapy is planned. Cystic lesions may be characterized by EUS and the fluid may be aspirated and sent for cytology including a mucin stain, carcinoembryonic antigen (CEA) and amylase concentration, and perhaps, genetic analysis. Furthermore, EUS may be used as an adjunct to the CT scan to further evaluate venous involvement and can be more sensitive than CT in detecting a small mass. If enlarged celiac lymph nodes are seen, they may be biopsied. EUS and CT can be compromised by the presence of a bile duct stent so ideally, these tests are performed prior to endoscopic retrograde cholangiopancreatography.

FIG 3 ● CT of an unresectable/locally advanced pancreatic cancer. The lesion has encircled the SMA. *PV*, portal vein.

- Endoscopic retrograde cholangiopancreatography (ERCP). ERCP may be used to provide biliary decompression. In cholangiocarcinomas, it is necessary to evaluate the entirety of the biliary tree and see the proximal extent of the stricture. This may require a percutaneous transhepatic cholangiogram. In ampullary carcinomas, the mass can be directly visualized and biopsied. A biliary stent should be placed if neoadjuvant therapy is planned, to allow time for referral to a high-volume pancreas surgery center, and in cases where the serum bilirubin is particularly elevated (>10 mg/dL).[4] Although stent placement has been shown to increase infectious complications, prolonged biliary obstruction causing liver insufficiency and coagulopathy adversely affects surgical outcomes.
- Duplex ultrasound of the neck is performed selectively in patients who may need to undergo PV resection to evaluate the patency of the internal jugular veins. It may also evaluate the carotids in patients at high risk for atherosclerotic disease.
- Octreotide scan. Octreotide scan is a radionuclide scan used for localization of primary and metastatic neuroendocrine tumors. Radioactive octreotide attaches to tumor cells that have receptors for somatostatin. Somatostatin receptor scintigraphy and three-dimensional single-photon emission computed tomography (SPECT) images are taken at 4 hours and 24 hours. The tracer is visible in the thyroid, liver, gallbladder, kidneys, spleen, and urinary bladder; the physiologic uptake by these organs is diffuse. Carcinoid tumors may be seen at 24 hours more clearly than at 4 hours by virtue of reduction in background activity.
- Tumor markers. Serum carbohydrate antigen 19-9 (CA 19-9) is shown to be predictive of outcomes in pancreatic adenocarcinoma. However, CA 19-9 can be falsely elevated in the setting of obstructive jaundice. If it is more than 1,000 U/mL in the absence of jaundice, there should be a high suspicion for metastatic disease.[5] In patients who receive neoadjuvant therapy, CA 19-9 may be used as a marker to assess response. A drop in CA 19-9 of greater than 50% may be predictive of improved survival.[2] A low value is not predictive of favorable biology. Serum chromogranin A should be performed in patients with pancreatic neuroendocrine tumors. Elevated chromogranin A may be followed as a marker; a low value is not predictive of favorable biology.
- Liver function test and coagulation profile: Bile salts are required for absorption of vitamins A, D, E, and K. Patients with biliary obstruction may require vitamin K (10 mg administered intramuscularly three times every day) if the prothrombin time/international normalized ratio (PT/INR) is prolonged. A serum albumin level of less than 3 may indicate the need for preoperative nutritional supplementation.
- Cardiopulmonary clearance and risk assessment by a cardiologist or appropriate internist may aid in perioperative optimization.

SURGICAL MANAGEMENT

Preoperative Planning

- Presentation of the case at a multidisciplinary tumor board with radiology, gastroenterology, medical oncology, radiation oncology, and surgical teams in attendance is optimal in the evaluation of all pancreatic lesions. This allows the case to be reviewed in an objective manner, facilitates enrollment in clinical trials, and allows the development of institutional guidelines of care among all specialties.

- All patients with pancreatic adenocarcinoma, whether resectable, locally advanced, or metastatic, should be offered access to a clinical trial.
- A pancreaticoduodenectomy should be performed at a high-volume center (approximately more than 16 pancreatic resections per year). Resections performed at institutions below that volume have higher perioperative morbidity and mortality rates and worse oncologic outcomes.[6,7]
- Be prepared to alter the sequence of the dissection; anatomic relationships of the tumor drive this up to the point of commitment for resection—unaffected planes should be addressed before embarking on those at risk.

Positioning

- Supine position with both arms out to the side. Tuck the sheet tight under the bed to ensure bed rails are accessible for retractor placement.
- Turn the head to the right with neck extended to expose the left internal jugular vein.

TECHNIQUES

DIAGNOSTIC LAPAROSCOPY

- Diagnostic laparoscopy. The value of staging laparoscopy has decreased as the accuracy of CT scanning has improved.[3] Laparoscopy should be performed as a prelude to potential surgical resection in selected patients who have pancreatic adenocarcinoma. We advocate selective laparoscopy on the same day as the planned resection in high-risk patients with potentially advanced disease, large (>4 cm) or borderline resectable tumors after neoadjuvant therapy, liver lesions too small to characterize or percutaneously biopsy, any ascites fluid, marked weight loss, hypoalbuminemia, and high (>1,000 U/mL) CA 19-9 levels.
- The peritoneum, omentum, and surface of the liver are inspected for evidence of metastasis. A multiport technique with mobilization of the tissues and use of a laparoscopic ultrasound probe is required for a thorough examination.

INCISION

- Pancreaticoduodenectomy can be performed through a midline incision from xiphoid to umbilicus or through a bilateral subcostal incision. A bilateral subcostal incision may be superior in patients with a shorter body habitus or significant obesity. A bilateral subcostal incision can be inferior in patients with a narrow costal angle and may limit exposure to the pelvis in patients with adhesions from previous pelvic surgery.
- The falciform ligament is ligated, keeping it long to place over the stump of the GDA at the end of the case.
- Surgical retractor of choice (Bookwalter or Thompson) is placed.

INITIAL ASSESSMENT OF RESECTABILITY

- The initial portion of the procedure is an assessment of resectability.
- The liver and visceral and parietal peritoneal surfaces are thoroughly assessed via a systematic four-quadrant exploration including bimanual palpation of the liver and running the small bowel from the ligament of Treitz to the cecum and palpation of the colon.
- The gastrohepatic omentum is opened, and the region of the celiac axis is examined for enlarged lymph nodes. The base of the transverse mesocolon to the right of the middle colic vessels is examined for tumor involvement.
- Additional information regarding the extent of the malignancy with respect to the PV, SMA, and so forth will be gleaned as the dissection progresses.

CATTELL-BRAASCH AND KOCHER MANEUVERS

- The ascending colon and hepatic flexure of the colon are freed of their lateral and superior attachments using an energy device. The colonic mesentery is completely mobilized and reflected medially to expose the second and third portions of the duodenum and the head of the pancreas (**FIG 4**). An avascular plane between these structures will develop over the third portion of the duodenum and extend up to the inferior border of the neck of the pancreas (**FIG 5**). A Kocher maneuver is performed by incising the peritoneum along the lateral edge of duodenum. This incision should be extended cephalad into the foramen of Winslow. Incise the avascular ligament that tethers the third portion of the duodenum inferiorly, allowing further dissection behind the head of the pancreas, thus elevating the duodenum and pancreas from the vena cava and aorta. The duodenum is mobilized medially until the left renal vein is seen crossing over aorta. This will usually also result in fully exposing and dividing the ligament of Treitz from the right side of the patient.

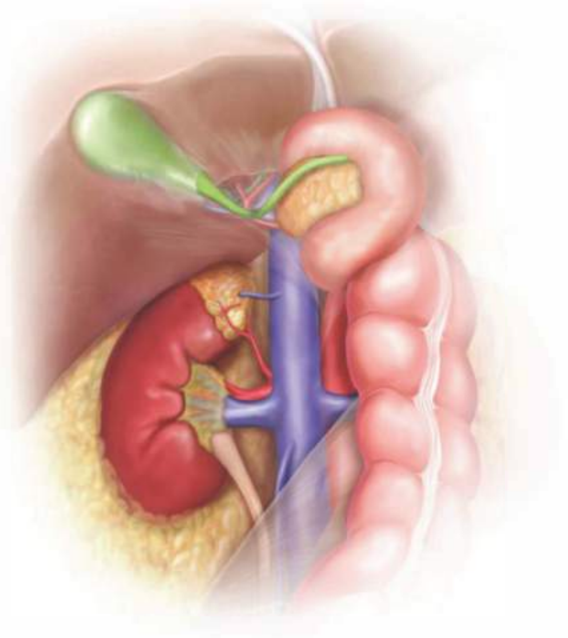


FIG 4 ● Artist's renditions of the Cattell-Braasch maneuver and subsequent wide Kocher maneuver.

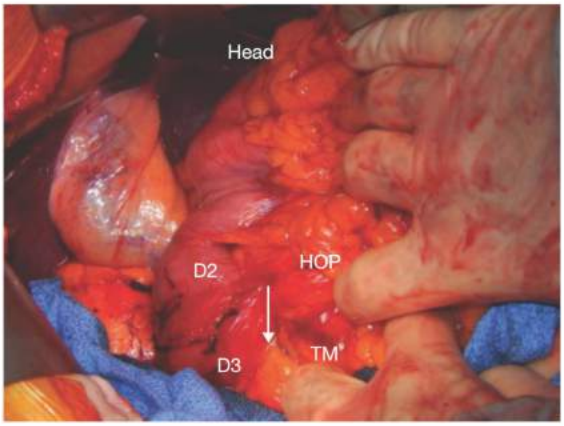


FIG 5 ● Operative photograph taken during performance of a Cattell-Braasch maneuver exposing the duodenum and pancreatic head. The *white arrow* points to the avascular plane between the transverse mesocolon and the head of the pancreas, which in this view has yet to be dissected from the mesentery and omentum. *TM,* transverse mesocolon; *D2,* second portion of duodenum; *D3, third* portion of duodenum; *HOP*, head of pancreas.

EXPOSURE OF THE INFRAPANCREATIC SUPERIOR MESENTERIC VEIN

- The gastrocolic omentum is divided, opening the lesser sac and exposing the body and tail of the pancreas. As the gastrocolic ligament is divided, the dissection is kept outside of the gastroepiploic vessels to preserve the gastric vasculature and blood supply to the duodenal cuff. Dissection proceeds from the patient's left to right with the goal of defining the avascular fusion plane between the omentum, the right gastroepiploic vascular pedicle, and the transverse mesocolon. This plane is fully mobilized to expose the pancreatic head. Congenital adhesions of the antrum to the anterior pancreas are then taken along the inferior border of the pancreas working toward the gastroepiploic vein (**FIG 6**).
- Dissect the anterior aspect of the middle colic vein(s) and circumferentially dissect the gastroepiploic vein as it inserts into the anterior surface of the SMV at the inferior border of the neck of the pancreas. They may enter as a common trunk (gastrocolic trunk) or separately. There is often a tributary vein inserting into the cephalad (unvisualized) aspect of the gastroepiploic vein. Although contraintuitive, the safest place to get around the vein is at the level of the SMV—not a little bit away from it. Once isolated, the gastroepiploic vein is ligated and divided (**FIG 7**). All efforts should focus on preservation of the middle colic vein; however, in rare circumstances, it is prudently divided based on anatomy to prevent traction injury or tearing of the vessels later in the dissection.

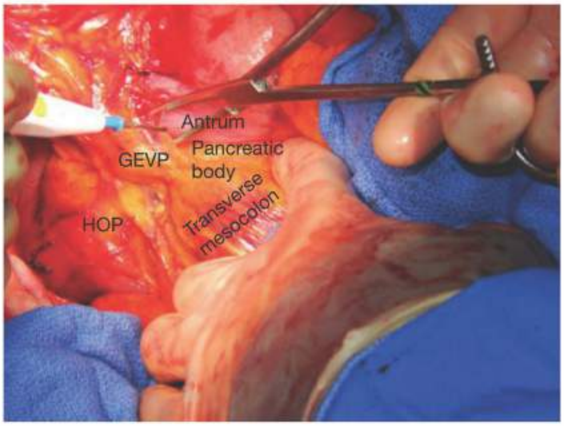
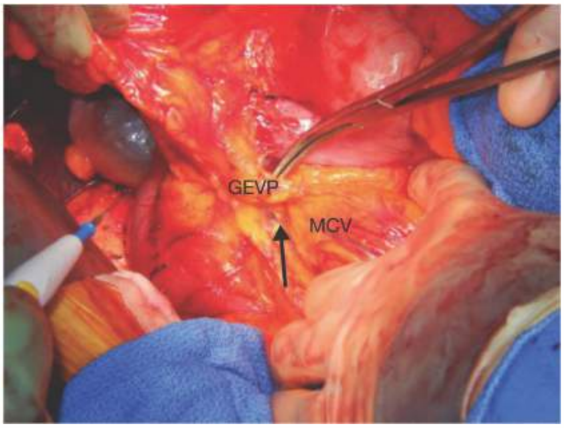
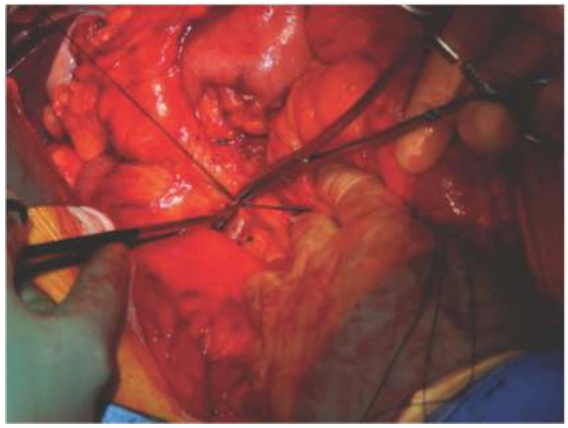


FIG 6 ● Take down the congenital attachments of the posterior stomach to the anterior aspect of the pancreatic body. After division of the gastrocolic omentum, dissect along the inferior border of the pancreas, working from the patient's right to left up to the gastroepiploic vascular pedicle (GEVP). The head of the pancreas (HOP) is visualized on the left.

- Dissection is continued to further mobilize inferior border of the pancreas to identify and expose the anterior surface of the SMV (**FIG 8**).
- At this point, the anterior aspect of the pancreas is fully exposed and the inferior aspect of the neck and body has



A



B

FIG 7 ● **A.** The gastroepiploic vein is circumferentially dissected (*black arrow* marks the course of the SMV) and **(B)** ligated between ligatures and divided. *GEVP*, gastroepiploic vascular pedicle; *MCV*, middle colic vein.

been dissected, including the anterior aspect of the SMV (**FIG 9**).

- The plane anterior to the SMV as it courses behind the pancreatic neck is now initially assessed. Completion of this retropancreatic tunnel should be deferred until the PV is exposed cephalad to the pancreatic neck in subsequent steps. The authors recommend the use of a blunt-tipped instrument such as a Kelly clamp to perform this exposure. Care must be taken to carefully assess potential involvement of this plane by tumor or inflammation during this step. Inadvertent injury to the SMV at this point will result in catastrophic hemorrhage that can be very difficult to control given the limited exposure.
- The relation of the tumor to the SMV and artery can now be relatively well assessed by palpation; however, palpation is not completely reliable, as posterior or lateral extension of the lesion that compromises these margins cannot be completely determined until later in the operation when the neck of the pancreas is divided and the surgeon is committed to resection.

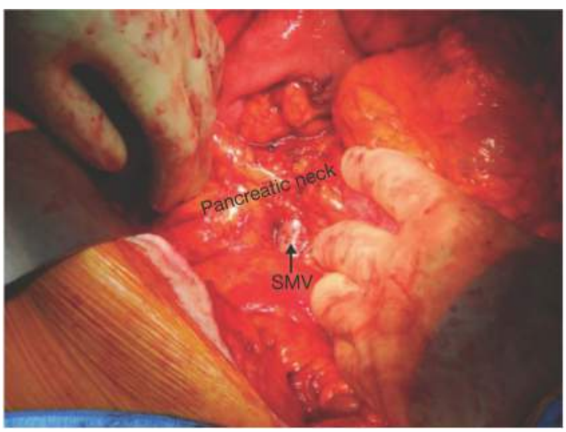


FIG 8 ● Once the gastroepiploic vein has been divided, the anterior aspect of the SMV is exposed. This dissection of the SMV is continued inferiorly to the caudad aspect of the third portion of the duodenum.

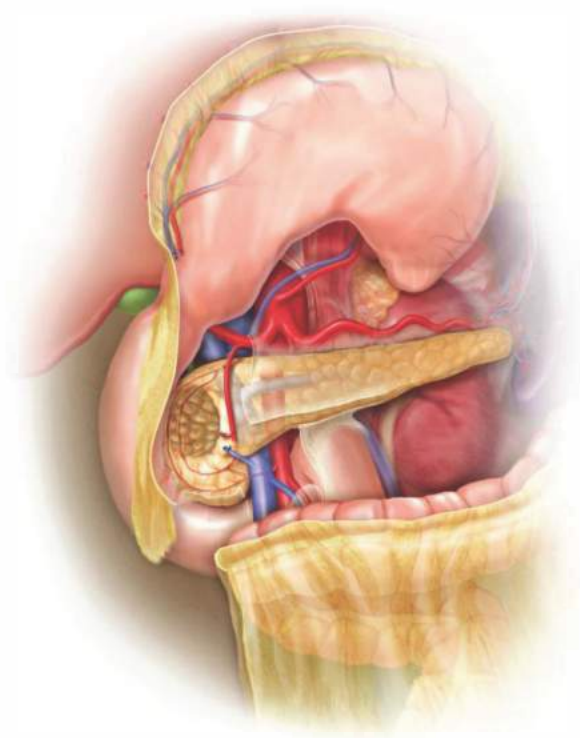


FIG 9 ● Schematic representation of exposure of the pancreatic head, neck, and body including the anterior aspect of the SMV.

DISSECTION OF THE PORTA HEPATIS

- The porta hepatis is palpated by placing a finger through the foramen of Winslow. Enlarged or firm lymph nodes that can be swept down toward the head of the pancreas with the specimen do not preclude resection.
- The presence of an aberrant right hepatic artery or other anomalies should be identified during review of the preoperative CT scan. Regardless, prior to initiating the dissection of the porta hepatis, it is important to assess for aberrant hepatic arterial anatomy, which is present in approximately 20% of patients, by palpation of the porta hepatis. The aberrant artery commonly arises from the SMA posterior to the pancreas and ascends parallel in a lateral and posterior location to the common bile duct and PV. Possible alterations in this anatomy are reviewed in Part 3, Chapter 15.
- The proximal hepatic artery is identified usually by removing a lymph node that lies anterior to the artery.
- The hepatic artery is dissected and traced toward the porta hepatis. Small vessels in this area can be ligated with silk ligatures or bipolar electrocautery to prevent bothersome hemorrhage that makes subsequent dissection more tedious.
- Inferior retraction of the pylorus will expose a band of tension from the hepatic artery—this is the right gastric artery and this is ligated and divided. The GDA is identified posterior to the right gastric artery coming directly off the caudad aspect of the hepatic artery (**FIG 10**).

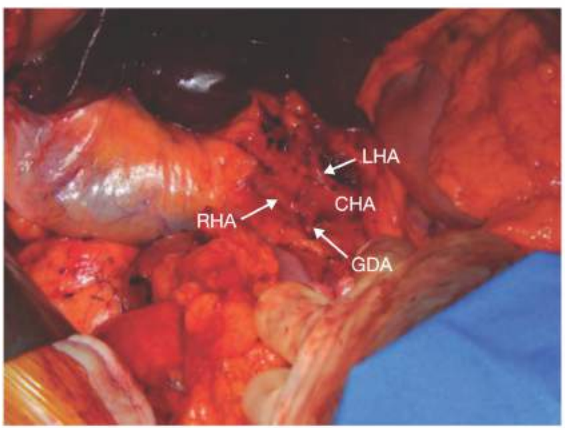


FIG 10 ● Operative exposure of the common hepatic artery (CHA) and its named branches. The demonstrated anatomy is not classic in that the bifurcation of the right and left hepatic artery (RHA and LHA) occurs prior to the origin of the GDA. The GDA arises from the RHA. The right gastric artery has been ligated and divided in this photograph.

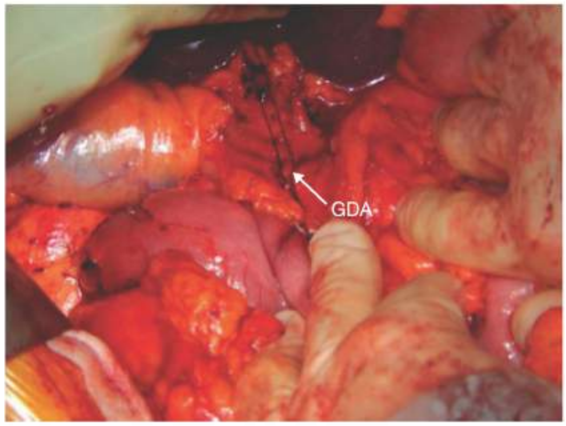


FIG 11 ● The GDA is ligated and divided. The authors recommend additional suture ligation or oversewing the GDA stump and marking it with a surgical clip.

- Once the GDA is identified (**FIG 11**), it is circumferentially dissected and test clamped to ensure that a strong pulse remains in the proper hepatic artery. This test rules out a hemodynamically significant celiac stenosis leading to hepatic blood flow depending on collateral circulation through the pancreatic head. If this clinical scenario is present, proceeding with resection is contraindicated.
- The GDA is doubly ligated and a surgical clip applied.
- Once the GDA is divided, the hepatic artery is retracted medially and the common bile duct is retracted laterally to reveal the anterior surface of the PV (**FIG 12**).

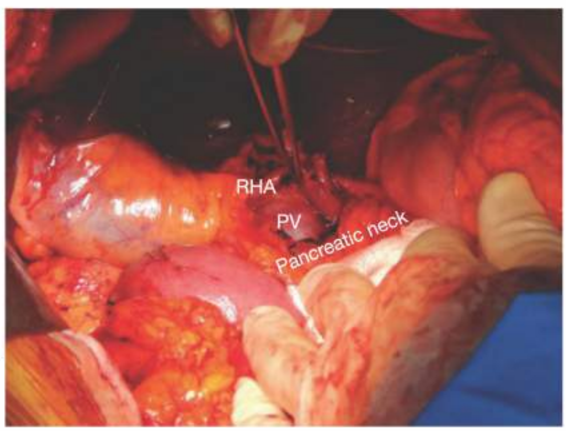


FIG 12 ● Division of the GDA facilitates medial and cephalad retraction of the hepatic artery and its branches (RHA), exposing the PV cephalad to the pancreatic neck.

CREATION OF A TUNNEL BETWEEN THE PANCREATIC NECK AND PORTAL VEIN

- The authors prefer to complete this step prior to dissection of the bile duct as findings may impact the decision to proceed.
- Dissection is performed only on the anterior surface of the vein.
- Dissect the PV superior to the neck of the pancreas. If there is no tumor involvement, the neck of the pancreas will separate from the vein easily. A large, blunt-tipped clamp is a safe instrument to use for this dissection.
- The tunnel under the neck of the pancreas can then be completed mostly under direct vision as one progresses from both the inferior and superior aspects of the pancreas (**FIG 13**).
- A vessel loop or umbilical tape is then placed under the neck of the pancreas.
- The common bile duct or hepatic duct (depending on the need for margin) is circumferentially dissected and a vessel loop is placed around the duct (**FIG 14**).

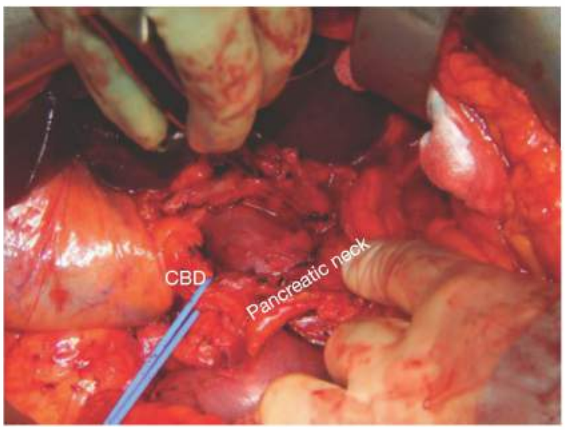


FIG 13 ● To circumferentially dissect the common bile duct (CBD), continue working anterior to posterior along the lateral margin of the PV establishing a plane between the PV and the CBD. The lateral lymphatic tissues are also dissected so they remain with the specimen. The encircled CBD can be controlled with a vessel loop. If a replaced hepatic artery is present, use care to ensure you establish a plane between the bile duct and the artery.

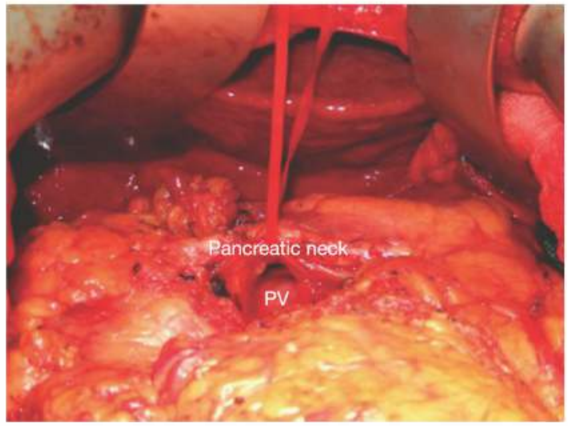


FIG 14 ● Complete the dissection of the anterior aspect of the PV from the neck of the pancreas. An umbilical tape can be placed to facilitate subsequent parenchymal transection.

- The cystic duct and artery are dissected, ligated, and divided (**FIG 15**). A cholecystectomy is performed. Alternatively, it is safer to perform a retrograde dissection of the gallbladder if inflammation is present.
- At this point (**FIG 16**), one must commit to resection or abort.

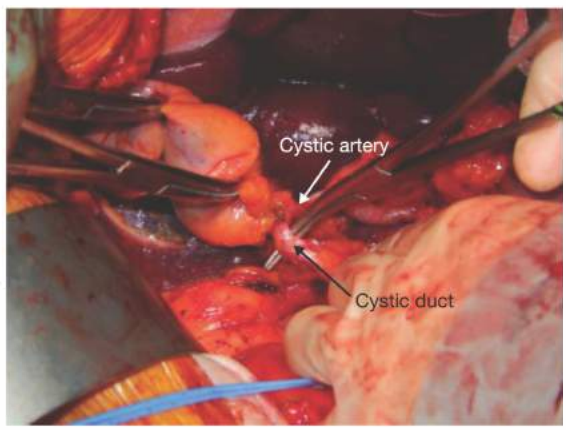


FIG 15 ● Cholecystectomy is performed. The cystic duct and artery are dissected, controlled with ligatures, and divided.

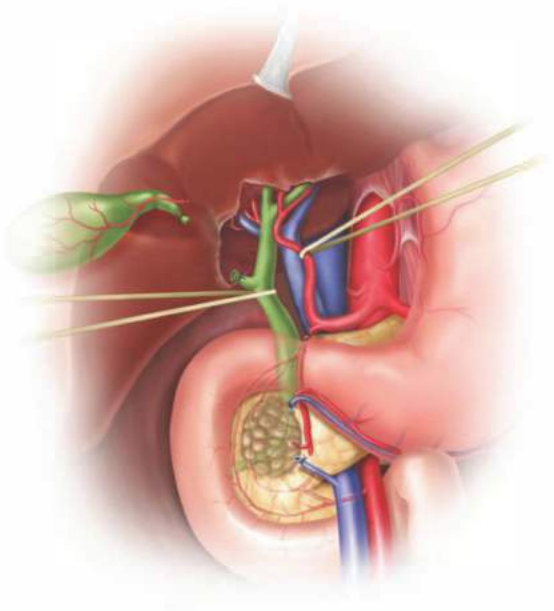


FIG 16 ● Schematic drawing of the dissection at the point of decision to proceed or abort. The next step commits to resection.

DIVISION OF THE DUODENUM

- If the operative plan is for pyloric preservation, the stomach and proximal duodenum are mobilized off the pancreas, preserving the gastroepiploic vessels down to the pylorus.
- Either the duodenum is divided 1.5 to 2 cm distal to the pylorus-preserving pancreaticoduodenectomy (PPPD) or, alternatively, the antrum is divided (**FIG 17**).
- Antrum division is performed at the division of the vagus nerves of Latarjet ("crow's feet") usually at the third or fourth transverse vein on the lesser curvature and at the confluence of gastroepiploic veins on the greater curvature.
- If the pylorus is preserved, the authors typically digitally dilate the pylorus prior to reconstruction just prior to the duodenojejunal anastomosis.

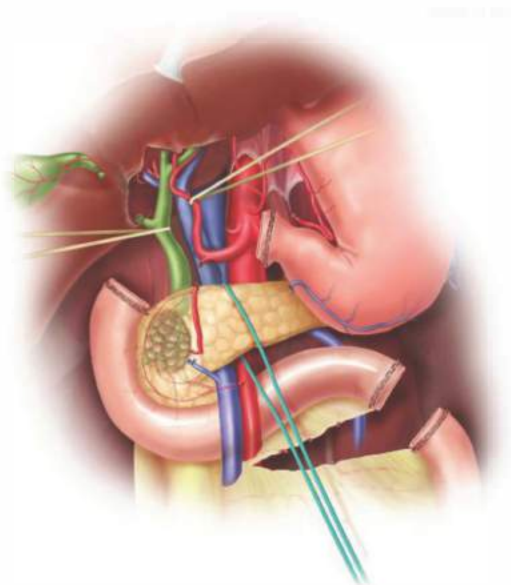


FIG 17 ● Division of the duodenum and the jejunum with a GIA stapler. The point of duodenal transaction should be at least 2 cm distal to the pylorus. Alternatively and in line with the classic performance of the operation, the antrum is divided. The jejunum is divided distal to the LT. The point of transaction is based on the vascular arcade and mesenteric length. The distal limb must reach the right upper quadrant without tension. The mesentery of the proximal limb is controlled and divided adjacent to the bowel wall to minimize risk of injury to the superior mesenteric vessels.

TAKEDOWN OF THE LIGAMENT OF TREITZ

- The jejunum is divided approximately 10 cm beyond the ligament of Treitz (LT). Careful attention is made to avoid injury to the inferior mesenteric vein just to the left of the LT.
- The mesentery of jejunum is ligated until the jejunum can be delivered posterior to the superior mesenteric vessels from left to right.
- The authors recommend performing the majority of this dissection from the left side of the patient and mobilizing as much as possible from this same side of the base of the mesentery. Dissection is continued proximally to divide and control the mesentery of the fourth and third portion of the duodenum. The visualization is maximized in this manner and this avoids moving the specimen back and forth and repositioning of retractors.
- The mesentery can be taken with ties; however, many surgeons have found that energy devices may speed this portion. Care must be taken as the dissection approaches the mesenteric vessels—the plane of dissection is the bowel wall.

DIVISION OF BILE DUCT

- The common hepatic bile duct is then sharply divided, usually above the entrance of the cystic duct.
- If present, the biliary stent is removed and passed from the operative field as a contaminated object. Of note, metallic stents do not impact division of the bile duct and can be extracted with minimal resistance.
- Some surgeons obtain cultures of the bile and continue directed, postoperative antibiotic therapy.
- A bulldog clamp is placed on the bile duct to prevent bile from contaminating the field (**FIG 18**). The distal bile duct is oversewn and the ends of the suture left elongated to orient the pathologist to this important margin.
- The distal bile duct and associated lymphatic tissue is then further dissected down along the anterior plane of the PV.

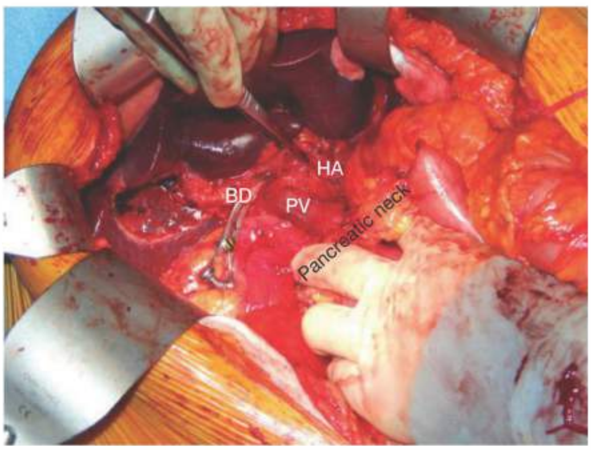


FIG 18 ● Division of the bile duct. A bulldog clamp is placed proximally to prevent ongoing contamination of the operative field with bile and maintain hemostasis. The bile duct is sharply divided. If present and easily retrievable, the biliary stent is removed and passed off the field. It should be cataloged as removed by the pathologist. The distal bile duct is sutured closed. The ends of this suture are left long to orient the pathologist. *BD*, bile duct; *HA*, hepatic artery; *PV*, portal vein.

DIVISION OF THE PANCREAS

- Hemostatic traction sutures are placed on the inferior and superior borders of the pancreas around the transverse pancreaticoduodenal vessels prior to division. These sutures should be placed to intentionally ligate the longitudinal arteries within the pancreas; however, care must be taken to ensure they do not entrap the pancreatic duct (**FIG 19**).
- The pancreatic neck is divided anterior to the PV (**FIG 20**). The authors would divide the pancreas with electrocautery on the superior and inferior ends and with the scalpel through the midsection of the pancreas to prevent cautery injury and assist in identification of pancreatic duct. Division is performed just anterior to the PV with a large blunt-tipped clamp being placed behind the pancreas to protect the vein.

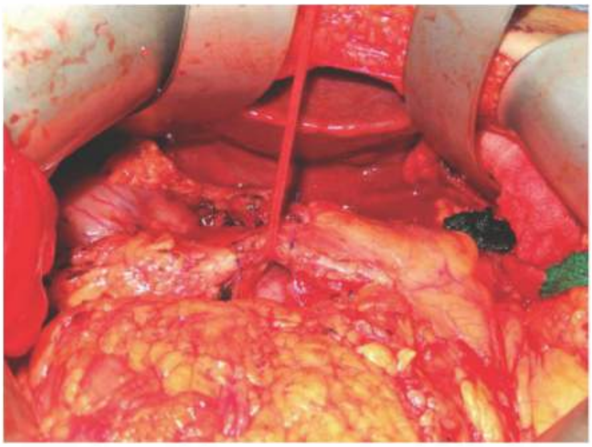


FIG 19 ● Place sutures at the proximal and distal margins of the pancreatic neck to control the longitudinal arteries and provide retraction.

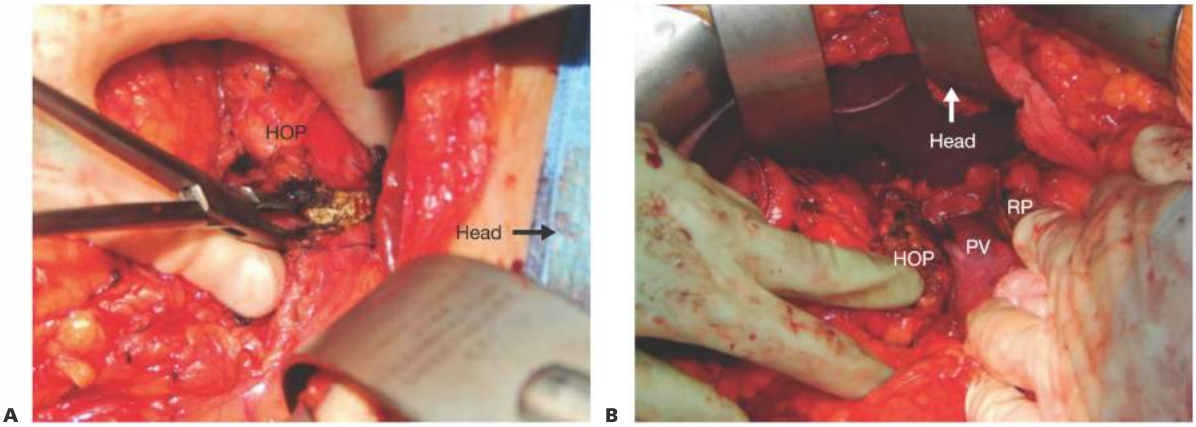


FIG 20 ● Divide the pancreatic neck. **A.** This is ideally performed sharply with judicious use of cautery to control hemorrhage to facilitate pathologic assessment of the margin. **B.** Once completed, the anterior aspect of the PV is fully exposed. *RP*, remnant pancreas; *HOP*, head of pancreas specimen; *PV*, portal vein.

DISSECTION OFF THE LATERAL ASPECT OF THE SUPERIOR MESENTERIC-PORTAL VEIN CONFLUENCE

- The pancreatic head and uncinate process are then dissected off of the right lateral aspect of the SMV, ligating the fragile branches draining the head and uncinate process into the PV (FIG 21).
- Superiorly, as the pancreatic head is being retracted inferiorly and laterally, the small venous tributaries from the PV and SMV to the pancreatic head including the superior pancreaticoduodenal vein (vein of Belcher), which inserts at the superior lateral surface of the PV, are ligated.
- Inferiorly, as the pancreatic head is retracted superiorly and laterally, the first jejunal branch will be encountered. The authors suggest ligating the first jejunal branch as it comes off of the SMV. If this is not ligated close to the SMV, it may be injured during the dissection and retract behind the SMA. Efforts to control bleeding once the vessel has retracted may result in injury to the SMA. If the tumor is inferior in location, this ligation is critical. In cases where the tumor is away from the first jejunal branch of the SMV, it can be preserved.
- The SMV is then fully mobilized off of the uncinate process to reveal the SMV/PV groove. The vein must be entirely mobilized away from the head of the pancreas to allow for maximal retroperitoneal margin resection (FIG 22).

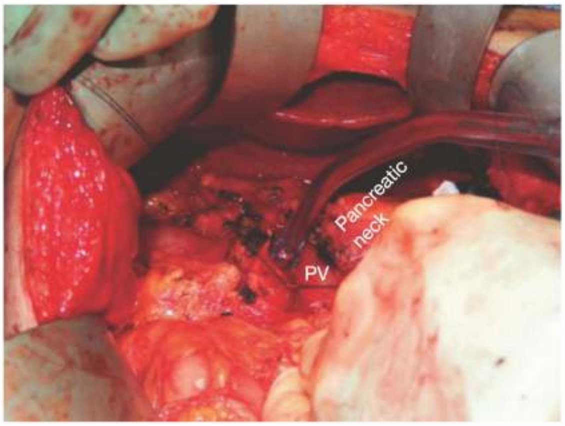


FIG 21 ● Ligate and divide the lateral venous branches of the pancreas inserting into the SMV/PV. Beware the first jejunal branch of the SMV. It inserts into the SMV posteriorly and receives a branch from the uncinate process. *PV*, portal vein.

- If the lesion is adhered to the SMV, PV, or confluence of these vessels, obtain vascular control by circumferentially dissecting the SMV. Mobilize the body of the pancreas off the splenoportal confluence and off the proximal splenic vein. Encircle the splenic vein with a vessel loop as well, and encircle the PV superiorly with a vessel loop. Once venous vascular control is achieved, the dissection then proceeds medial to the SMV directly anterior down onto the SMA and is continued around the right lateral aspect of the SMA, retracting the specimen laterally and mobilizing the specimen up so that it is then only attached by the venous involvement and is otherwise completely free. Part 3, Chapter 39 discusses PV resection and reconstruction.

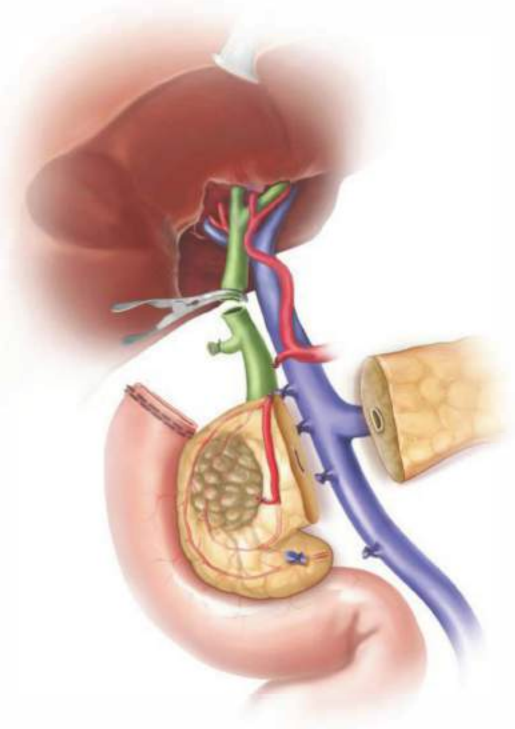


FIG 22 ● Dissect the anterior and lateral surface of the SMA. The splanchnic nerves and lymphatics in this region can make identification of the inferior pancreaticoduodenal artery or arteries challenging. Avoid the impulse to divide these structures with an energy device alone—pseudoaneurysm in the setting of pancreatic fistula from this site is universally life threatening.

COMPLETION OF THE RETROPERITONEAL AND SUPERIOR MESENTERIC ARTERY DISSECTION

- In cases without vein involvement, the superior mesenteric-portal vein (SMPV) confluence is retracted medially with a peanut or vein retractor to allow exposure of the retroperitoneal attachments to the SMA.
- The uncinate process is then dissected off of the posterior and right lateral aspect of the SMA, removing all associated autonomic nerve tissue so that the dissection plane is along the adventitia of the SMA. This can be the most tedious portion of the operation, but thoroughly clearing all tissue from the mesenteric vessels minimizes the risk of a margin-positive resection.
- The authors recommend taking the retroperitoneal margin in a controlled fashion with small bites separating out the tissue and division with either suture ties or energy device. They prefer ligation of the inferior pancreaticoduodenal artery and any lesser, unnamed nutrient arteries arising from the SMA (**FIG 23**). The authors think that use of a stapler for this portion of the procedure leaves tissue behind on the SMA and will increase the incidence of R1 resections.
- If an energy device is used on this portion, caution must be taken to avoid lateral spread to the SMA which can result in a catastrophic, postoperative SMA pseudoaneurysm.
- Once the pancreatic specimen is out (**FIG 24**), the remaining pancreatic neck should be fully mobilized approximately 2 to 3 cm off of the splenic artery and vein to facilitate the reconstruction.

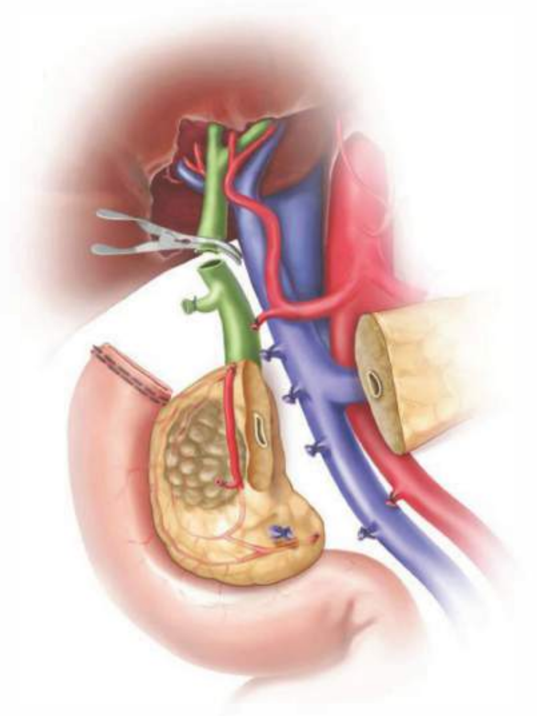


FIG 23 ● Operative image of the completed dissection. *PV,* portal vein; *SMV,* superior mesenteric vein; *CBD,* common bile duct.

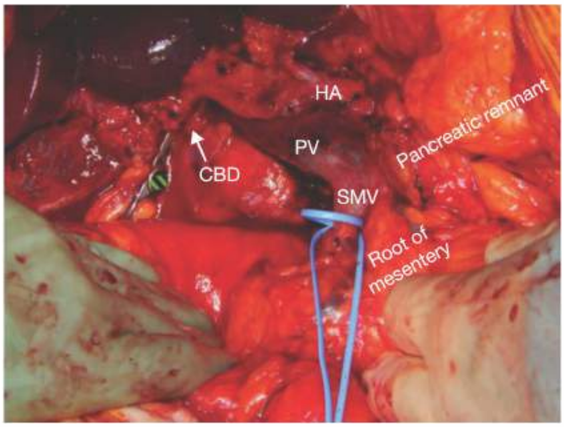


FIG 24 ● Operative image of the completed dissection.

ORIENTING THE SPECIMEN FOR PATHOLOGIC ANALYSIS

- Before the specimen is sent to pathology, it is critical that the specimen be labeled by the surgeon in a standardized fashion to facilitate communication with the pathologist. We place sutures on the bile duct, pancreatic neck, and retroperitoneal/SMA margin. The SMA margin cannot be marked retrospectively. Furthermore, if any portion of the SMV or PV was resected, the vein should be marked and sent for frozen section.
- Positive resection margins of the pancreatic neck or bile duct may warrant further resection, but recently forwarded data would suggest that this maneuver does not impact outcome.
- If there is a positive margin on the SMA margin, no further tissue can be taken and gold fiducial markers can be left in place for postoperative radiation therapy.

PEARLS AND PITFALLS

Preoperative assessment	■ Not adequately identifying a replaced hepatic artery can result in injury leading to an ischemic injury to the liver and possibly subsequent liver failure.
Opening of the lesser sac	■ Ligate the gastroepiploic and sometimes middle colic veins early. This provides improved exposure of the SMV and prevents a traction injury to the vein.
Dissection of the SMV/PV confluence	■ First jejunal branch not being properly ligated can result in division or injury to the vein with it retracting behind the SMA. Attempts to control this bleeding may result in iatrogenic injury to the SMA.
Retroperitoneal dissection	■ Complete removal of uncinate process and the mesenteric soft tissue from the SMA decreases the chance of an R1 resection.

Vein involvement	▪ If the tumor is adhered to SMPV confluence, we obtain vascular control of the PV, SMV, and splenic vein and dissect medial to the PV/SMV and perform an artery-first dissection. Completing this dissection first decreases clamp time once the vein is divided.
Pancreatic neck	▪ Mobilization of the pancreatic neck off of the splenic artery and vein facilitates a secure reconstruction and anastomosis.
Pylorus preservation	▪ If the pylorus is preserved, the authors typically digitally dilate the pylorus prior to reconstruction once the staple line is removed. The authors think this reduces postoperative gastroparesis.

POSTOPERATIVE CARE

- Patients should be monitored in the intensive care unit for hemodynamic changes, urine output, or changes in drain characteristics.
- Monitoring of drains: The authors would check postoperative drain amylase on postoperative days 1 and 3. If a pancreatic leak exists, the drain should be left in place. In addition, the drain fluid should be monitored for change in character to bilious or sanguineous. If no pancreatic or biliary leak exists, the drains should be removed on postoperative day 3.
- A low amylase level in the drain does not ensure the absence of a leak. Tachycardia and leukocytosis should drive concern and may warrant CT evaluation.
- Patients should be placed on perioperative antibiotics. If the bile cultures come back positive, the authors continue culture-directed antibiotics for 7 days.

OUTCOMES

- At high-volume institutions, 30-day mortality rates are less than 1.5% and 90-day mortality rates are 4%.
- The overall 1-year survival rate of people with pancreatic cancer is 26%, and the 5-year survival rate is approximately 6%. If the cancer is detected at an early stage when surgical removal of the tumor is possible, the 5-year survival rate is about 22%.

COMPLICATIONS

- Pancreatic fistula
- Delayed gastric emptying
- Biliary fistula
- Fistula-associated pseudoaneurysm—uncommon. Often, a herald bleed presents as an episode of hypotension accompanied by hematemesis and blood from the intraabdominal drain. These should be treated emergently with angiography
- Wound infection
- Abdominal abscess

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Chapter 34

Pancreaticoduodenectomy: Minimally Invasive Resection

Song Cheol Kim   Ki Byung Song

DEFINITION

- Pancreaticoduodenectomy (PD) is defined as the resection of the pancreatic head, duodenum, bile duct, and gallbladder, with or without the distal stomach (pylorus preserving), for benign or malignant periampullary diseases.
- Gagner and Pomp first introduced laparoscopic pyrolus preserving pancreatoduodenectomy (LPPPD) in an advanced laparoscopic surgical trial in 1994. Subsequently, there has been technical progress in laparoscopic pancreatoduodenectomy (LPD) that includes hand-assisted LPD as well as laparoscopic-assisted and robot-assisted PD.

DIFFERENTIAL DIAGNOSIS

- Pancreatic cancer
- Distal bile duct cancer
- Ampullary cancer
- Duodenal cancer
- Pancreatic neuroendocrine neoplasms
- Others

PATIENT HISTORY AND PHYSICAL FINDINGS

- Not all patients are suitable candidates for LPD. Table 1 shows the currently accepted contraindications for LPD. LPD with portal vein (PV) resections and reconstructions has been reported. With increasing experience, LPD can be attempted in obese patients.
- A history of extensive, previous abdominal surgery or pancreatitis may preclude successful completion of LPD. Hence, a detailed patient history and medical record review is vital to minimize the rate of conversion.
- A high body mass index (BMI) should be considered a significant factor for morbidity, especially during the learning period. Patients with a high BMI usually have a large amount of parietal and visceral fat, which makes identification of the detailed structures of the inner abdominal organ challenging. Exposure of the third and fourth portions of the duodenum is particularly challenging in the obese patient. Furthermore, the fragile nature of a fatty pancreas leads to difficulties in manipulating or suturing the organ during anastomosis.

Table 1: Current Contraindications for Laparoscopic Pancreaticoduodenectomy

Locally advanced disease
Obesity (BMI >35)
Extensive adhesions from previous operations or inflammation
Cardiopulmonary disease that will not tolerate prolonged insufflation of the abdomen
Aberrant anatomy

BMI, body mass index.

IMAGING AND OTHER DIAGNOSTIC STUDIES

- Patients require abdominal or abdominopelvic computed tomography (CT) or magnetic resonance imaging for diagnosis and surgical planning. Multidetector CT (MDCT) is a useful diagnostic tool for detecting the vascular involvement of the tumor, including the PV, the superior mesenteric vein (SMV) or artery, and the celiac axis. MDCT has been reported to have a sensitivity of 85% to 95% and a specificity of 95% for pancreatic cancer.
- The advent of MDCT has eliminated the need for routine magnetic resonance imaging. Heavily weighted T2 imaging sequences in magnetic resonance cholangiopancreatography can depict the pancreatic duct, biliary tree, liver, and vascular structures. Magnetic resonance cholangiopancreatography can replace endoscopic retrograde cholangiopancreatography for imaging of pancreatic and biliary lesions, thereby avoiding endoscopic retrograde cholangiopancreatography-related complications such as bleeding, perforation, and pancreatitis.
- Endoscopic ultrasound (EUS) with a high-frequency probe produces a high-resolution image of the pancreas and its surrounding structures; a small pancreatic mass or cancer can be detected with a sensitivity of 91% to 99% and a specificity of 100%. EUS fine needle aspiration (EUS-FNA) is useful for the diagnosis of an indeterminate pancreatic cystic lesion or when a clinical diagnosis prior to operation is clinically indicated. However, EUS-FNA is not mandatory in operable patients who have been diagnosed with a resectable surgical pancreatic mass by conventional CT and who have clinical signs compatible with a malignant diagnosis. Surgeons should also be mindful of possible risk factors and complications that are associated with an extended surgical time, a possibility that may arise during LPD. (See the guidelines of the Society of American Gastrointestinal Endoscopic Surgeons.)

SURGICAL MANAGEMENT

Preoperative Planning

- Preoperative palliation of obstructive jaundice may be appropriate for jaundiced patients but such procedures are associated with an increased risk of operative complications.
- In the case of colon or mesocolon invasion, a bowel prep should be considered before the operation.
- Prophylactic antibiotics and chemical and mechanical venous thromboembolism prophylaxis are warranted.

POSITIONING

- The patient is placed in the supine position with pads underneath the right side of the back to elevate the right side of the abdomen. Alternatively, a split-leg positioning can be used for LPPPD. In this position, the operator stands between the legs of the patient and the assistants stand on either side of the patient.
- A nasogastric tube and Foley catheter are inserted to decompress the stomach and bladder, respectively.
- Reverse Trendelenburg (10 degrees to 30 degrees) position is used to expose the operative field.
- Two monitors are placed at the sides of the operator and first assistant. The primary surgeon and second assistant, who holds the laparoscope, stand to the right of the patient, and the first assistant and the scrub nurse are positioned to the left of the patient. Intravenous patient-controlled analgesia systems are used to control the pain after the operation.

TROCAR PLACEMENT

- Open technique is used to establish the pneumoperitoneum through a 12-mm trocar on the umbilicus.
- Thirty-degree angled vision scope is used for visualization of the deep portion. The trocar locations are shown in **FIG 1**.
- An additional three or four trocars are placed under direct vision. Two or three 5-mm trocars (one on the right flank for the left hand of the surgeon and one or two on the left flank for surgical assistance, if necessary) and two 12-mm trocars (one for the laparoscope and one on the umbilicus for the right hand of the surgeon) are employed.
- Abdominal pressure is maintained at 12 mmHg using carbon dioxide (CO_2) gas insufflation. Keeping the abdominal inflation pressure low, not more than 12 mmHg, is important to minimize accumulation of CO_2 gas; the LPD procedure can routinely take more than 6 hours.

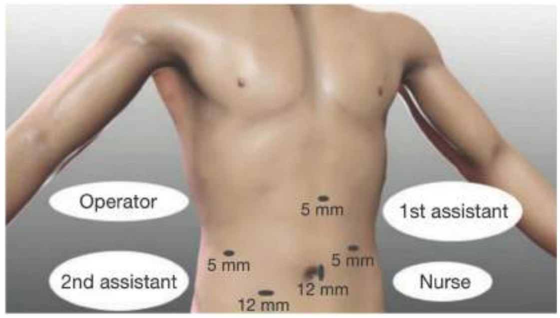

FIG 1 ● Location of trocar placement for laparoscopic pylorus-preserving PD. Two or three 5-mm trocars (one on the right flank for the left hand of the surgeon and one or two on the left flank for surgical assistance) and two 12-mm trocars (one for the laparoscope and one on the umbilicus for the right hand of the surgeon) are employed.

IDENTIFICATION OF THE PORTAL VEIN AND DIVISION OF THE DUODENUM OR STOMACH

- The entire abdomen is examined for any abnormalities or metastasis. The entire hepatic and peritoneal surfaces should be inspected. Intraoperative ultrasound may be used for further examination.
- The gastrocolic omentum is dissected to allow entry into the lesser sac (**FIG 2**).
- The PV is identified at the inferior border of the pancreas by distally following the gastroepiploic vein (GEV) to its insertion into the SMV. The GEV is clipped and divided as it inserts into the SMV (**FIG 3**). The GEV often drains into the middle colic vein, and in this circumstance, efforts should be made to preserve the middle colic vein.
- The anterior aspect of the retropancreatic segment of the PV/SMV is dissected, creating a tunnel, and potential invasion of tumor into the PV is assessed (**FIG 4**).
- The gastrohepatic omentum is opened to expose the hepatic artery coursing cephalad to the pancreas. The right

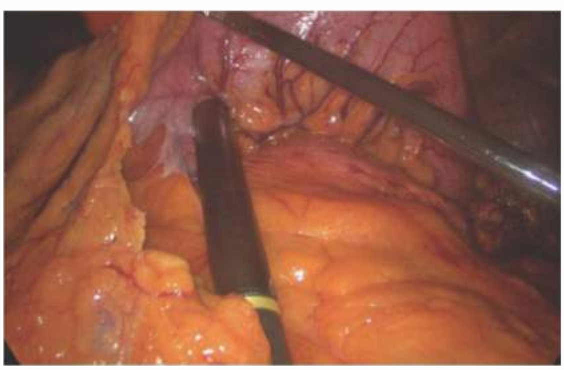

FIG 2 ● Laparoscopic ultrasound. Laparoscopic intraoperative ultrasound probe is inserted into the 12-mm trocar, and ultrasonography is performed for identifying the location of the lesion.

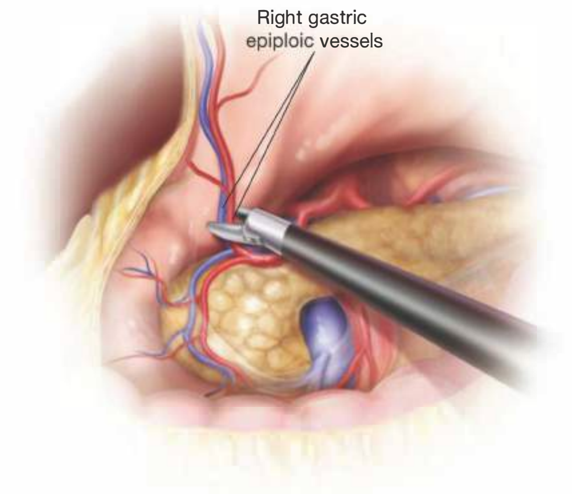

FIG 3 ● Right gastric epiploic vessels are transected and divided.

gastric artery is ligated using a metal clip or Harmonic scalpel. After dividing the branches of the right gastroepiploic vessels along the duodenum, the duodenum is divided 2 cm distal to the pylorus using an endoscopic linear stapler (**FIG 5**). Alternatively, resection of the gastric antrum can be performed according to surgeon preference or when there is concern for obtaining an adequate margin. The stomach is placed in the upper region of the abdominal cavity.

- The upper border of the pancreas is dissected to establish "Kim's triangle," formed by the common hepatic artery, upper border of the pancreas neck, and gastroduodenal artery (GDA) (**FIG 6**). The GDA is ligated at its origin and

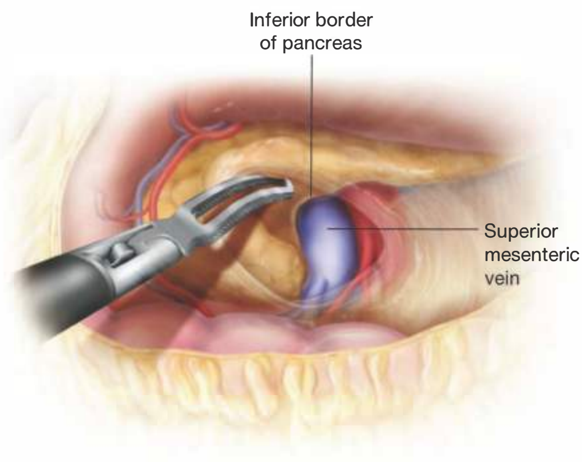

FIG 4 ● Identification of PV and SMV. The SMV is identified at the inferior border of the pancreas and dissected up to the retropancreatic PV.

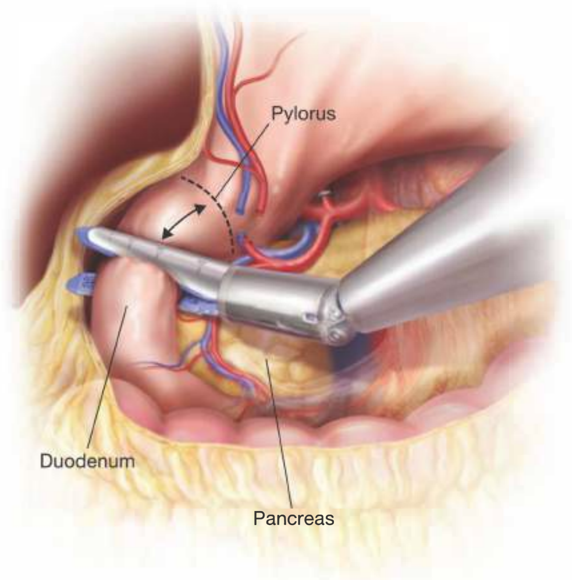

FIG 5 ● The duodenum is divided approximately 2 cm distal to the pylorus *(dotted line)* using an endoscopic linear stapler. We prefer early division of the duodenum to facilitate the subsequent dissection.

then divided with a vascular staple load. The author recommends marking this vessel as well using a clip.

- The PV tunnel is completed and gentle upward traction of the isolated pancreas is applied using an umbilical tape in preparation for division of the pancreas.

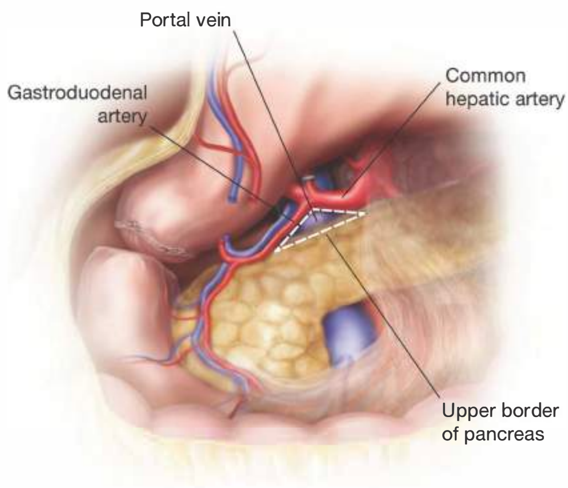

FIG 6 ● Kim's triangle. The outline of common hepatic artery, upper border of the pancreatic neck, and GDA forms a triangle for the tunneling behind the neck of the pancreas. The triangular space is dissected to isolate the pancreas from the PV (tunneling) and gentle upward traction of the isolated pancreas is applied using cotton tape ("lasso technique") in preparation for division of the pancreas.

MOBILIZATION OF THE RIGHT COLON AND DUODENUM AND IDENTIFICATION OF THE SUPERIOR MESENTERIC VEIN

- The peritoneum of the hepatic flexure of the right colon is incised. The right colon is mobilized downward and to the left side of the patient to fully expose the second and third portions of the duodenum. The dissection between the mesocolon and the duodenum/pancreatic head proceeds along the avascular surgical plane and is facilitated by the first assistant pulling the mesentery of the right colon toward the patient's left lower quadrant (**FIG 7**). Any remaining branches of right gastroepiploic vessels are divided (**FIG 8**).
- Mobilization of the third and fourth portions of the duodenum (Kocher maneuver), including division of the ligament of Treitz, is performed (**FIG 9**). Careful traction of the duodenum should be applied to prevent perforation. Dissection is continued to the left of the aorta and up to the origin of the superior mesenteric artery (SMA). The ligament of Treitz can be successfully taken down from this exposure in the majority of patients, but occasionally, there are additional peritoneal attachments to the first portion of the duodenum that will need to be divided with exposure beneath the transverse mesocolon. The third and fourth portions of the duodenum must be fully exposed prior to initiating the division of the mesentery to the duodenum.

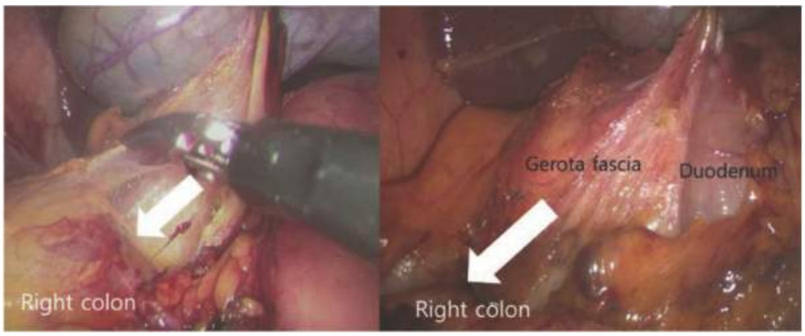

FIG 7 ● Dissection of coloduodenal avascular plane. The coloduodenal plane is bluntly dissected along the avascular surgical plane. This step is a crucial to avoid colonic ischemia due to injury of the mesocolic vessels near the colon.

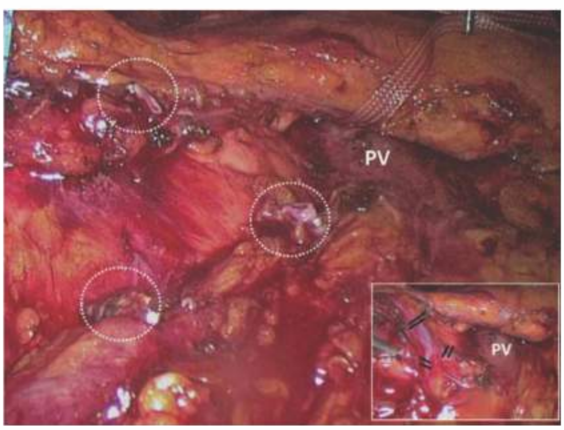

FIG 8 ● Division of branches of right GEV. *Black line*, division line of branches of right GEV; *dotted white circle*, ligated branches of right GEV.

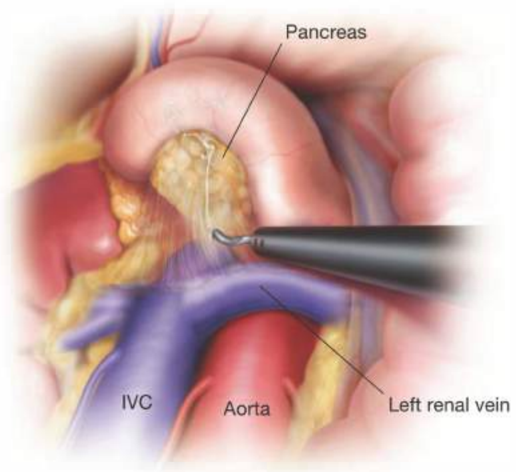

FIG 9 ● Mobilization of the retroperitoneal duodenum. Kocher maneuver is performed to the left renal vein and aorta. Careful traction of the duodenum should be performed to prevent perforation of the duodenum. A full mobilization of the retroperitoneal duodenum facilitates the separation of duodenum from the root of the mesentery.

DISSECTION OF THE PORTA HEPATIS

- Cholecystectomy is performed.
- The lymphatic dissection proceeds distally from divided origin of the GDA up to the bifurcation of the proper hepatic artery.
- Careful dissection of the bile duct should be performed to avoid injury to the accessory or replaced hepatic artery from the SMA traveling posterior to the common bile duct or the low-lying right hepatic artery travelling anterior to the bile duct (**FIG 10**). Preoperative review of the CT scan and careful inspection before division of the bile duct are crucial to avoid unexpected injury to the hepatic artery because palpation of the porta hepatis is impossible in laparoscopic surgery.
- Division of the common bile duct is executed 2 to 3 cm proximal to the duodenum. The proximal duct is controlled with a bulldog clamp. The distal duct is oversewn to prevent contamination and to provide hemostasis. The PV can now be fully exposed by dissecting the soft tissues and lymphatics using ultrasonic shears or bipolar electrocautery.

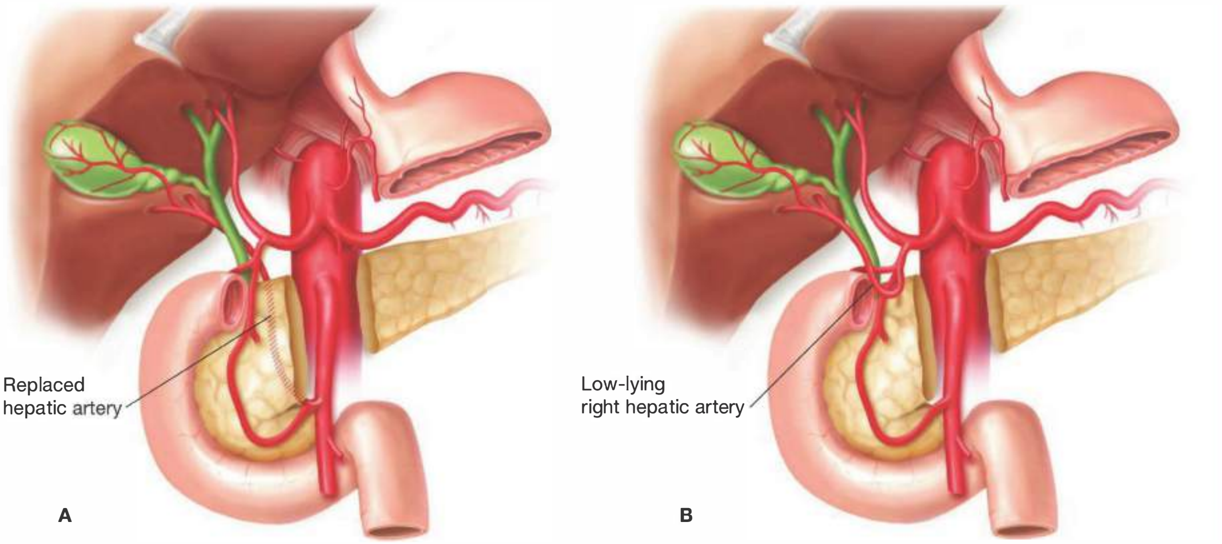

FIG 10 ● Replaced hepatic artery **(A)** and low-lying right hepatic artery **(B)**. Careful dissection of the bile duct should be performed to avoid injury to the accessory or replaced hepatic artery from the SMA travelling posterior to the common bile duct or the low-lying right hepatic artery travelling anterior to the bile duct.

DIVISION OF THE NECK OF THE PANCREAS

- Suture ligation of the longitudinal arteries coursing within the parenchyma along the superior and inferior border of the neck of the pancreas can help control bleeding from the cut surface during transection of the pancreas. We prefer to use ultrasonic shears to divide the pancreas to minimize bleeding (**FIG 11**).
- Retraction of the pancreas parenchyma using cotton tape to separate the PV/SMV helps prevent injury to

FIG 11 ● Division of pancreas using ultrasonic shears. Electrocautery can be used depending on the surgeon's preference. We prefer to use ultrasonic shears to divide the pancreas with minimal bleeding.

the PV. Meticulous control of bleeding from the cut pancreatic surface is necessary to prevent postoperative bleeding and failure of the pancreaticoenteric anastomosis. The pancreatic duct is identified (**FIG 12**). A frozen tissue section can be obtained from the margin of the pancreas.

- The SMV and PV are further dissected, identifying, controlling, and dividing the few venous tributaries arising from the head of the pancreas and uncinate process. The authors recommend the use of clips to control these vessels.
- The remaining pancreatic stump is further dissected to provide the 1 to 2 cm of mobility necessary to invaginate the pancreas into the jejunum for the pancreaticojejunostomy (**FIG 13**).

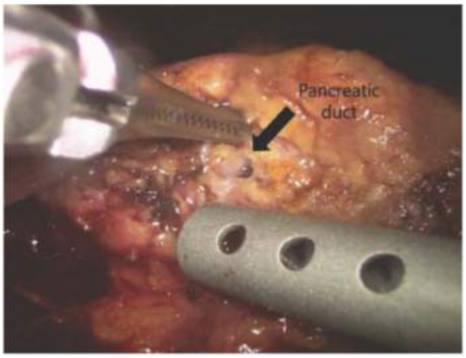

FIG 12 ● Identification of pancreatic duct.

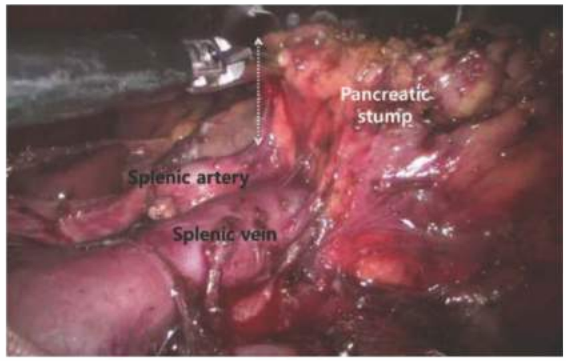

FIG 13 ● Mobilizing the pancreatic remnant. The remaining pancreatic stump is mobilized by 1 to 2 cm to facilitate invagination of the pancreas into the jejunum for the pancreaticojejunostomy.

TRANSECTION OF THE PROXIMAL JEJUNUM

- The jejunal mesentery, 10 to 15 cm distal to the ligament of Treitz, is divided between vascular arcades and the mesenteric vessels are ligated (**FIG 14**). The jejunum is transected with an endoscopic linear gastrointestinal stapler. This procedure can be performed to the right side of the base of the mesentery after pulling the jejunum through the retromesenteric space. Alternatively, we perform this procedure in its original position (performing the division of the jejunum and mesentery prior to pulling the jejunum into the right side).
- Although the Harmonic scalpel or bipolar electrocautery are useful for dividing the mesentery of the proximal jejunum, it is prudent to clip the mesenteric (remaining) side (**FIG 15**).
- The nutrient vessels of the jejunum and duodenum should be taken at the level of the bowel to minimize risk of injury to the cisterna chyle or mesenteric vessels.

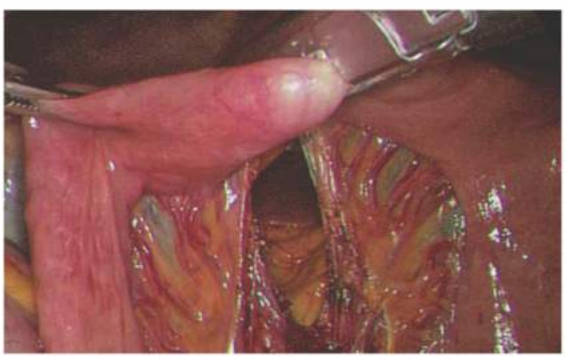

FIG 14 ● Transection of proximal jejunum. The jejunal mesentery 10 to 15 cm distal from the ligament of Treitz is divided along the mesenteric vascular arch and mesenteric vessels are ligated.

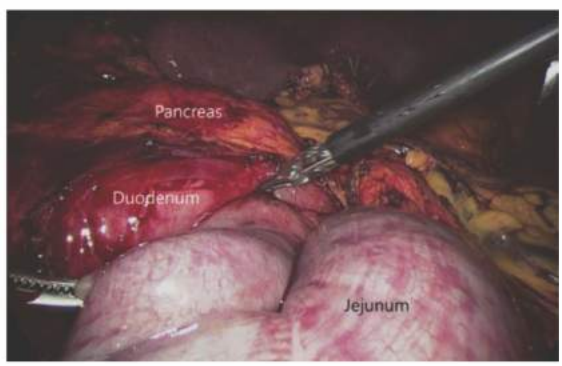

FIG 15 ● Retraction of the jejunum behind the mesenteric vessels without division of the mesenteric vessels can complicate the operation due to the resulting large volume of bowel in a confined space; this is a particularly relevant point for laparoscopic surgery.

DISSECTION OF THE UNCINATE PROCESS FROM THE SUPERIOR MESENTERIC ARTERY

- This step is the most technically difficult part of the procedure, and also, the most critical in terms of obtaining tumor-free margins. Elevation of the specimen reveals detailed features of the remaining attachments, including tributaries of the PV or SMV. The first jejunal vein and its tributaries to the uncinate process of the pancreas can also be identified with this lateral anterior traction of the specimen (**FIG 16**). Importantly, this maneuver rotates the mesentery facilitating visualization of the SMA; however, this change in the anatomic relationship puts the artery to the right of the PV and at risk for injury.
- To aid in the dissection and to control any unexpected bleeding from the PV or SMV, an umbilical cotton tape is applied to the PV and SMV, respectively, just above the splenic vein and the first jejunal vein (**FIG 17**). A hooked retractor is useful for traction of the mesenteric root to the left in order to dissect the plane between the uncinate process and the mesenteric veins. Traction with umbilical tape allows the neurolymphatic soft tissues around the SMA to be clearly visualized.
- Two possible methods can be used to dissect between the SMA and the uncinate process: downward (from the common bile duct side to the mesentery of the jejunum) or upward (from the mesentery of the jejunum to the common bile duct side) (**FIG 18**). We prefer an upward dissection because this exposes the venous branches more effectively than the downward approach.

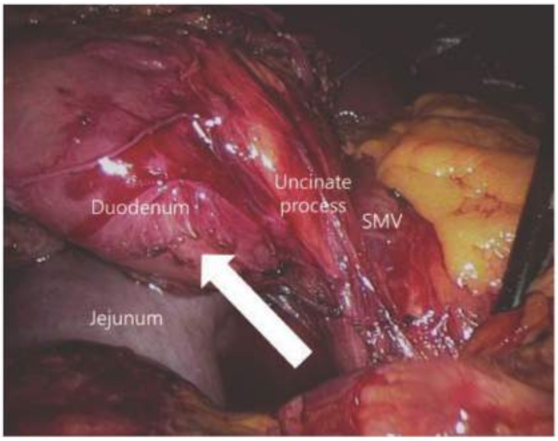

FIG 16 ● Lateral and anterior retraction of the specimen is useful to identify the first jejunal vein and its tributaries to the uncinate process of the pancreas.

FIG 17 ● The application of umbilical cotton tape to the PV and SMV is useful to aid in the dissection and control any unexpected bleeding from the PV or SMV.

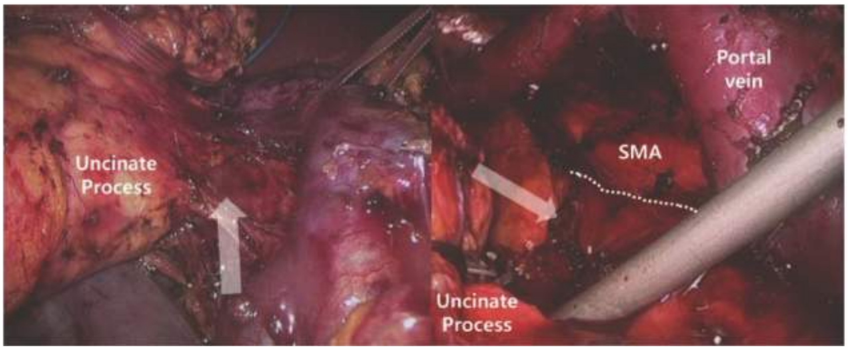

FIG 18 ● Two possible methods to dissect between the SMA and the uncinate process: upward dissection (from the mesentery of the jejunum to the common bile duct side) or downward (from the common bile duct side to the mesentery of the jejunum). We prefer an upward dissection *(arrow)* because this exposes the venous branches more effectively than the downward dissection *(arrow)*.

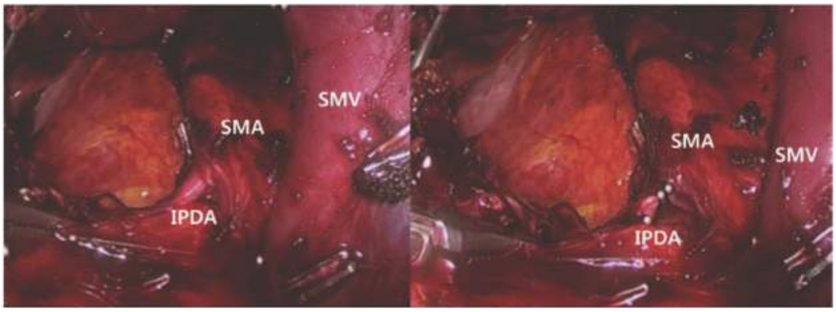

FIG 19 ● Identification of inferior pancreaticoduodenal arteries (IPDA). After dividing the tributaries from the first jejunal branch, the soft tissue near the SMA should be dissected to identify one or two IPDA.

- With upward traction of the SMV using umbilical tape and caudal traction of the specimen, posterior venous tributaries draining from the uncinate process to the first jejunal vein (two or three veins) can be identified and divided with clips and a Harmonic scalpel. After dividing the tributaries from the first jejunal branch, the soft tissue near the SMA should be dissected to identify one or two inferior pancreaticoduodenal arteries (**FIG 19**). A Harmonic scalpel may be used to divide these arteries; however, we prefer to separately clip the remaining pancreaticoduodenal arteries. Occasionally, small branches that cannot be identified may be easily divided using a Harmonic scalpel.
- The remaining dissection of the soft tissue between the SMA and the uncinate should be performed according to the oncologic status of the disease. For diseases other than pancreatic ductal adenocarcinoma, the dissection can be performed near the uncinate process without risk of injury to the SMA. However, for pancreatic ductal adenocarcinoma, a clear dissection of the neurolymphatic soft tissues of the right side of the SMA is needed to obtain a margin-negative specimen.
- Most soft tissues including small mesenteric vessels can be safely sealed with a Harmonic scalpel to transect the pancreas head from the SMA. However, the remaining large superior pancreaticoduodenal vein should be tied or clipped securely.
- The specimen is placed in a specimen bag and retrieved at the end of procedure, either through the 2- to 3-cm extension of the umbilical port or a separate incision (**FIG 20**). The specimen bag containing the gallbladder is removed at the same time.

FIG 20 ● Periumbilical and Pfannenstiel incisions. The specimen is placed in a specimen bag and retrieved at the end of procedure, either through the 2- to 3-cm extension of the umbilical port or a separate Pfannenstiel incision.

PEARLS AND PITFALLS

Indications	■ Surgeons wishing to perform LPPPD should have sufficient experience in both OPD and advanced laparoscopy and laparoscopic suturing techniques. ■ The indications for LPD should be limited initially to patients with low BMI, benign or low-grade malignant disease, or confined malignant disease without vascular involvement.
Preoperative planning	■ Palpation cannot be used to identify aberrant arterial anatomy. Review preoperative imaging specifically to this regard.
Technique	■ Early division of the duodenum facilitates further dissection. ■ Mobilization of the right colon is crucial to clearly expose the operative field. ■ Staple and ligate the GDA—Clips will slip off the specimen side during subsequent manipulation of the specimen. Staple lines are at risk for pseudoaneurysm. Ligate above the staple line. ■ A bulldog clamp on the proximal bile duct prevents contamination and provides hemostasis. ■ Ligation of longitudinal arteries and energy division of the pancreatic neck are essential steps to a hemostatic field. ■ Anterior and lateral retraction of the specimen is essential for visualization of the attachments of the uncinate process to the SMV and SMA. ■ Identification and careful division of the first jejunal vein and its tributaries to the uncinate process of the pancreas is critical to prevent unexpected bleeding. ■ Applying umbilical cotton tape around the PV and SMV just above the splenic vein and first jejunal vein can also help control any unexpected bleeding.

Postoperative care	■ Hemorrhage is managed based on timing and clinical observations.
	  ■ Within 24 hours, return to the operating room.
	  ■ Within the first 5 to 7 postoperative days, consider endoscopy to assess for an anastomotic source.
	  ■ Over 5 to 7 days, CT arteriography and catheter-based control of pseudoaneurysm

POSTOPERATIVE CARE

- In the majority of cases, patients should be transferred to an intensive care unit for monitoring. However, patients may be transferred to a general ward in highly specialized centers.
- The patient should wear antithrombotic stockings and receive prophylactic low-molecular-weight heparin until discharge.
- Intravenous patient-controlled analgesia systems are used to control pain.

OUTCOMES

- When compared to open pancreaticoduodenectomy (OPD), LPD potentially offers the recognized advantages of laparoscopic surgery, including faster postoperative recovery, improved cosmesis, and fewer wound complications.
- Mortality rates of 1% to 8% for LPD have been reported. Our series of 100 cases showed a mortality rate of less than 1%. The postoperative morbidity rate was approximately 30%. The operative time is usually longer than that of conventional pyrolus preserving pancreatoduodenectomy (PPPD). The time between surgery and hospital discharge is the same or less than that of an open procedure. Oncologic outcomes for advanced cancer, such as the number of harvested lymph nodes and the rate of negative margin status, also show similar results to those of open procedures.
- The perioperative outcomes of LPPPD in large series including ours are shown in the Table 2.

COMPLICATIONS

- Morbidity rates of between 20% and 40% have been reported. The most common and fatal complications are pancreatic leakage and hemorrhage. The majority of intraabdominal infections are associated with pancreatic leaks and fistulas.
- Pancreatic fistula
- Hemorrhage

Table 2: Mortality and Morbidity in Large Series of Total Laparoscopic Pancreaticoduodenectomy

Variables	Dulucq et al.	Palanivelu et al.	Kendrick et al.	Zureikat et al.	Kim et al.
Number	13	75	65	14	105
Conversion (%)	NA	0	4.6	14	4.7
Mortality (no.)	1	1	1	1	1
Operative time (median, minutes)	295	357	368	456	474
Pancreatic fistula (%)*	8	7	18	36	6
Length of hospital stay (median, days)	16	8	7	8	11
Margin-negative resection (%)	100	97	89	100	100

NA, not available.
**Definition of pancreatic fistula varies according to authors. Current table represents International Study Group on Pancreatic Fistula (ISGPF) grade B or C.*

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Chapter 35

Pancreaticoduodenectomy: Robotic-Assisted Resection

Brian A. Boone Herbert J. Zeh

DEFINITION

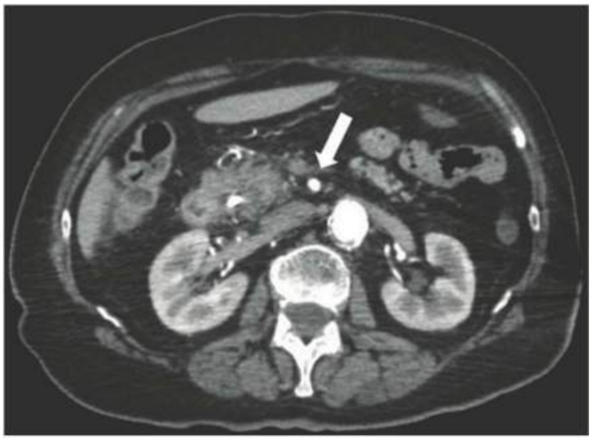
- Pancreaticoduodenectomy entails resection of the head of the pancreas and duodenum, which requires mobilization and transection of the pancreas, stomach, common bile duct, and jejunum. This chapter will focus on the resection and extraction of the specimen using a robotic-assisted technique, with subsequent chapters devoted to reconstruction.

PATIENT HISTORY AND PHYSICAL FINDINGS

- The history and physical exam should focus on identifying evidence of metastatic disease, which would preclude resectability.
- The robotic technique is routinely used for both benign and malignant disease.
- Patients are not excluded from the robotic approach based on age, body mass index (BMI), or comorbidities.
- Relative contraindications to robotic surgery are the anticipation of vascular resection and reconstruction and extensive prior abdominal surgery.

IMAGING AND OTHER DIAGNOSTIC STUDIES

- A primary goal of imaging modalities for pancreatic cancer is to determine resectability by excluding metastatic disease and involvement of the mesenteric vessels.
- Based on consensus guidelines,[1] resectable tumors are those that have no distant metastasis; have no radiographic evidence of abutment or distortion of the superior mesenteric vein (SMV) and portal vein (PV); and have clear fat planes surrounding the celiac axis, hepatic artery, and superior mesenteric artery (SMA) (**FIG 1**). Patients with tumor abutment of the SMV/PV, gastroduodenal artery (GDA) abutment or encasement up to the hepatic artery, or abutment of the SMA less than 180 degrees are considered to be borderline resectable and may benefit from neoadjuvant treatment.[2]
- Computed tomography (CT) scan—A triphasic CT scan of the chest, abdomen, and pelvis with fine cuts through the pancreas is the mainstay of imaging for pancreatic pathology. CT allows for characterization of the pancreatic mass, identifies involvement of the mesenteric vessels, and evaluates for metastatic disease, particularly in the liver or lungs.
- Endoscopic ultrasound (EUS)—This diagnostic modality, although not routinely performed at all institutions, should be considered standard of care in most cases. EUS allows for visualization and biopsy of the mass, particularly if a tissue diagnosis is required for treatment with neoadjuvant or adjuvant chemotherapy. Mesenteric vessel involvement can be evaluated. Additionally, suspicious lymph nodes can be identified and biopsied, which helps to accurately stage the patient.
- Staging laparoscopy—The role of staging laparoscopy in the management of pancreatic cancer remains controversial and is not routinely performed at most institutions.[3] For patients with large tumors, equivocal CT findings, or highly elevated carbohydrate antigen (CA 19-9), staging laparoscopy can be considered.



A

B

FIG 1 ● A CT scan demonstrating the tumor relationship to the surrounding vasculature is required to determine resectability during the preoperative planning phase. **A.** CT scan of the abdomen with arterial contrast demonstrating clear fat planes around SMA in resectable pancreatic cancer *(white arrow)*. **B.** Venous phase scan demonstrating clear fat planes around SMV *(white arrow)*.

SURGICAL MANAGEMENT

Preoperative Planning

- Determining resectability based on high-quality diagnostic and imaging modalities is the key step in preoperative planning, particularly because the use of the robotic technique precludes the ability of the surgeon to palpate the tumor and readily identify vascular involvement intraoperatively.
- Four units of crossmatched packed red blood cells should be prepared and available.
- Preoperative antibiotics should be administered.

Positioning

- The general setup for the robotic operating room is depicted in **FIG 2**.
- The patient is positioned supine on a split-leg table, which allows space for the assistant surgeon to have access to the abdomen. The right arm is tucked with protective foam padding.
- Prior to the start of the procedure, central and arterial lines are inserted in addition to a nasogastric tube and Foley catheter. A convective warming blanket is used on the upper body.

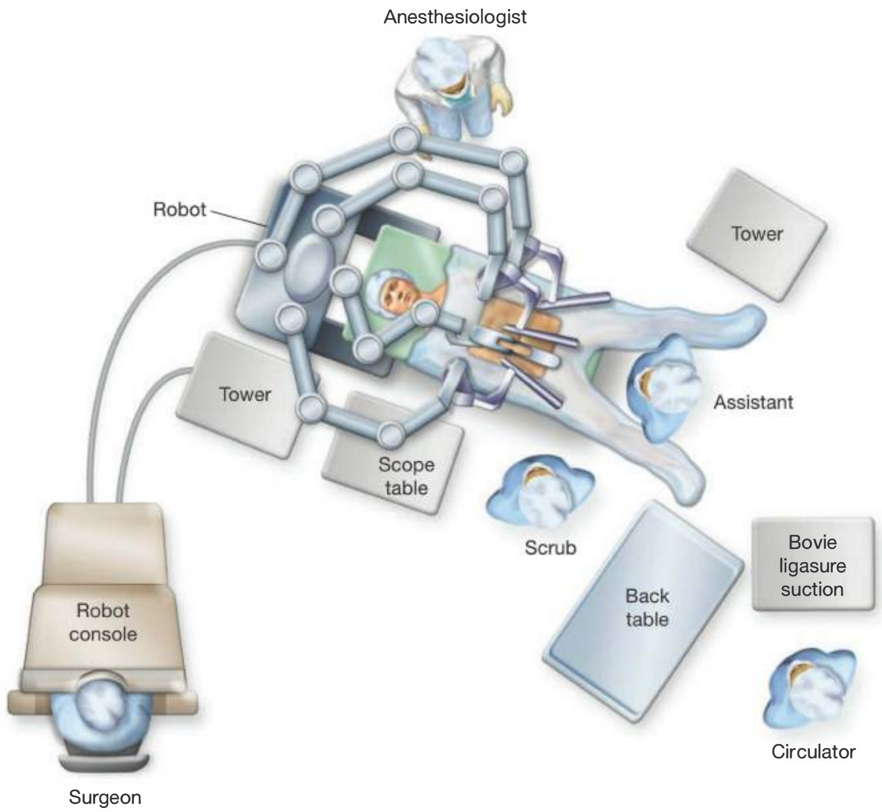


FIG 2 ● Setup of operating room for robotic pancreaticoduodenectomy. The robot is placed above the patient's head. A split-leg table is used to allow the assistant access to the abdomen and robotic arms. The robotic console is placed to the side of the room to allow ample space for the circulator and scrub tech.

PORT PLACEMENT

- Seven ports are used for robotic assistance during pancreaticoduodenectomy. Ports include a 10-mm camera port, three robotic arm ports, two assistant ports, and a 5-mm liver retractor port. Our port location and configuration is displayed in **FIG 3**.
- Access to the abdomen is obtained using a 5-mm optical separator port inserted to the left of the umbilicus in the midclavicular line. This port is eventually upsized to 8 mm and serves as a robotic arm.
- A 4- to 5-cm incision to extract the specimen is placed in the left midclavicular line.

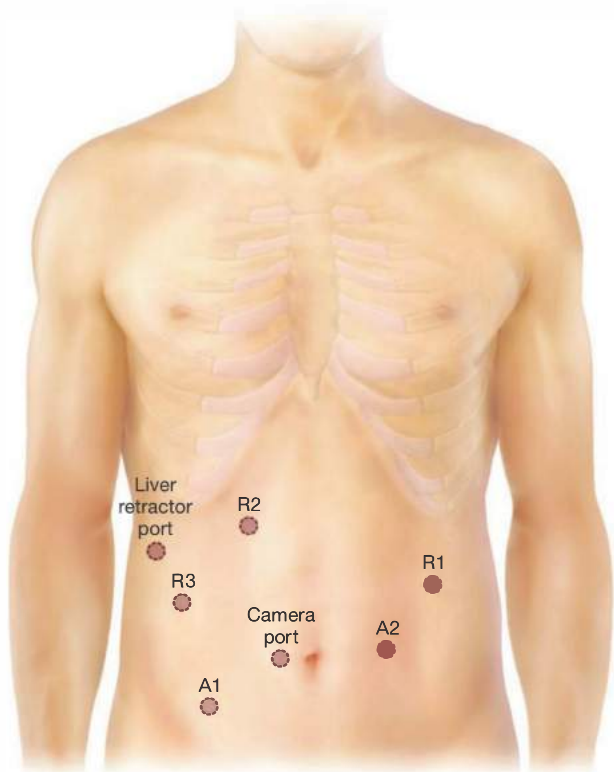


FIG 3 ● Seven ports are used for robotic assistance during pancreaticoduodenectomy, including a 10-mm camera port, three robotic ports, two assistant ports, and a 5-mm liver retractor port.

MOBILIZATION OF THE RIGHT COLON AND DUODENUM

- Standard laparoscopic instruments including an atraumatic grasper and bipolar electrocautery are used to fully mobilize the right colon.
- The duodenum is kocherized with mobilization of the third and fourth portion until the jejunum reaches into the right upper quadrant and the SMV is exposed at the root of the small bowel mesentery (**FIG 4**).
- The jejunum is transected 10 cm distal to the ligament of Treitz using a linear stapler. The proximal jejunum is passed back under the superior mesenteric vessels. The distal jejunum is then marked with a suture at aprproximately 50 cm and secured to the stomach in an antecolic fashion, ensuring it is easily identified for reconstruction of the gastrojejunostomy (**FIG 5**).

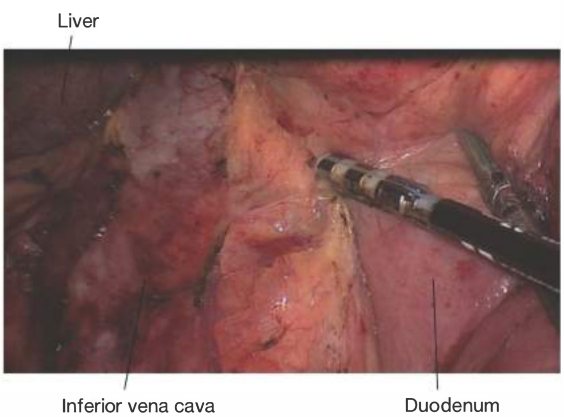


FIG 4 ● Complete kocherization of the duodenum using laparoscopic instruments brings the duodenum into the left upper quadrant. The inferior vena cava is visualized during mobilization of the duodenum.

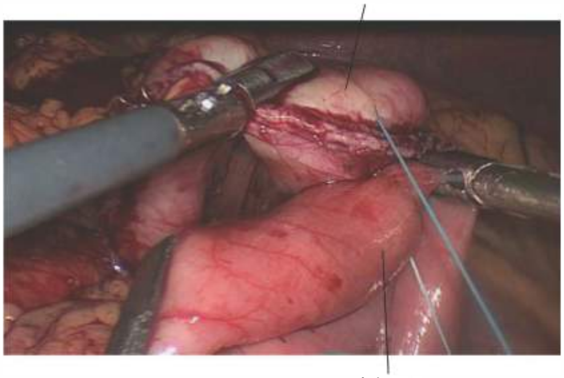


FIG 5 ● Suturing the divided jejunum to the stomach facilitates finding it for the gastrojejunostomy.

MOBILIZATION AND DIVISION OF THE STOMACH

- Continuing laparoscopically, the lesser sac is entered by division of the gastrocolic omentum. The posterior stomach is freed from the anterior pancreas.
- The right gastric and right gastroepiploic arteries are ligated close to the stomach with a bipolar electrocautery device and clips (**FIG 6**).
- The stomach is divided with a linear stapler after removal of the nasogastric tube.

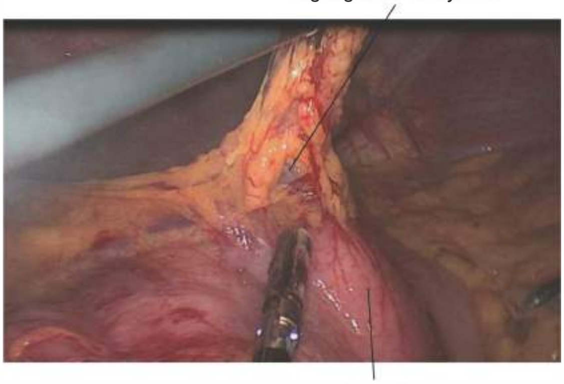


FIG 6 ● The right gastric artery is identified and ligated close to the stomach using bipolar electrocautery.

DISSECTION OF THE PORTA HEPATIS

- At this point in the operation, the robot is docked directly over the head of the table with the patient in steep reverse Trendelenburg position. The operating surgeon moves to the robotics console and the assisting surgeon stands between the legs to exchange instruments, pass needles, and assist with suction and stapling.
- Dissection is continued along the superior border of the pancreas and into the porta hepatis using the robotic hook cautery. The common hepatic artery (CHA) lymph node is identified and removed (**FIG 7**). This allows exposure of the CHA. The CHA is exposed and followed until the right gastric and GDAs are identified (**FIG 8**). A vessel loop is passed around the GDA and it is occluded while flow is checked by color flow and 3-D Doppler

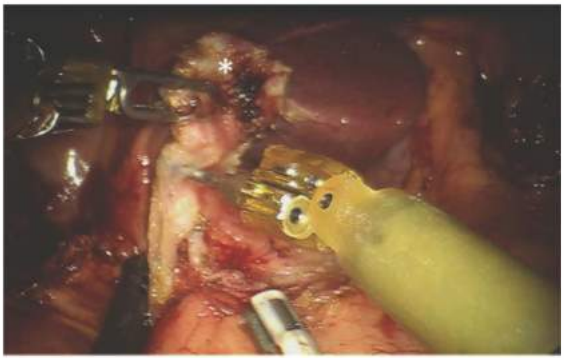


FIG 7 ● The CHA lymph node is identified *(white asterisk)* and removed using hook cautery. This allows exposure of the CHA.

in the CHA. Once flow is confirmed, the GDA is ligated with a vascular load stapler and reinforced with a 10-mm titanium clip.

- Portal lymph nodes are dissected and removed. The PV and common bile duct are then exposed (**FIG 9**).
- Cholecystectomy may be performed in an antegrade fashion at this point or reserved for after the main specimen is removed.
- The common bile duct is dissected and divided with a vascular load of the endostapler.

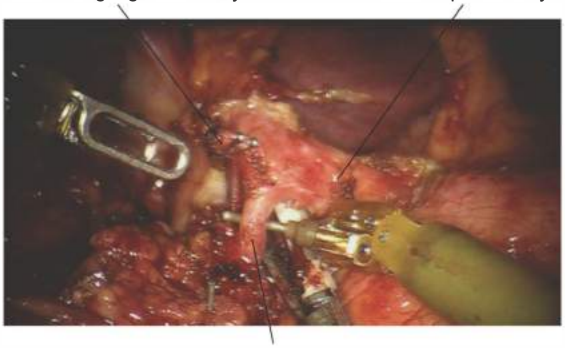


FIG 8 ● The GDA is identified. Flow in the CHA is confirmed with a vessel loop constricting the GDA. The GDA is then ligated with an endostapler with a vascular load.

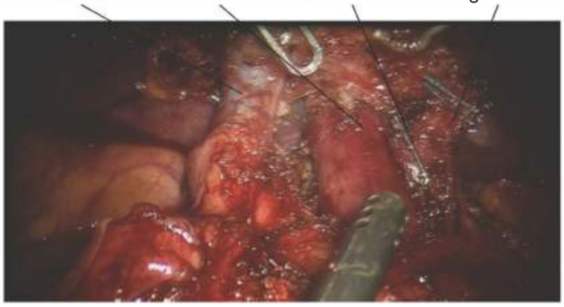


FIG 9 ● The portal dissection continues until the common bile duct and PV are identified and exposed.

MOBILIZATION AND DIVISION OF THE PANCREAS

- The right gastroepiploic vein is followed to its origin to identify the SMV. The SMV is dissected off the inferior border of the pancreas and a tunnel is created between the pancreas and PV. The robotic camera angles allow for excellent visualization of the tunnel (**FIG 10**).
- Once a tunnel is formed, the neck of the pancreas is divided with electrocautery (**FIG 11**). Care is taken to identify the pancreatic duct and leave small extension on it.
- The pancreas is then mobilized, first at the lateral border of the SMV/PV. The first jejunal branch of the SMV is identified as it crosses over the SMA inferiorly. The first jejunal branch of the SMV is preserved by taking several small recurrent branches to the uncinate process over clips or silk ties.
- The SMV/PV is brought medially, exposing the SMA, which is then dissected along the plane of Leriche (**FIG 12**).
- The superior and inferior pancreatico-duodenal artery (PDA) are individually identified and secured with clips, silk ligatures, or LigaSure, depending on size and location (**FIG 13**).
- The superior uncinate branch of the PV is identified and ligated with the vascular load, clips, or silk ligature.
- The specimen is removed in an EndoCatch bag through a 4- to 5-cm extraction incision in the left midclavicular line. Following removal of the specimen, the resection field is prepared for reconstruction (**FIG 14**).

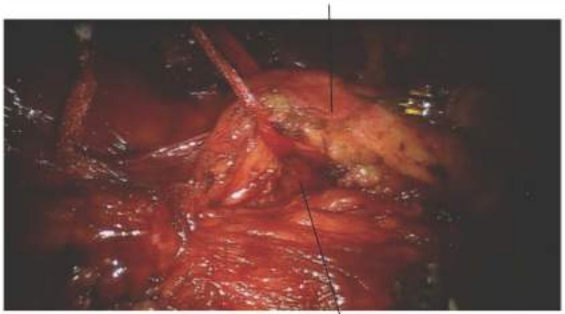


FIG 10 ● Dissection at the inferior border of the pancreas allows the tunnel underneath the pancreas and over top of the mesenteric vessels.

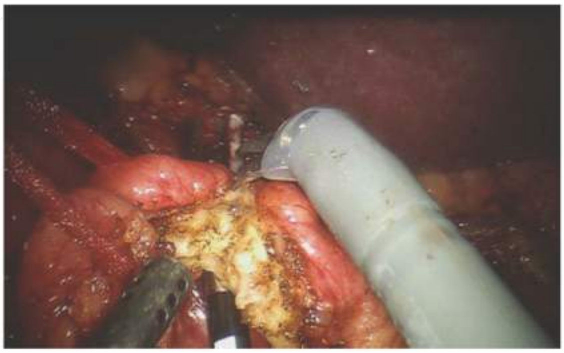


FIG 11 ● The pancreas is divided using cauterized scissors. The enhanced camera angles on the robotic system allow for excellent visualization during the tunnel and subsequent division of the pancreas.

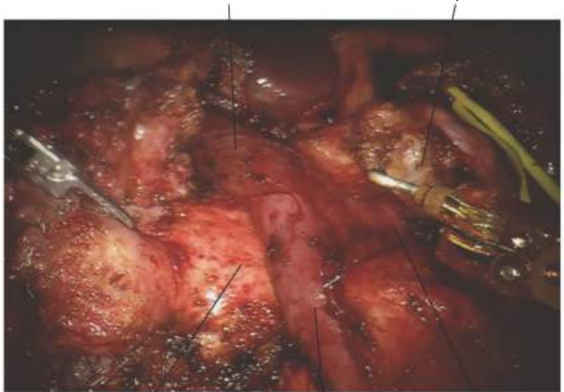


FIG 12 ● The uncinate process is dissected using a combination of hook cautery and fine scissors.

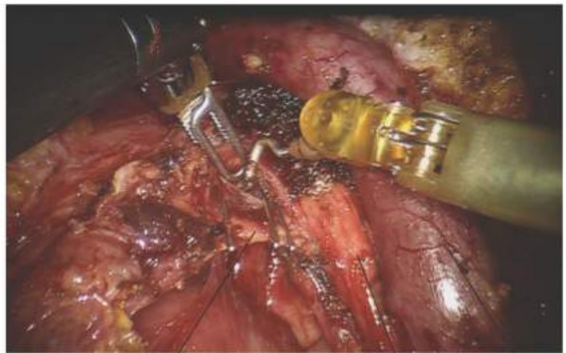


FIG 13 ● Retraction of the SMV medially exposes the SMA to allow for dissection along the plane of Leriche. The inferior pancreaticoduodenal artery is identified and ligated.

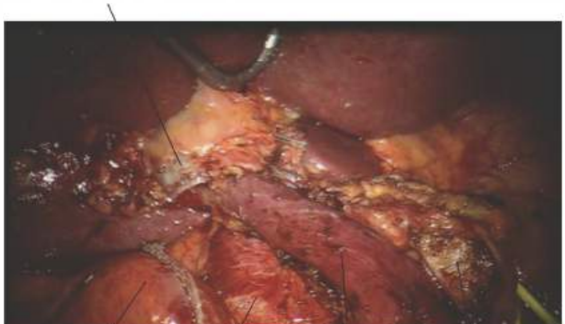


FIG 14 ● The resection bed following removal of the specimen. The field is now prepared for reconstruction.

PEARLS AND PITFALLS

Preoperative planning—determination of resectability	■ Invasion of the tumor into the mesenteric vessels cannot be fully assessed by palpation until after the pancreatic neck is divided and the surgeon is committed to resection; therefore, a high-quality preoperative CT and planning are required to determine resectability.
Port placement	■ If the ports are placed too close together, the robot arms will hit each other. The camera port needs to be superior and lateral to the umbilicus to allow for adequate portal and uncinate dissection exposure.
Securing the divided jejunum to the stomach	■ The suturing of the jejunum to the stomach prior to docking the robot facilitates finding it for reconstruction.
Dissection of the porta hepatis	■ Assess for aberrant vascular anatomy such as a right hepatic artery from the SMA, which occurs in up to 20% of patients.
Hanging technique for uncinate	■ The third robotic arm must rotate the specimen laterally and superiorly to allow for adequate exposure of the SMA.

POSTOPERATIVE CARE

- Following completion of the operation, the patient is extubated and transferred to either the intensive care unit or a monitored floor bed based on individual patient and operative factors. A nasogastric tube is left in the place.
- A drain is left in the pancreatic bed and a drain amylase is checked after postoperative day 3. Drains with normal amylase are removed prior to discharge.

OUTCOMES

- Although no randomized or large case-control series have been published comparing robotic and open pancreaticoduodenectomy, the preliminary experience of several groups suggests that outcomes of robotic pancreaticoduodenectomy are comparable to open surgery.[4–7] Several series have consistently demonstrated a reduction in estimated blood loss with the robotic approach.
- The largest series of robotic pancreaticoduodenectomy from a single institution was recently reported,[8] with outcomes for 132 pancreaticoduodenectomies listed below:
  - Thirty-day and 90-day perioperative mortality was 1.5% and 3.8%, respectively.
  - Clinically significant morbidity (grade 3 or 4 Clavien Dindo) affected 21% of patients.
  - Median operative time was lengthy at 527 minutes; however, significant improvement was noted over the experience.
  - The median estimated blood loss was around 300 mL for the series.
  - Conversion to open was required in 8% of cases.

COMPLICATIONS

- The types of complications following robotic pancreaticoduodenectomy are identical to open. The incidence and severity appears to be similar to open surgery in series detailing preliminary experiences with robotic pancreaticoduodenectomy.[4–8]
  - Pancreatic leak
  - Pseudoaneurysm
  - Delayed gastric emptying
  - Infection (wound, intraabdominal abscess)
  - Biliary leak
  - Gastric leak
  - Gastric outlet obstruction
  - Bowel obstruction

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Chapter **36**

Pancreaticoduodenectomy: Pancreaticojejunostomy

Charles M. Vollmer

DEFINITION

- Pancreaticojejunostomy is defined as the anastomosis of a remnant pancreas to the jejunum. This is a necessary step in restoring intestinal tract continuity following pancreaticoduodenectomy (PD).
- Although there are numerous options on how to restore continuity of the pancreas to the enteric tract following PD, central pancreatectomy, or distal pancreatectomy (rarely), pancreaticojejunostomy is the most frequently applied technique worldwide. Furthermore, there are a number of technical variations available for this procedure including "dunking" and "invagination" approaches. This chapter depicts construction of the widely prevalent double-layered, duct-to-mucosa, end-to-side pancreaticojejunostomy.
- This chapter's importance lies in the following: Although the first half of PD hinges on the optimal resection of diseased tissue, which determines long-term (usually oncologic) outcomes, the reconstruction phase sets the tone for the immediate postoperative recovery period through the prevention of complications. Chief among these is pancreatic anastomotic failure, which occurs roughly 15% of the time.

PATIENT HISTORY AND PHYSICAL FINDINGS

- An improved, international consensus definition of this complication has been enthusiastically adopted by most pancreatic surgeons (International Study Group on Pancreatic Fistula [ISGPF]).[1] Subsequently, patient-specific risk factors for clinically relevant leaks have been identified as (1) soft gland texture, (2) small pancreatic duct diameter, (3) pathology exclusive of pancreatic cancer or pancreatitis, and (4) elevated blood loss.[2] These variables are best elucidated at the time of the operation, but preoperative prediction of these important variables is possible, should factor into decision making, and understanding them can influence intra- and postoperative management techniques.[3]

TECHNIQUES

SURGICAL MANAGEMENT

Pancreatic Transection

- A successful anastomosis begins well before the reconstruction phase of the procedure. Limiting blood loss and careful handling of the pancreas during the resection stage should be regular goals.
- Once an appropriate site of transection over the portal vein (PV) canal is chosen, it is helpful to place hemostatic transfixion sutures on each side of the proposed plane. There are reproducible horizontal arterial arcades a few millimeters within the superior and inferior borders of the pancreas. A 2-0 silk, figure-of-eight suture is deeply placed into each border and on each side of the transection plane (total of four). Care must be taken to not place these too deeply in to the parenchyma on the left (stay) side, such that the pancreatic duct is inadvertently occluded. This is not a concern on the right side where the pancreatic head specimen will ultimately be removed. Once tied down, these sutures are not cut but rather maintained long on a snap to aid in leverage of the distal gland during the reconstruction phase (**FIG 1**).
- Transection can occur via a number of techniques including scalpel or staplers. However, Bovie cautery is preferred for its ability to limit blood loss. A needle-tipped cautery provides good precision with focused coagulation. The cut mode is used to transect the capsule and most of the parenchyma, whereas focal use of the coagulation mode is valuable to control distinct blood vessels when encountered. This approach proceeds through the majority of the gland until the area of the duct is anticipated. Sharp transection of this area is preferred to prevent thermal damage to the duct.
- Cautery is then focally applied to dry up any oozing from the cut edge of the pancreas. There is quite often a reproducible arterial vessel on the posterior edge of the gland just beneath where the duct lies.
- The distal pancreatic remnant should be elevated off of the splenic vein beneath it for a distance of at least 2 to

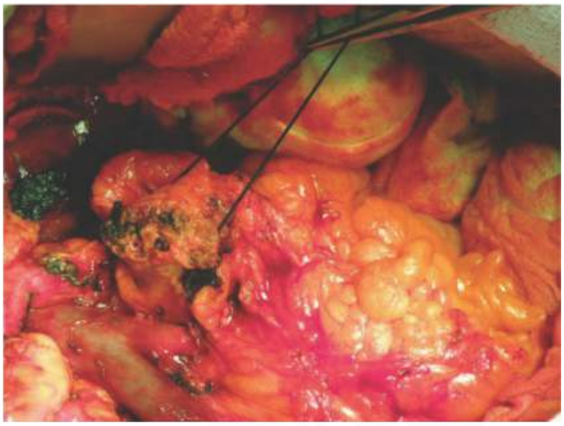


FIG 1 ● En face picture of the transection plane of the pancreatic neck. Two sutures are placed into the parenchyma to control the superior and inferior vascular arcades. These also provide leverage in "lifting" the pancreatic remnant out of the retroperitoneum for the anastomotic construction.

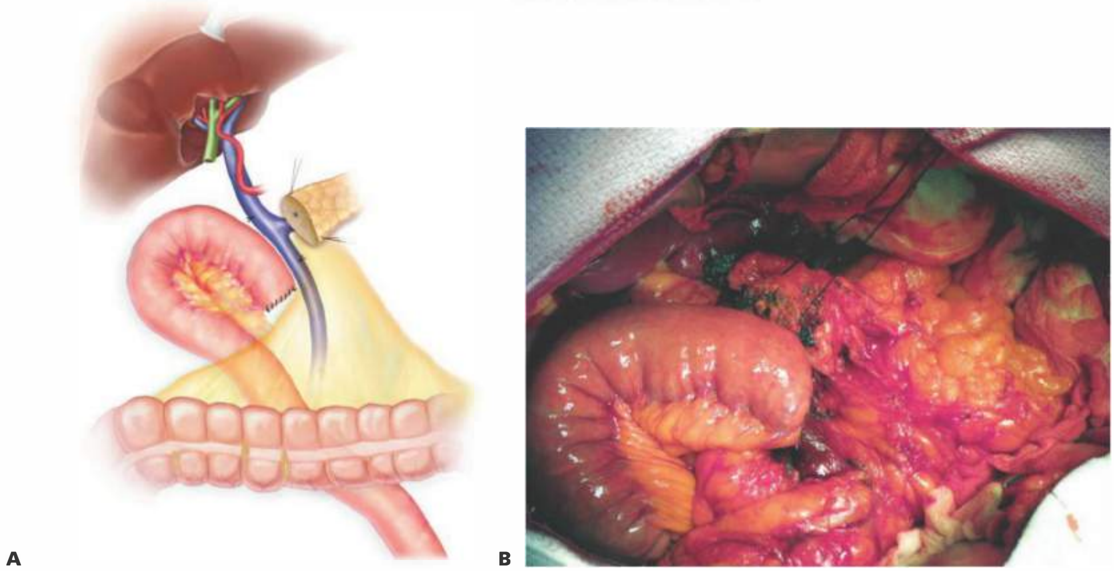


FIG 2 ● **A.** The pancreaticobiliary limb is positioned in the RUQ by bringing it behind the mesenteric stalk through the ligament of Treitz canal. **B.** In effect, this becomes a neoduodenum, as it lays comfortably in apposition with the pancreas and bile duct. Undue tension on this limb can be avoided by resecting at least 20 cm of proximal jejunum initially.

3 cm. This, along with traction on the transfixion sutures, will expose the back side of the gland so that the posterior row of the outer anastomotic layer can eventually be created. This is generally an avascular plane until the point where the splenic vein becomes incorporated by pancreatic parenchyma.

The Setup

- Once hemostasis of the pancreatic transection planes is achieved, the pancreaticobiliary drainage limb is introduced to the right upper quadrant (RUQ). Although many achieve this by placing it through the transverse mesentery in a retrocolic position, the author prefers to lay the limb in a completely retromesenteric fashion. The limb is introduced from the infracolic compartment (left side of midline) through the previous ligament of Treitz canal to the RUQ. Once placed in apposition with the remnant pancreas and the transected bile duct, this, in essence, becomes a "neoduodenum" (**FIG 2**). However, this may also be achieved in the more traditional fashion mentioned earlier, particularly in the cases where the patient has significant central obesity.
- Remember the hallmark surgical dictum that the success of an anastomosis is predicated on the following factors: (1) healthy tissue with a good blood supply, (2) lack of tension, and (3) freedom of distal obstruction. You can assure that the pancreaticobiliary drainage limb has a good pulse by palpating the vascular arcade within the mesentery after it has been placed in the desired position. Meticulous technique during the jejunal resection should assure that there is not a mesenteric hematoma, which might compromise the health of the limb. Do not shortchange the amount of proximal jejunum, which is originally resected, as this will shorten the mesenteric "leash" and therefore place tension on the limb as it reaches to the RUQ.
- Hemostasis of the transection plane of the neck of the pancreas is achieved by judicious use of the needle-tipped Bovie cautery on a low power (15 to 20). Energy near the pancreatic duct is avoided.
- The pancreatic duct diameter is examined and measured with a flexible ruler. An absorptive "Weck-Cel" arrowhead spear is useful in keeping the duct dry both now, and later, when precision is needed during suture placement in the duct (**FIG 3**).
- The duct can be actively dilated by placing the tips of a fine instrument (Gemini or pediatric right angle) within the duct and gently spreading and holding them open, being careful to not disrupt the duct tissue. Finally, the patency of the course of the pancreatic duct should be assured by advancing a 5- or 8-Fr pediatric feeding tube within the duct in a retrograde manner. These are flexible and safer than a rigid probe, which might be advanced inadvertently through the duct wall and even the parenchyma.
- The operative field is then prepared by covering the retraction devices with an arrangement of white towels which, in effect, excludes the retractor from the field and provides a neutral background to better visualize fine, colored monofilament sutures (**FIG 4**).

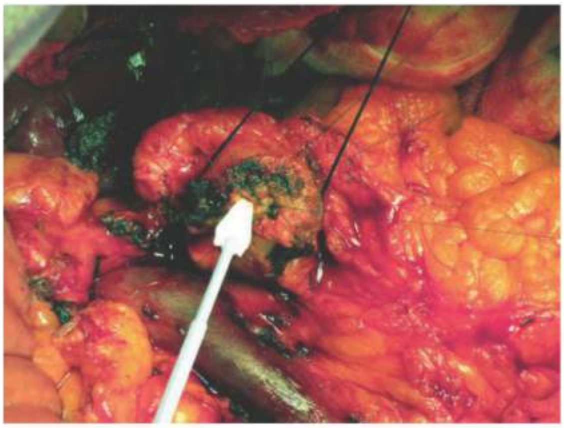


FIG 3 ● An arrowhead Weck-Cel facilitates precise visualization of the pancreatic duct.

FIG 4 ● Placement of four white surgical towels around the periphery of the incision enhances visualization of fine suture and prevents it from tangling on the retractors.

TECHNICAL CONSIDERATIONS

- The inner (duct-to-mucosa) anastomosis is constructed with monofilament absorbable suture. A 6-0 caliber is favored for normal to small ducts, but a 5-0 caliber can be used on larger, dilated ducts (≥8 mm). In select circumstances in *extremely* small diameter ducts (1 to 2 mm), a 7-0 caliber may be necessary. Remember that smaller grade suture has smaller needles, and thus creates smaller puncture holes. Double-armed sutures provide the most flexibility for needle placement, as some sutures are best applied from in to out, whereas others are optimally placed from out to in. This should be determined on a suture-for-suture basis, depending on how the arc of the needle is applied the most effortlessly through the duct.
- Due to the precision required for this step, a Castro Viejo needle driver is recommended rather than a bulky, longer driver controlled in the palm. Finer sized ducts (<3 mm) may benefit from the use of Loupe glasses for magnification.
- The author routinely *avoids* placing a pancreatico-enteric stent across the anastomosis, in light of its inefficiency in preventing pancreatic fistula, particularly in high-risk patients.[4] However, to increase precision of the needle placement in precarious ducts, some surgeons find value in creating the anastomosis with a small pediatric feeding tube temporarily in place during the anastomotic construction.

THE INNER LAYER—FRONT ROW

- The objective of this step is to "open" the duct orifice and further elevate the face of the transection plane into the field. The appearance of the transected duct can be compared to the face of a clock (**FIG 5**).
- Start by placing the 12 o'clock suture. These needles are curved considerably, and thus, the hand motion should allow for perpendicular placement of the needle tip into the parenchyma about 2 mm behind the duct. A curving motion will deliver it about a millimeter into the duct lumen, where it should be retrieved using a smooth "roll out" motion rather than a "tugging" technique.
- The two limbs of the suture are gathered, and the needle from the parenchymal side is removed while the needle attached to the limb emanating from the duct is maintained. A *straight snap* is used to identify that this is an ordinal point (3, 6, 9, and 12 o'clock positions; **FIG 5**) and is placed off the field in a manner that elevates the pancreas out of the incision slightly.

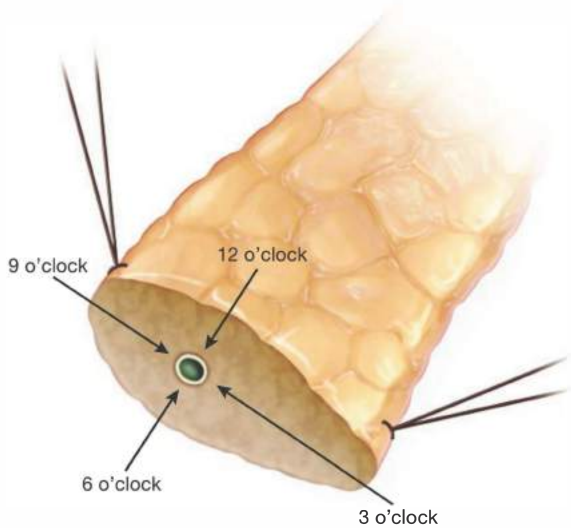
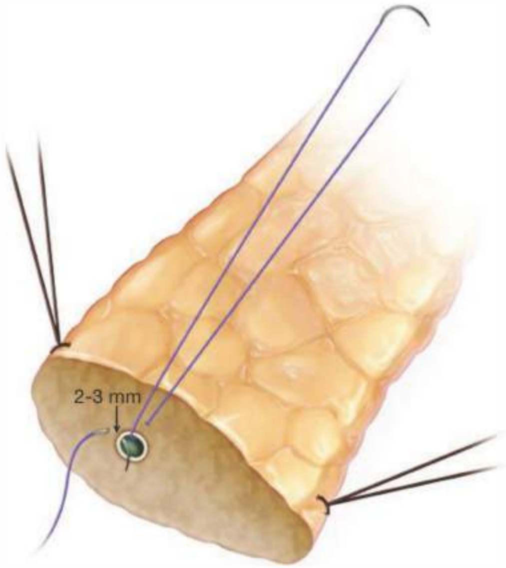


FIG 5 ● Clockface orientation of the pancreatic duct at the transection plane.



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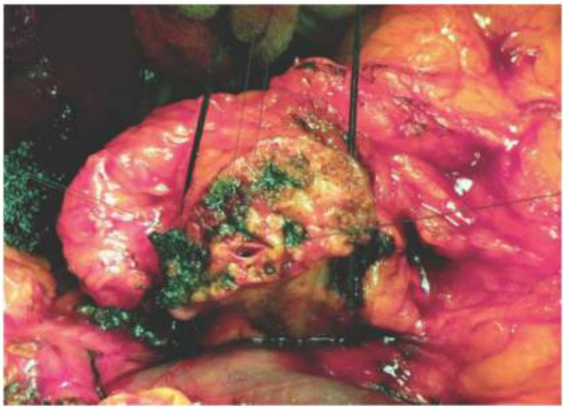
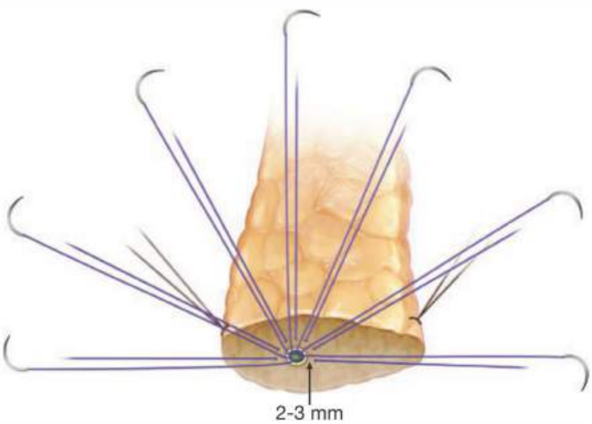


B

FIG 6 ● **A.** Placement of the 9 o'clock stitch from in to out on the pancreatic duct, incorporating a few millimeters of parenchyma around the duct. **B.** Placement of these initial stitches in the front row provides better exposure for subsequent stitch placement.

- The next moves consist of placing the 9 o'clock and 3 o'clock (horizontal plane) sutures which, when under tension, will fully "open up" the lumen of the duct (**FIG 6**). These are also gathered with straight snaps.
- Next, the two limbs can be completed from the horizon to the zenith (3 o'clock to 12 o'clock positions and 9 o'clock to 12 o'clock positions, respectively). A 3-mm duct will usually accommodate two evenly placed sutures in each of these limbs, for a total of seven sutures placed during this sequence (**FIG 7A**). However, there is room for flexibility to add more sutures as necessary (three to four per quadrant) for larger diameter ducts. To keep a semblance of order, these intermediate limb sutures should be gathered with *rubber shods* (**FIG 7B**).



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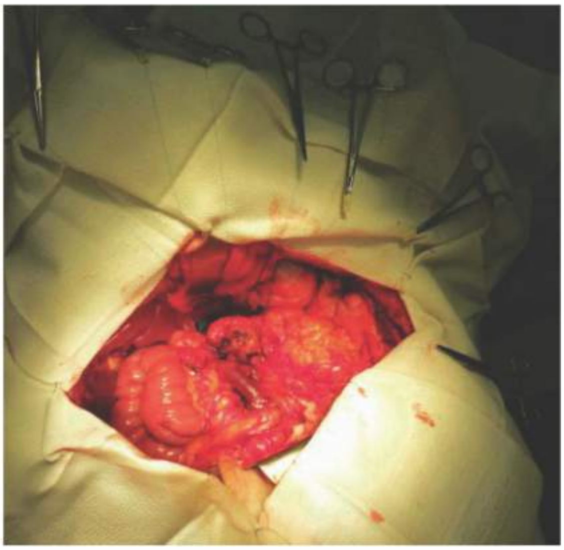


B

FIG 7 ● **A.** A 3-mm duct will accommodate seven double-armed sutures on the anterior row. Needles should be maintained on the limbs that exit the duct and cut off on the sides that enter the duct. **B.** To maintain consistency, sutures should be carefully laid out in an array across the external field. Straight snaps are used to gather the corner sutures, whereas rubber shods delineate other positions around the duct circumference.

PREPARATION OF THE ENTEROTOMY

- An appropriate-sized enterotomy is created on the antimesenteric side of the pancreaticobiliary drainage limb, about 5-cm upstream from the oversewn staple line. Care should be taken to match the diameter of this to correspond to the size of the pancreatic duct lumen. Do not make the enterotomy too big; in fact, undersize it if anything, as the opening tends to expand as you are working on it.
- A needle-tipped Bovie cautery works nicely here (**FIG 8**). Use the "cut" mode to precisely open the serosal level. Then, create a pinpoint opening of the mucosa in an atraumatic fashion. Avoid manipulating this fragile tissue with unnecessary instrumentation to minimize bleeding, hematomas, and edema.
- To optimize orientation and control of the mucosal outpouching, place four 6-0 sutures at the ordinal positions (3, 6, 9, and 12 o'clock) (**FIG 9A**). In doing so, the clock faces of the duct and the enterotomy should now mirror themselves (**FIG 9B**). These sutures should be very small bites, which tack the mucosa to the serosa in the four corners (**FIG 9B**, *inset*). Again, the precision of a Castro Viejo instrument is preferred to minimize tissue trauma.

FIG 8 ● The enterotomy is created with excellent precision using a needle-tipped Bovie cautery. The serosal layer is opened about 2 mm for a corresponding 3-mm wide pancreatic duct. Create a pinpoint opening in the mucosa at first.

A

B

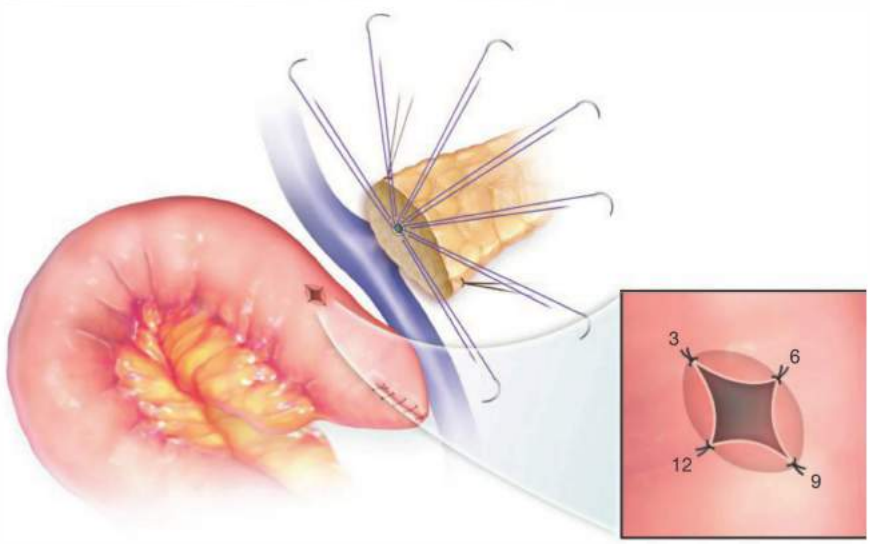


FIG 9 ● **A.** In order to "tidy up" the enterotomy, 6-0 absorbable sutures are applied to each corner by tacking the mucosa to a small (1 mm) bite of serosa. Use care to prevent undue manipulation of the mucosa. **B.** These sutures prevent puckering of the mucosa *(inset)* and again indicate a clockface configuration, which now forms a mirror image of that of the duct.

THE OUTER LAYER—BACK ROW

- This element is best achieved earlier in the process rather than after the inner layer has been completed. It is important to properly size up where the sutures will be placed vis-à-vis the duct and enterotomy. In doing so, you can assure a good apposition of the duct and the enterotomy, which will not be under tension.
- Fewer sutures here mean less opportunity to damage the usually fragile pancreatic parenchyma. Therefore, most of distance of the back row can be approximated with two *horizontally* placed 2-0 or 3-0 silk sutures, limiting the number of holes introduced into the gland.
- The first suture is placed on the lateral posterior surface of the pancreatic capsule and emerges in the midline of the pancreas about 1 cm behind the transection edge (**FIG 10A**). Care is taken to keep this bite rather superficial so as not to incorporate the pancreatic duct beneath yet deep enough to "grip" enough parenchyma so that it does not rip through when being tied down.
- This is then brought across to the bowel, where the direction of the needle travel is now from medial to lateral on a line about 1.5 to 2 cm peripheral from the enterotomy (**FIG 10B**). Assuming the enterotomy is situated at the antimesenteric edge of the bowel circumference, this essentially equates to about a quarter of the way from the interface of the bowel and its mesentery.
- A second posterior suture is placed in an analogous fashion. This time, however, the first move is from lateral to medial on the bowel (**FIG 11A**), and then across to the gland where it is placed in a medial to lateral trajectory (**FIG 11B**). Thus, the knots of each of these sutures are tied down laterally.
- Extra security of the periphery of this row can be achieved by one to two additional silk sutures on each side, tied again on the outside. The bowel now lays in direct apposition with the cut face of the pancreas (**FIG 11C**).

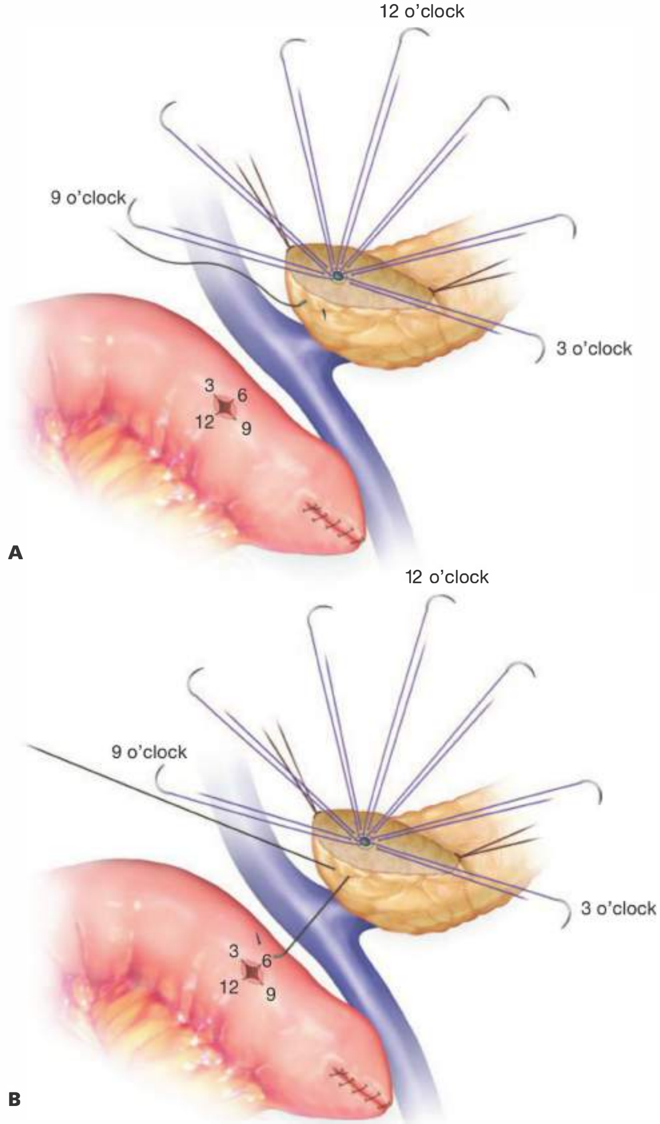
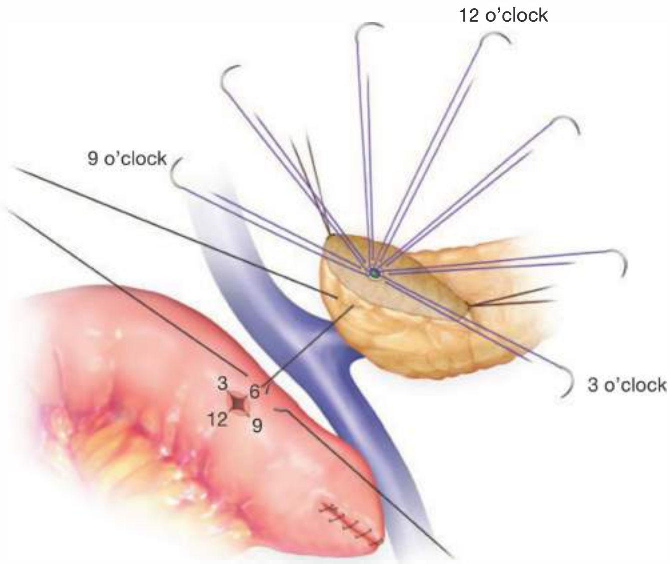


FIG 10 ● **A.** Construction of the back row of the outer layer commences with a horizontally oriented silk suture placed from lateral to medial on the posterior surface of the pancreas. The needle should emerge at the midpoint of the gland but be placed superficially to avoid involving the pancreatic duct behind it. **B.** This suture is then brought across to the bowel and applied in a medial to lateral direction so that the knot can be tied on the periphery of the pancreas.



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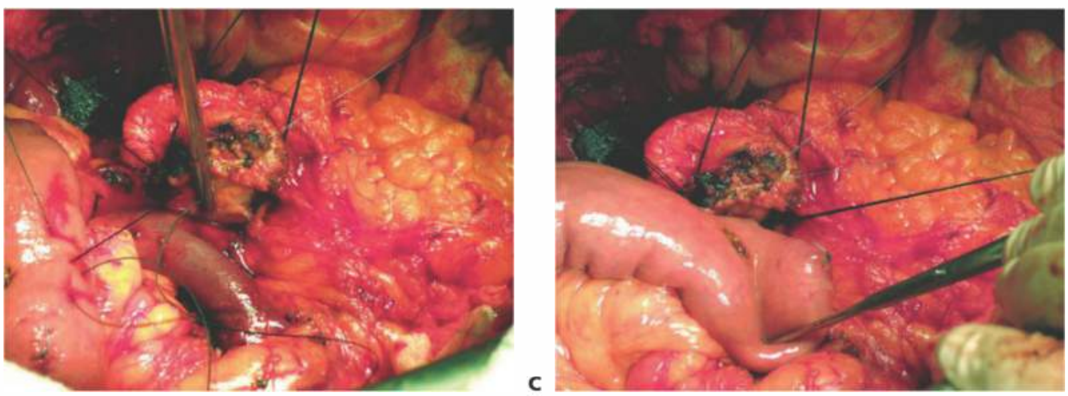

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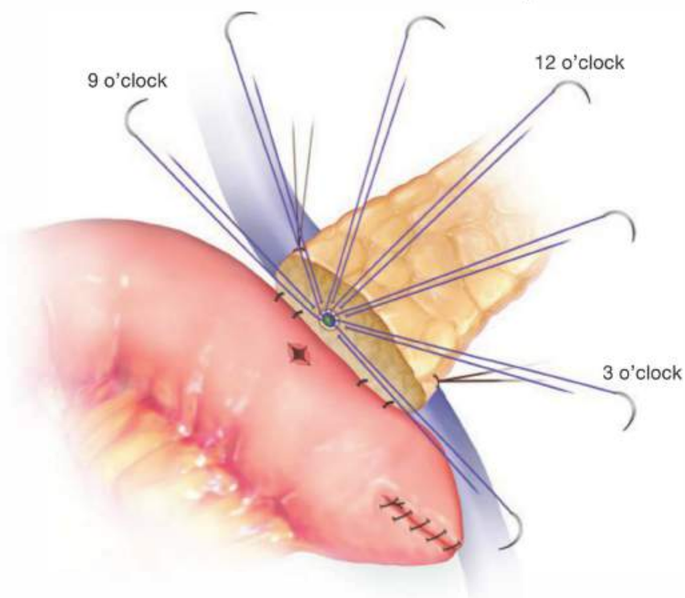


D

FIG 11 ● **A.** The back row is continued in an analogous fashion. First, a silk suture is placed from lateral to medial in the horizontal plane on the bowel to meet the prior stitch. **B.** Then, the suture is applied from the midpoint of the pancreatic parenchyma laterally to the inferior border of the posterior pancreas. **C.** Demonstration of the relative distance of suture placement. Sutures on the posterior pancreatic parenchymal surface should be about 1 to 2 cm behind the transection margin, whereas the position on the bowel usually corresponds to about one-fourth around the circumference from the enterotomy site. **D.** Once the back wall is completed with a few additional sutures on the periphery, the enterotomy will be appropriately positioned across from the orifice of the pancreatic duct.

THE INNER LAYER—BACK ROW

- If the previous step is well performed, the enterotomy site of the bowel should "roll over" to align with the pancreatic duct without any tension. Now, place a single-armed 6-0 monofilament suture at 6 o'clock position within the duct such that it curves out about 2 mm in the transected plane of the parenchyma (**FIG 12A**). Roll this through carefully.
- Then, place it through the bowel serosa about 2 mm away from the edge of the mucosa of the enterotomy (**FIG 12B**). Advance this through the enterotomy at the site of the 6 o'clock marking stitch, being careful to not incorporate the mucosa of the opposite side. Gather the suture, and after the needle is removed, apply a straight clamp to indicate that this is the midpoint of the posterior row.
- Next, using the same technique, place two to three sutures in each lower quadrant of the duct coming from medial to lateral (**FIG 13**). Gather these with rubber shods after the needle is placed through the bowel and removed. The sequence of placement of this row is demonstrated in (**FIG 14**). Again, you can be flexible with how many sutures are needed on each quadrant based on the actual duct diameter.
- Once these have all been placed, tie them down from the middle suture (6 o'clock position) to the periphery. You will notice that the knots of this absorbable suture are all on the inside of the anastomosis.

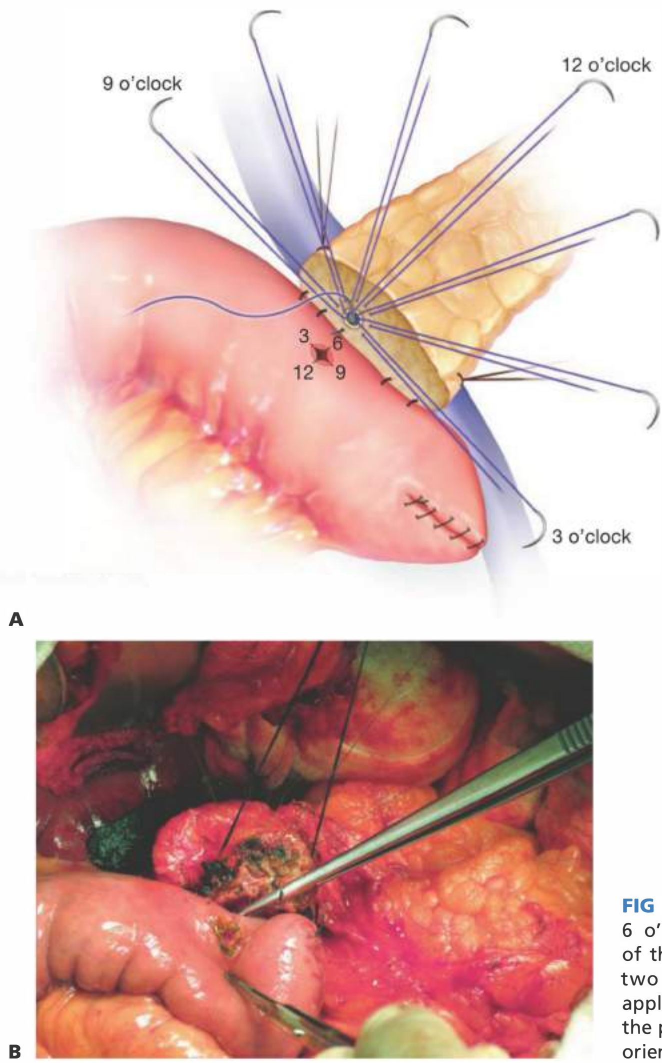


FIG 12 ● **A.** Placement of a suture from in to out at the 6 o'clock position of the duct begins the construction of the back row of the inner layer. Take a millimeter or two of parenchyma with the bite. **B.** This suture is then applied to the bowel and brought through the mucosa at the point corresponding to the previously placed 6 o'clock orientation suture.

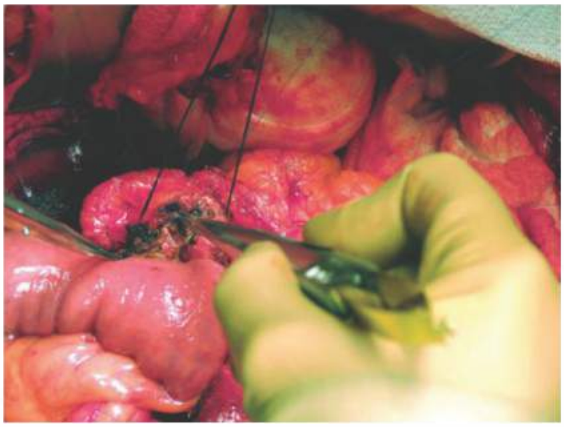


FIG 13 ● Placement of the 7 o'clock stitch from in to out on the duct. This is then continued from out to in at 4 o'clock position on the bowel.

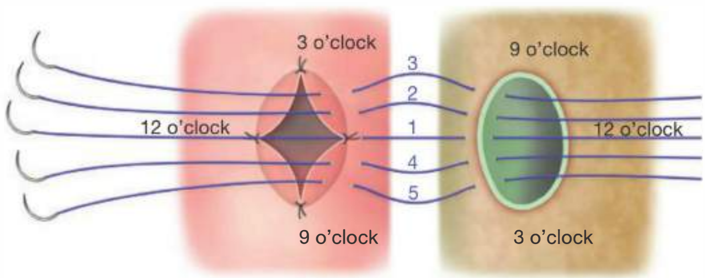
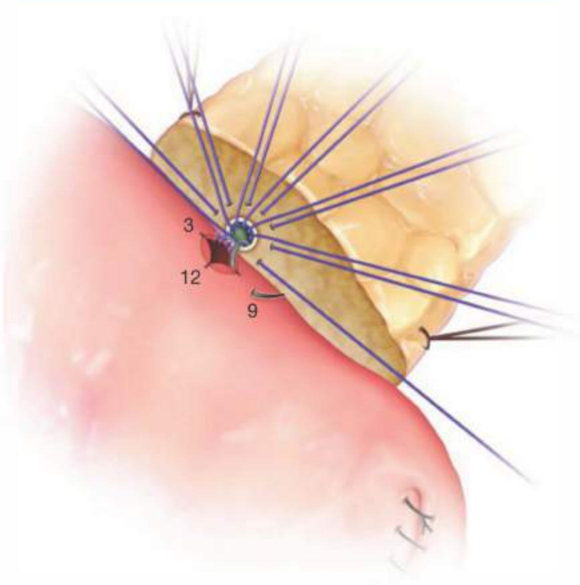


FIG 14 ● Sequence of placement of sutures for the back row of the inner layer. The general theme is to work from medial to lateral for optimal exposure of needle placement.

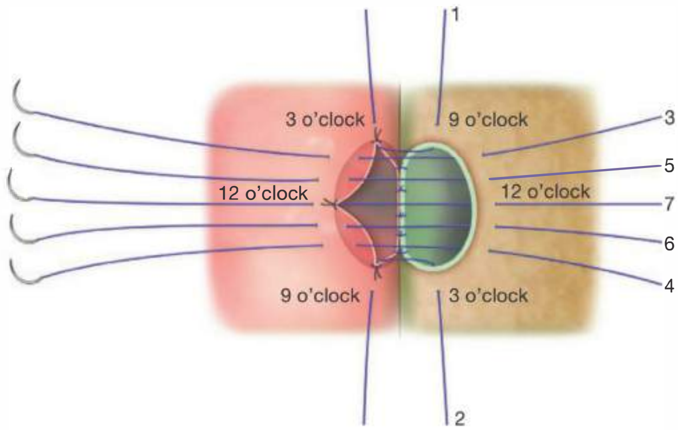
COMPLETION OF THE INNER LAYER—FRONT ROW

- Now it's time to revisit the originally placed sutures from the front row of the inner layer. These are placed serially across to the enterotomy—this time working from the lateral (3 o'clock and 9 o'clock) positions up to the zenith (12 o'clock position) (**FIG 15A**). The sequence of placement is depicted in **FIG 15B**.
- Ensure that the suture limbs are unwound completely before placing across to the enterotomy, as twisted sutures across the anastomosis will lead to a leak. Again, be careful not to incorporate the mucosa of the back wall of the enterotomy. Only once, all the sutures from both limbs are placed across to the bowel should you tie them down. These knots will be external to the anastomosis.



A

FIG 15 ● **A.** Completion of the front row of the inner layer starts by placement of the previously placed corner sutures (either 3 o'clock or 9 o'clock position) from in to out on the enterotomy. *(continued)*



B

FIG 15 ● *(continued)* **B.** The optimal sequence of this placement is depicted, reflecting a general movement from the horizon (3 o'clock and 9 o'clock positions) up to the zenith (12 o'clock position). Place all sutures across to the bowel before any one of them is tied.

THE OUTER LAYER—FRONT ROW

- The pancreaticojejunal reconstruction is completed by securing the front row of the outer layer. The 2-0 silks are placed carefully into the pancreas about half a centimeter behind the cut edge of the parenchymal transection edge (**FIG 16**). Although these need to be substantial particularly in softer glands, take care to stay superficial to the inner anastomosis, particularly, because as you get closer to the center of the gland, the parenchyma becomes shallower.
- Bring these sutures across to the serosa of the bowel limb. Allow for some distance (5 to 10 mm) between the inner anastomosis and the needle placement into the bowel. This allows for enough redundancy such that the bowel will roll over to the face of the transection without placing undue tension to the pancreatic capsule (**FIG 17**).
- The greatest of care is needed when tying these sutures down to avoid "sawing" through the parenchyma. Avoid "bobbing" movements as you are tying these knots, as this will lift the suture out of the field and thus cause a linear tear through the parenchyma.

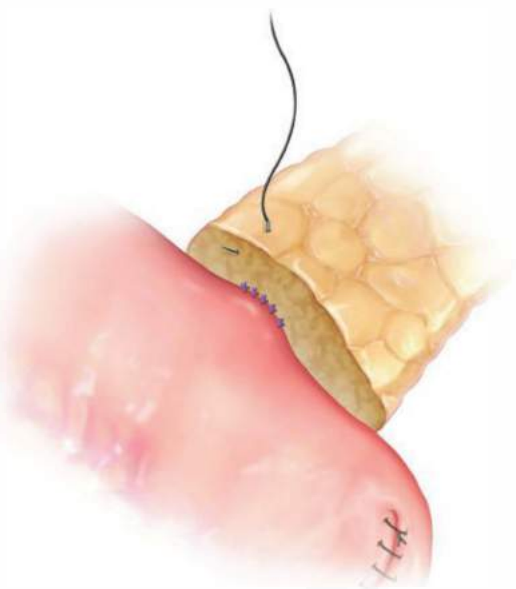


FIG 16 ● The front aspect of the outer layer is completed by placing silk sutures into the pancreatic parenchyma. Once placed across to the bowel, tie these down with the greatest of care because the pancreas capsule is vulnerable to tearing. Again, work from the lateral aspects of the gland sequentially to the midpoint (directly over the inner anastomosis).

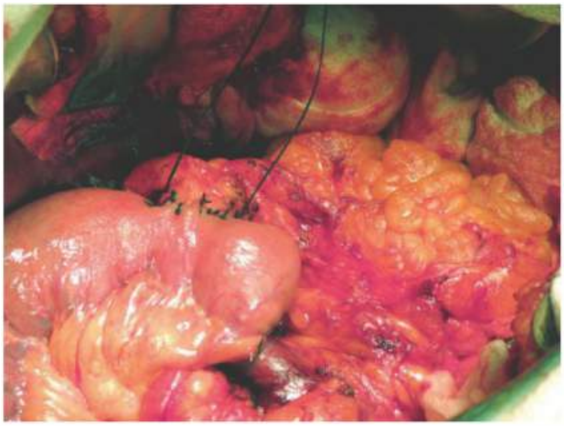


FIG 17 ● Final appearance of the double-layered anastomosis showing the tension-free apposition of the bowel to the pancreatic capsule.

TECHNIQUES

FINAL STEPS

- In select circumstances, some pancreas will have a fibro-fatty layer on their anterior surface. Try to preserve this when initially dissecting and transecting the pancreas, and keep it attached to the pancreatic body. If it is available, it can be applied across to the bowel wall with silk sutures to essentially provide a third layer (hood) for the anterior row.
- You may also be able to attach the redundant bowel near the distal staple line to elements of the transverse mesocolon inferior to the anastomosis in order to help secure the limb against an outright dehiscence.
- Finally, a drain can be placed in the vicinity. I prefer a thin, fluted 19-Fr Blake drain and place it just anterior to the anastomosis. Avoid placing rigid drains directly behind the anastomosis, which necessarily places them between the pancreas and the portal and superior mesenteric veins.

PEARLS AND PITFALLS

Prelude	■ A good pancreaticojejunostomy begins during the resection phase with attention to detail. Minimize unnecessary blood loss and avoid undue tissue trauma to the pancreatic parenchyma. ■ Although finesse is required for the first half (resection phase) of PD, the tone of the reconstruction phase is markedly different, with concentration on detail, and the surgeon should reorient their mindset accordingly at this point of the case.
Setup	■ Assure that the pancreaticobiliary drainage limb is viable, nonedematous, and healthy with good blood flow, and adequate laxity to the RUQ structures. ■ To minimize technical mishaps with fine-caliber sutures, cover the retractor system with a field of white towels. ■ Castro Viejo needle drivers provide the precision necessary for the delicate suturing required.
The inner anastomosis	■ Control the operative field by consistently applying straight clamps to gather ordinal (3, 6, 9, and 12 o'clock positions) sutures. Employ rubber shods for the in-between positions. ■ Use a deliberate, rolling motion in placing the suture through the duct and parenchyma, taking advantage of the natural arc of the needle. Avoid tugging motions when controlling the needle.
The outer anastomosis	■ Take care to keep the bites shallow, yet substantial, so as to avoid the inner layer of the anastomosis or pancreatic duct distal to it. ■ Careless suture tying at this point can lead to tissue fractures of the pancreatic capsule, even in firm glands.

POSTOPERATIVE CARE

- The drain can be assessed for amylase activity once the patient is tolerating a soft diet, which will stimulate vigorous pancreatic secretion (usually around day 5 or 6).
- The drain can be removed if the patient appear clinically well, the drain amylase level is low (generally under 300 International Unit), the volume is reasonable, and the fluid does not appear sinister.[1]
- Drain amylase values between 300 and 1,000 International Unit are indeterminate and require judgment about the individual patient's circumstances. Levels over 1,000 International Unit are highly suggestive of a leak and warrant the continuation of external drainage, and possibly, more intervention (radiology assessment, percutaneous or operative procedures, etc.).
- If a postoperative leak is clinically apparent, general guidelines for management are provided in a review by Callery et al.[5]

OUTCOMES

- This described pancreatic anastomotic technique has resulted in a 3% clinically relevant fistula rate in the author's last 70 cases in patients with an average Fistula Risk Score of 3.70.[3]

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Chapter **37**

Pancreaticoduodenectomy: Pancreaticogastrostomy

Laureano Fernández-Cruz

DEFINITION

- Pancreaticogastrostomy (PG) is defined as the anastomosis of the remnant pancreas to the stomach rather than a limb of jejunum. This procedure is necessary following pancreaticoduodenectomy or central pancreatectomy.

DIFFERENTIAL DIAGNOSIS

- PG is a viable option regardless of the indication for pancreatic resection requiring reconstruction.
- PG may be a particularly attractive option for patients with intraductal papillary mucinous neoplasms (IPMN). In these patients, the rationale for surgical intervention is reduction of risk for malignant transformation. Many surgeons advocate partial pancreatectomy for IPMN, trading the risk of progression of disease in the remnant against the brittle diabetes associated with total pancreatectomy. However, this approach mandates surveillance of the pancreatic remnant. PG theoretically provides straightforward access to the remnant duct to facilitate this surveillance, but clinical benefit has not been proven.
- PG should also be considered for reconstruction of the distal, remnant pancreas in the rare situation that central pancreatectomy is performed. PG avoids the need for creation of a Roux limb, and although complications of this component of intestinal reconstructions are rare, they do occur.

PATIENT HISTORY AND PHYSICAL FINDINGS

- Pancreatic fistula has a central role in the development of other intraabdominal complications and occurs with a frequency of 5% to 30%.[1,2] Risk factors for pancreatic fistula include a soft pancreas, a small pancreatic duct, the underlying pathology, reduced regional blood supply, and the surgeon's experience.[3,4] Thus, patient factors impact the risk of pancreatic fistula.

SURGICAL MANAGEMENT

Preoperative Planning

- Efforts to reduce the rate of pancreatic fistula have encompassed the consideration of replacing the pancreaticojejunal (PJ) anastomosis with PG.
- The lack of a uniform technique for performing PG has led to the same debate as that regarding the PJ anastomosis (duct-to-mucosa, invagination, or telescoping the pancreatic remnant into the gastric cavity).
- At present, there is still no consensus on the choice of anastomotic technique (PJ vs. PG). There have been four prospective randomized controlled trials (RCTs) comparing PJ with PG.[3,5–7] Three RCTs[5–7] showed similar pancreatic fistula rates for the two types of pancreatic anastomosis: 12%, 16%, and 13% for PG and 11%, 21%, and 16%, respectively, for PJ. In one recent RCT,[3] the pancreatic fistula rate was significantly lower after PG (4%) compared with that after PJ (18%).
- PG has been gaining favor in recent years. Of historical interest, the clinical introduction of this procedure originated when Waugh and Claggett[8] reported it in 1946.

TECHNIQUES

TELESCOPIC INVAGINATION

- Delcore et al.[2] reported a method of PG in which the pancreatic remnant was telescoped into the gastric lumen (a small gastrotomy is made in the posterior gastric wall) without any stenting of the main pancreatic duct.
- PG is performed either through the transected gastric stump prior to gastrojejunostomy or through an anterior wall gastrotomy (in the case of a pylorus-preserving procedure) (**FIG 1**).
- The most important technical aspect of this anastomosis is establishing adequate mobilization of the remnant pancreatic body and tail. At least 3 cm is required, but greater mobilization is not discouraged provided it does not compromise perfusion.
- A posterior, transverse gastrotomy is created. Attention to the size of the gastrotomy is paramount and should take the elastic nature of the stomach into consideration. The need to dilate the gastrotomy to accommodate the pancreatic remnant is a welcome finding.
- A generous longitudinal, anterior gastrotomy is performed directly opposite of the posterior gastrotomy to provide access to the lumen side of the PG. (Alternatively, the staple line from the antrectomy that will be used for a subsequent gastrojejunostomy is removed.)
- The pancreaticogastric anastomosis is fashioned by taking full-thickness bites of the stomach to the pancreas.
  - Start at the most cranial aspect of the anastomosis. Work caudally, alternating between the posterior and anterior sutures so that the anastomosis

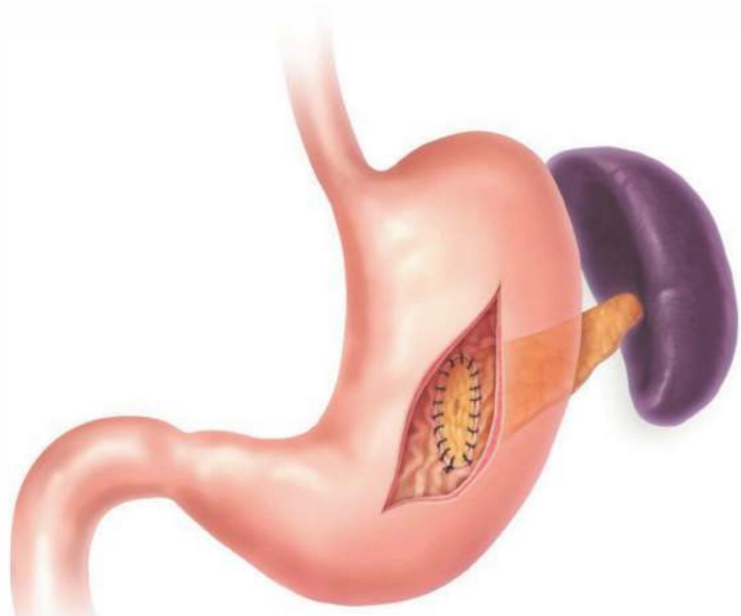

FIG 1 ● The PG anastomosis described by Aranha.[9] The pancreatic remnant is invaginated into a posterior gastrotomy while being visualized through a generous anterior gastrotomy. In a single layer of interrupted sutures, the pancreatic parenchyma is sutured to full-thickness bites of the stomach.

is finished at the caudal aspect. This approach facilitates exposure to each subsequent bite without having to put undue tension on previously placed sutures.

- Interrupted 3-0 silk sutures are used. Pass the needle through the pancreas tissue outside of the stomach lumen so that the needle can be retrieved on the extraluminal side. Then, pass the suture through the gastrotomy and then "back inside-out," taking a full-thickness bite of the stomach wall.
    - Most experienced surgeons prefer to tag each suture; they will be tied after all sutures have been thrown.
    - Place the sutures circumferentially, spaced every 3 to 4 mm.
- As the sutures are tied, the pancreas is invaginated into the lumen of the stomach.
- The anterior gastrotomy is closed in two layers as classically described.

INVAGINATING PANCREATICOGASTROSTOMY

- Aranha[9] describes a one-layer invaginating PG after pancreaticoduodenectomy.
- For this approach, the pancreatic remnant is mobilized for a distance of 4 cm.
- As mentioned earlier, the size of the gastrotomy must accommodate stretching of the gastric wall, and an anterior longitudinal gastrotomy is created to provide exposure to the lumen.
- Interrupted 3-0 silk sutures are placed.
- The beauty of this technique is the visualization and simplicity. It is performed entirely while visualizing the luminal aspect of the anastomosis.
- Begin inside the lumen of the stomach, taking a full-thickness bite. In one move, take a bite of pancreas, entering the exterior gland exiting in the transected edge that can be seen from the luminal side of the intended anastomosis.
- The sutures are tied as they are placed; the end result is a mild invagination of the pancreas into the stomach (FIG 2).

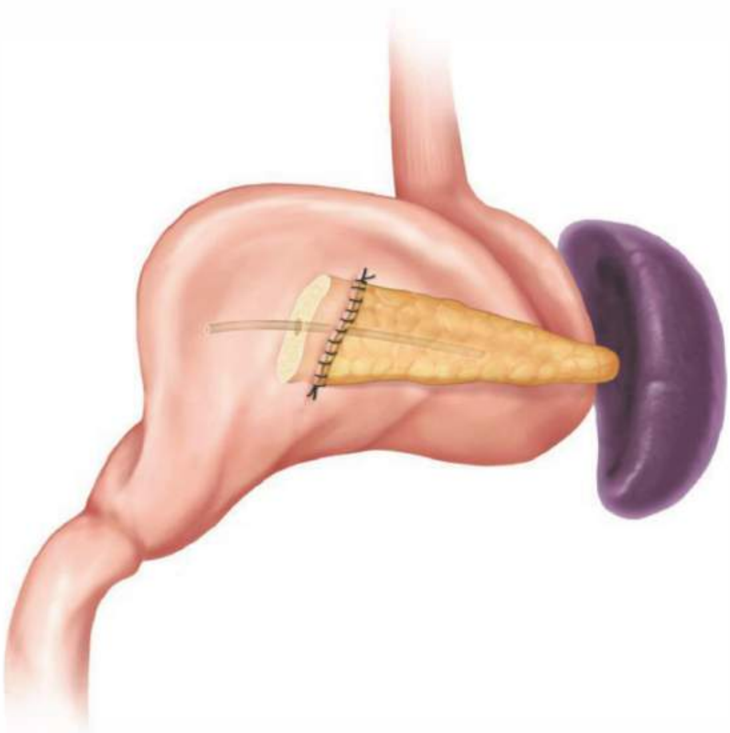

FIG 2 ● Line art drawing of the completed anastomosis. The value of the surgeon's ability to visualize the intussusception through a generous, longitudinal gastrotomy cannot be overemphasized.

DUCT TO MUCOSA

- As an alternative PG, Telford and Mason[10] have reported that direct anastomosis of the pancreatic duct to gastric mucosa provides better patency of the pancreatic duct as compared to a simple invagination procedure (**FIG 3**).
- Initially, silk sutures are placed from the posterior, cephalad gastric wall to the anterior pancreas body. Importantly, this is contrary to PJ, where the posterior aspect of the pancreas is first addressed.
- With this layer in place, a duct-to-mucosa anastomosis is fashioned.
- A small gastrotomy is made adjacent to the pancreatic duct. Posterior, cephalad, interrupted 5-0 absorbable, monofilament sutures are placed so that the subsequent knots are within the lumen of the anastomosis. With the surgeon on the right side of the patient, these sutures enter the lumen of the pancreatic duct, exit the parenchyma, and then proceed outside-to-inside, incorporating the full thickness of the gastric wall.
- Magnification is highly recommended during the placement of these sutures.
- The report by Telford and Mason[10] included the use of a silastic stent. This is optional, but if used, the stent should be placed after the sutures of the posterior row have been thrown and tied.
- The anterior, inferior suture line of the duct-to-mucosa anastomosis is placed and the sutures tied. These knots lie outside the lumen.
- Sutures (3-0 silk) are placed to oppose the posterior, inferior gastric wall to the posterior pancreas body.

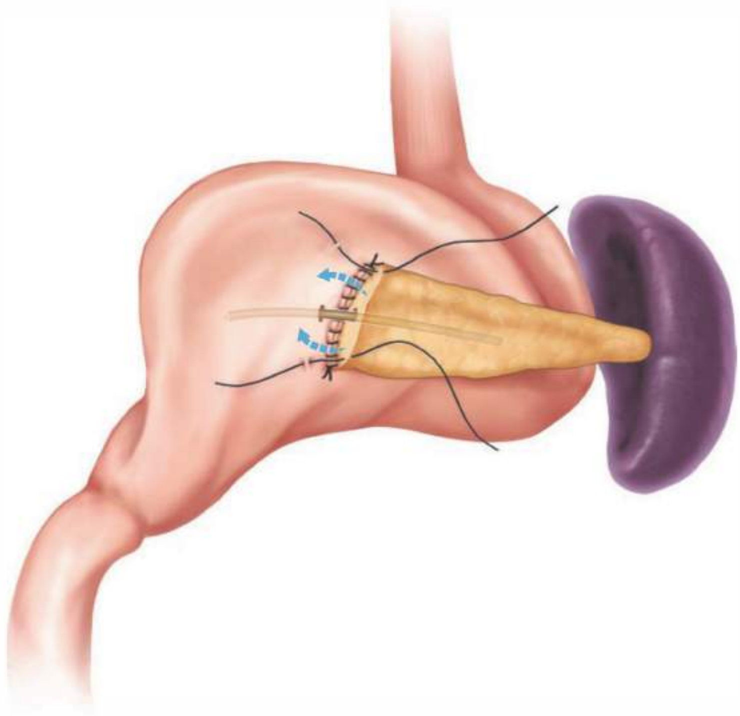

FIG 3 ● Duct-to-mucosa anastomosis. The posterior row of the anastomosis is opposite of that of a PJ anastomosis; the anterior aspect of the pancreatic remnant is first approached.

GASTRIC PARTITION

- Recently, a new technique of pylorus-preserving PD with gastric partition has been reported.[6]
- Gastric partition is performed using two or three Endo GIA staplers along the greater curvature of the stomach, 3 cm from the border. This gastric segment, 10 to 15 cm in length, is placed in close proximity to the cut edge of the pancreatic stump. An end-to-side, duct-to-mucosa anastomosis or invagination anastomosis is constructed (**FIG 4**).
- The construction of this duct-to-mucosa anastomosis is essentially identical to that described earlier, differing only in that the anastomosis is to the gastric partition conduit. This technique is particularly attractive for resections that are performed for IPMN. It provides access to the PD, should completion pancreatectomy prove indicated at a later date, and has profound implications regarding the complexity of that procedure; one only needs to fire a staple load across the stomach to manage the restorative conduit.

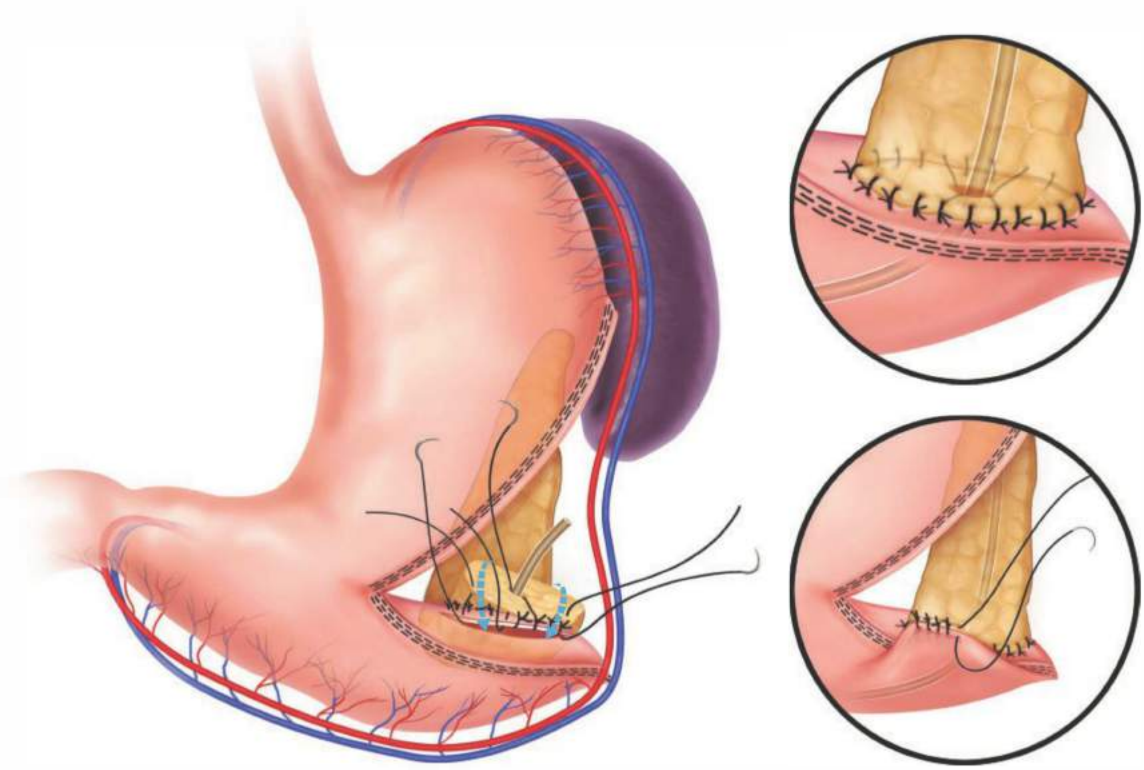

FIG 4 ● Gastric partitioning and duct-to-mucosa anastomosis. The setup to this approach is identical to that of pancreaticojejunostomy. The partition provides additional mobility and access for surveillance and simplifies completion pancreatectomy.

PEARLS AND PITFALLS

History and physical exam	■ PG should be considered when the remnant pancreas is at risk of IPMN progression; it facilitates surveillance and completion pancreatectomy. ■ PG is an attractive option when central pancreatectomy is performed. It avoids the need to fashion a Roux limb.
Surgical management	■ The reduced technical demands of invaginating a soft pancreatic remnant deeply into a posterior gastrotomy, when compared to a duct-to-mucosa PJ, largely explain the enthusiasm for this approach. ■ The back suture row of a PG is to the anterior aspect of the pancreas.
Outcomes	■ Outcome comparisons of PG to PJ have been hampered by variations in technique.

POSTOPERATIVE CARE

- A nasogastric tube is left in place. Despite natural concerns, it can safely be removed on postoperative day 1 in the majority of patients.
- A liquid diet is initiated the following day, provided the patient does not complain of hiccups, nausea, or excessive belching and does not have a distended stomach by physical examination.
- A drain is left in the pancreatic bed and a drain amylase is checked after postoperative day 3. Drains with normal amylase (<1,000 IU/dL) are removed prior to patient discharge.

OUTCOMES

- The analysis of the four RCT[3,5–7] comparing PG and PJ does not allow us to conclude that one of the techniques is superior to the other regarding prevention of complications after PD.
- In the Yeo et al.[7] study, PJ was performed in either end-to-end or end-to-side fashion, at the surgeon's discretion. PG was accomplished by anastomosing the pancreatic remnant to the posterior gastric wall; the average size of the posterior gastrotomy is 2.5 to 3 cm. In the Bassi et al.[5] study, PJ was carried out using a single-layer PJ or duct-to-mucosa technique, and PG was carried out by telescoping the pancreatic remnant into the gastric cavity.
- In the Duffas et al.[6] study, PJ could be performed end-to-end or end-to-side, but the technique of PG was not described.
- In the Fernández-Cruz et al.[3] study, PJ was carried out as an end-to-side, duct-to-mucosa anastomosis, and PG was performed using a gastric partition and duct-to-mucosa anastomosis. Transanastomotic internal stent was used for both PJ and PG.
- Given this variability in techniques, these RCTs have not resolved the notion that PG is superior to PJ with respect to the rate of pancreatic fistula, and this topic remains a subject of controversy.

COMPLICATIONS

- Pancreatic fistula
- Pseudoaneurysm
- Delayed gastric emptying

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Chapter **38**

Laparoscopic Pancreaticojejunostomy

Steven J. Hughes

DEFINITION

- Laparoscopy indicates the use of a camera combined with minimal access techniques to perform surgical, abdominal procedures.
- Pancreaticojejunostomy (PJ) is the operative anastomosis of a remnant pancreas (distal pancreas) to a limb of jejunum to restore continuity of pancreatic secretions into the intestinal tract. This procedure is necessary following pancreaticoduodenectomy.

PATIENT HISTORY AND PHYSICAL FINDINGS

- Pancreatic texture will vary depending on the underlying indication for pancreaticoduodenectomy as well as associated patient factors.[1] The pancreatic duct may also vary in size, depending on whether the duct has been previously obstructed, has been involved in intraductal papillary mucinous neoplastic changes, or is of normal caliber.
- The major risk of PJ is leakage of pancreatic secretions leading to abscess or fistula. A classification scheme for the severity of this complication has been characterized.
- This complication is less frequent when the pancreas is firm in texture, thus providing a substrate that firmly anchors sutures and is not prone to laceration.

SURGICAL MANAGEMENT

Positioning

- The patient is positioned supine; tucking of the arms is not necessary (**FIG 1**). Some surgeons prefer a "split-table" approach, where the surgeon is positioned between the patient's legs.
- Reverse Trendelenburg position facilitates the exposure. Thus, a footboard should be used.

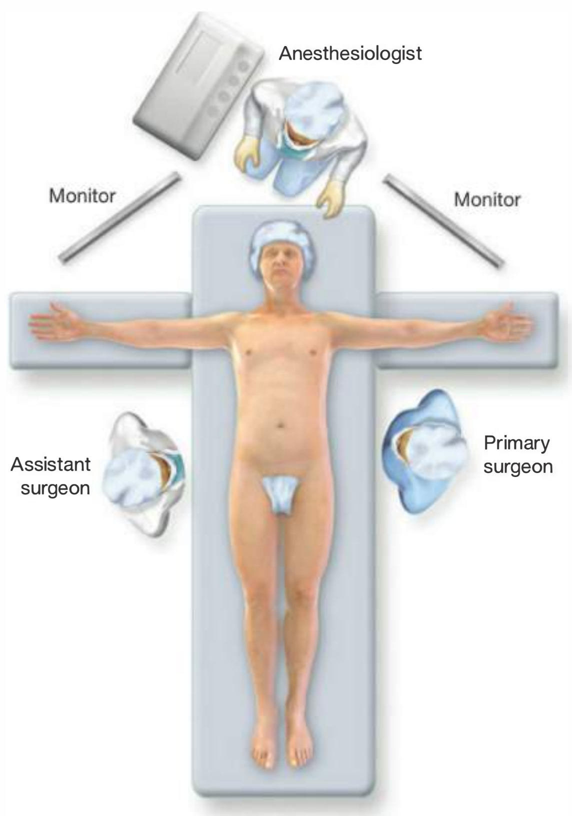


FIG 1 • The patient is positioned supine with both arms extended. The operating table is placed in reverse Trendelenburg to facilitate exposure of the upper abdomen. The surgeon is positioned to the patient's left. Some surgeons use a split-leg position so that the operating surgeon can be positioned between the patient's legs.

TROCAR PLACEMENT

- Trocar placement is depicted in **FIG 2**. Five access points are the minimum required to perform the technique laparoscopically. A fixed retractor is placed in the far right port to elevate the left lobe of the liver and improve exposure to the pancreatic remnant. The other trocars are used for the camera, a first assistant, and the operative surgeon.

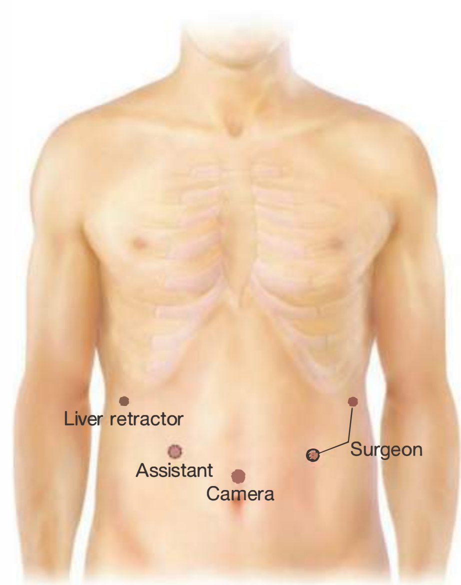


FIG 2 ● Trocar placement. A five-trocar scheme is employed.

MOBILIZATION OF THE REMNANT PANCREAS

- To complete the posterior suture row of the anastomosis, a minimum of 1 cm and ideally 2 cm of the remnant pancreas must be mobilized (**FIG 3**). Increased mobilization of the remnant pancreas facilitates elevation of the gland during the anastomosis and results in improved visualization.
- The reconstructive limb should be fashioned focusing on adequate mesenteric length and preservation of the arterial and venous blood supply. A number of options regarding reconstructive anatomy are available. The author favors positioning the reconstructive limb posterior to the mesenteric vessels as a "neoduodenum."[2] Given the natural orientation of the mesentery of the proximal jejunum, this reconstructive approach minimizes the length of the mesentery necessary to perform the PJ in a tension-free environment. This approach also reduces the potential for internal hernia or other technical errors associated with creating a window in the transverse mesocolon. Importantly, this approach avoids excessive rotation of the jejunal limb behind the mesenteric vasculature.

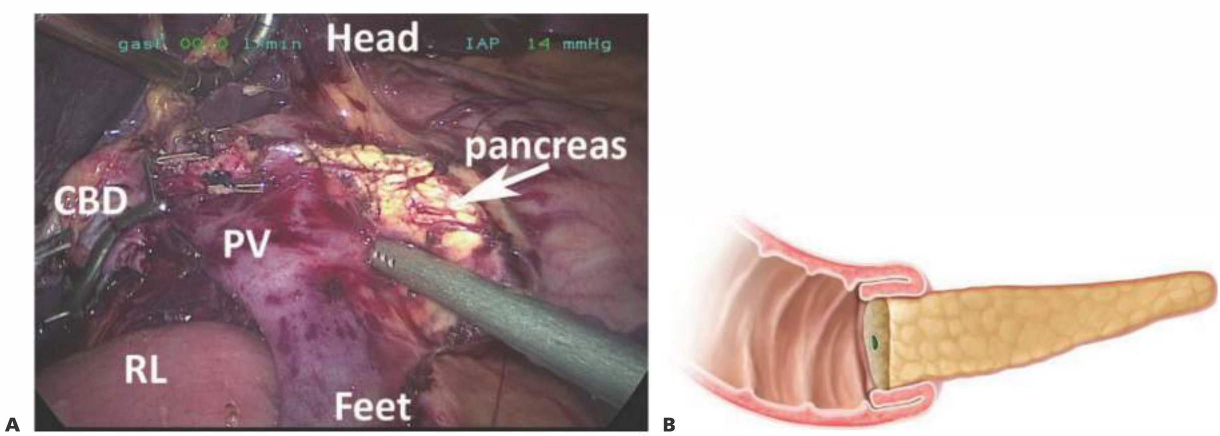
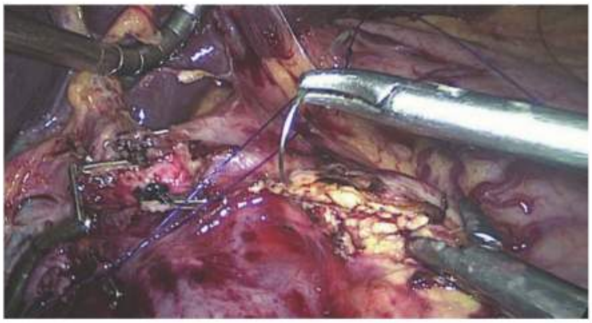


FIG 3 ● **A.** The surgical field prior to initiation of the PJ. After completion of the dissection, the pancreatic neck is circumferentially mobilized for at least 1 to 2 cm. *CBD*, common bile duct; *PV*, portal vein; *RL*, reconstructive limb of jejunum. **B.** Schematic drawing of the completed anastomosis with the pancreas intussuscepted approximately 1 cm into the end of the reconstructive limb of jejunum.

TECHNIQUE 1: END-TO-END INTUSSUSCEPTING ANASTOMOSIS

- The anastomosis is constructed with a running 4-0 polydioxanone suture on a vascular RB-1 needle. A double-armed suture measuring 40 cm in length (20 cm for each arm) is fashioned by tying two sutures together. The suture is placed through a 12-mm trocar and one arm is positioned out of the surgical field in the left upper quadrant. This arm will be used later for the anterior suture line. The staple line on the reconstructive limb of jejunum is removed using electrocautery.
- The anastomosis is initiated by placing the first suture in the reconstructive limb as shown in **FIG 4**. This will facilitate forehand suturing for the entire anastomosis and place the tension of posterior suture line on the serosa of the bowel rather than the soft parenchyma of the pancreas. This suture should be placed at the antimesenteric border of the reconstructive limb.
- The first bite of the pancreatic parenchyma is placed back hand at the cephalad aspect of the remnant pancreas as depicted in **FIG 5**. This suture is typically oriented transverse to the longitudinal plane of the pancreatic remnant. Subsequent sutures in the pancreas will be oriented longitudinally.
- The suture is then passed posterior to the suture that now bridges the bowel and the pancreas as shown in **FIG 6**. This maneuver is essential to prevent locking of the suture as the posterior suture line of the anastomosis is initiated.
- An additional purchase of the reconstructive limb is taken and then the suture is "parachuted" down to appose the reconstructive limb to the remnant pancreas (**FIG 7**). Care should be taken to ensure that the knot securing the two arms of the suture is in good apposition to the serosa of the bowel. Failure to do so will subsequently impact the ability to obtain adequate tissue apposition at the cephalad aspect of the anastomosis with the first tissue bites of the anterior suture line.
- The first assistant provides exposure and maintains tension on the suture line by grasping the suture with an


A

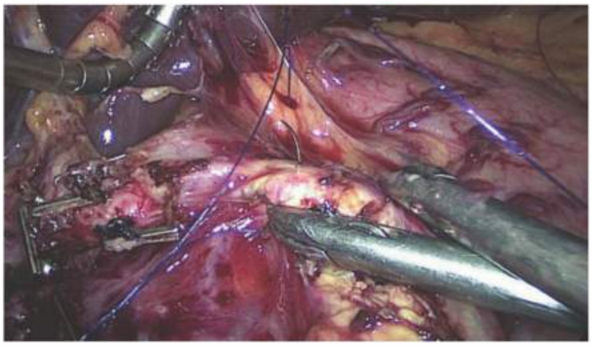

B

FIG 5 ● **A.** The first bite of pancreatic parenchyma is taken at the cephalad aspect of the gland. This suture can be thrown in a longitudinal, proximal-to-distal orientation; however, this orientation can be difficult to achieve without the placement of an additional 5-mm trocar in the subxiphoid space. **B.** A posterior-to-anterior orientation (as shown) is an acceptable alternative often employed to avoid the need for this additional trocar.

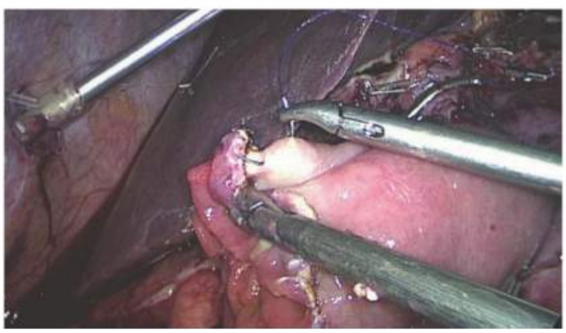


FIG 4 ● The initial bite of tissue is taken in the jejunum in a longitudinal, distal-to-proximal orientation. This suture should be placed at the antimesenteric border to facilitate the orientation of the reconstructive limb to the base of the mesentery. By starting the posterior row on the side of the jejunum, this row and the anterior row of the anastomosis are placed forehand.

FIG 6 ● To place the second bit of the posterior row in the jejunum without locking the suture, the needle is passed posterior to the strand that now bridges the jejunum and pancreas. The second bite of jejunum is then taken, advancing 3 to 4 mm along the posterior row.

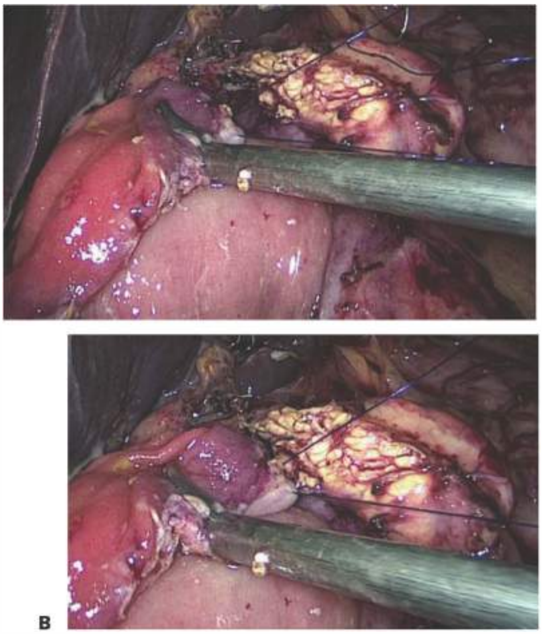


FIG 7 ● The suture is parachuted, bringing the pancreas and jejunum into apposition. **A.** The knot that was fashioned to create the double-armed suture (cannot be visualized in this photograph) is brought into apposition with the serosa of the jejunum and then the suture is tightened while the jejunum is grasped and moved into position adjacent to the pancreas. **B.** The serosa of the jejunum is now in apposition with the posterior capsule of the pancreas.

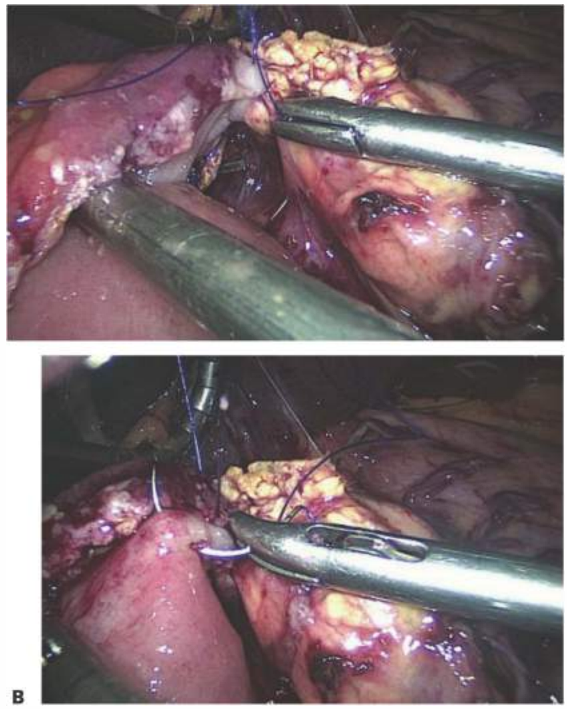


FIG 9 ● **A.** Formation of the posterior row is continued with a forehand bite of the pancreas, followed by **(B)** a seromuscular bite of the adjacent jejunum. The surgeon then applies tension to the stitch and passes it back to the assistant who again maintains tension and exposure. This process is repeated every 3 to 4 mm until the caudad aspect of the suture line is reached.

atraumatic grasper approximately 1.5 to 2 cm above suture line as shown in **FIG 8**. The posterior suture line is then run continuously (**FIG 9**). The operating surgeon sets the tension of the suture on the tissue after each bite of jejunum, and then passes the suture on tension to the first assistant. At the caudad aspect of the pancreas, the suture is held by the placement of a Lapra-Ty™ (**FIG 10**).

- The anterior suture line is performed next. The first bite of tissue is taken on the cephalad aspect of the pancreas immediately adjacent to the initial suture of the posterior row (**FIG 11**). The first bite of the reconstructive limb is similarly positioned in close proximity to the knot that holds the two arms of the suture together and also serves to provide tension on the cephalad aspect of the posterior suture line (**FIG 12**).
- The assistant applies tension to the suture line after each subsequent bite of jejunum as the primary surgeon inverts the mucosa of the bowel. Applying this tension to the left side of the patient facilitates the drawing of the

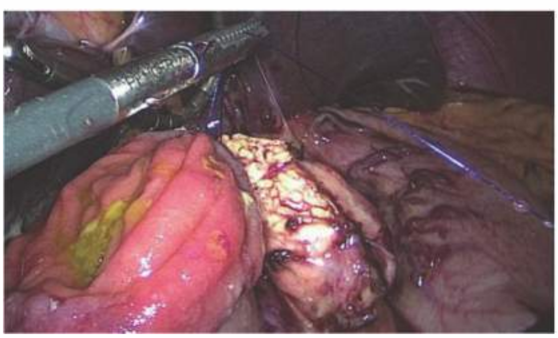


FIG 8 ● The first assistant provides anterior tension to the suture line. This tension also facilitates exposure to the posterior surface of the pancreas.

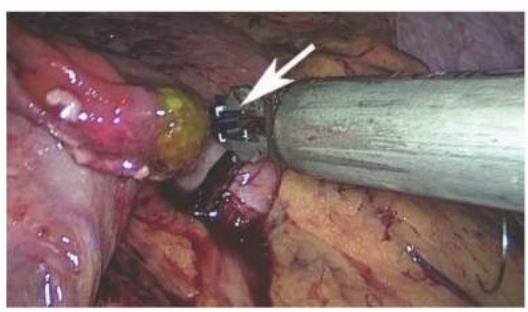
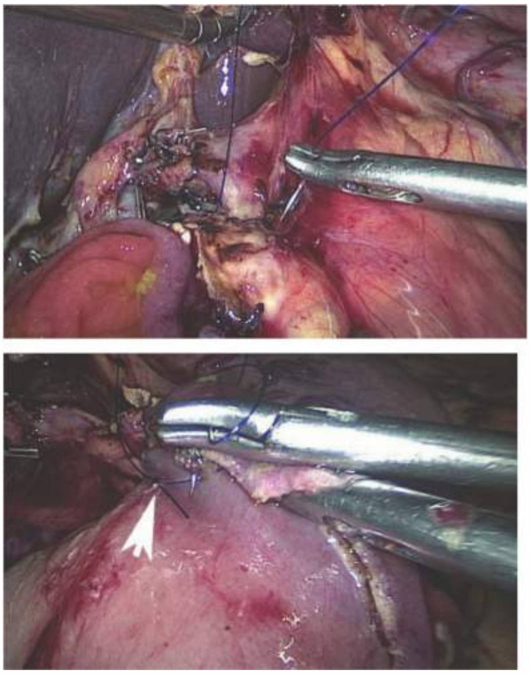


FIG 10 ● At the caudad aspect of the posterior suture line, a Lapra-Ty™ is placed to maintain tension.



A

B

FIG 11 ● **A.** The first bite of the anterior suture line is taken in the cephalad aspect of the pancreas. **B.** Placement of the initial bite of jejunum. The *arrow* marks the suture knot that holds the two arms of the suture together and is now located at the cephalad aspect of the posterior suture line.

jejunum up over the anterior aspect of the pancreas, thus inducing the intussusception.

- As this suture line is continued caudally, the intussusception progresses, and typically, the tension on the jejunum will lead to completion of the intussusception prior to the placement of the last few bites of tissue (**FIG 13**).
- At the completion of this suture line, a second Lapra-Ty™ is placed to maintain tension. The suture is then tied (**FIG 14**).

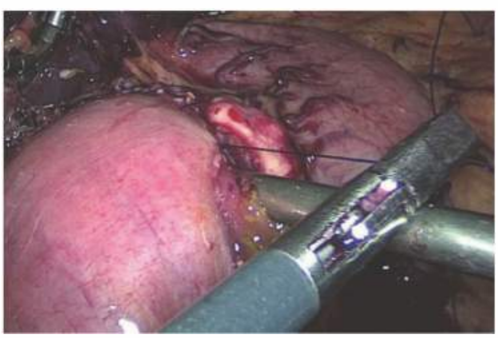
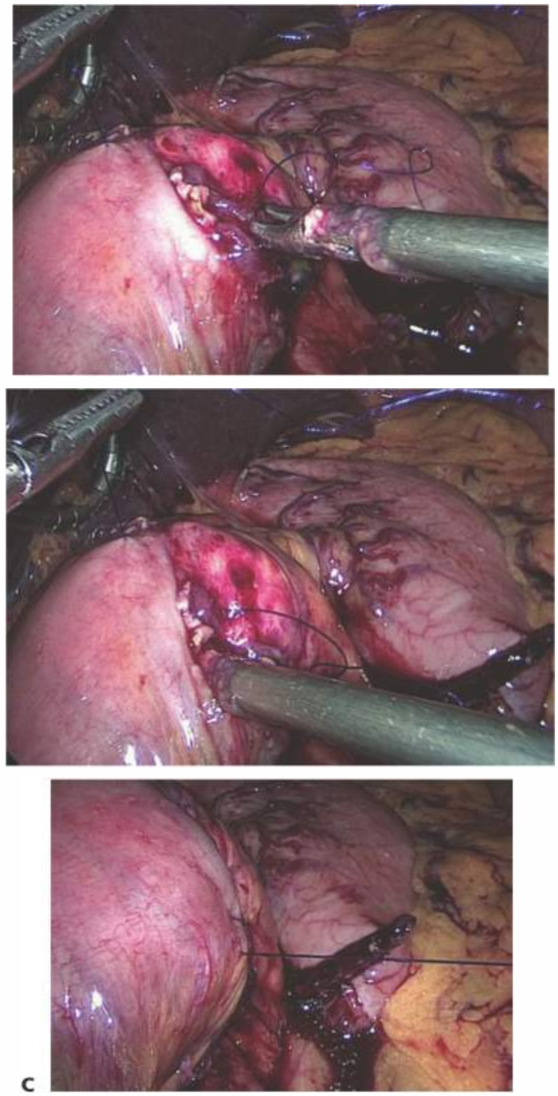


FIG 12 ● The surgeon inverts the jejunal mucosa as the first assistant applies tension to the suture. This tension should be applied to the patient's left to facilitate rolling of the jejunal wall over the anterior aspect of the pancreas, resulting in the pancreas intussuscepting into the lumen of the jejunum.



A

B

C

FIG 13 ● **A–C.** As the anterior suture line nears completion, a final tuft of jejunal mucosa is typically present and subsequently inverted with each additional suture until the intussusception of the pancreas into the lumen of the jejunum is complete.

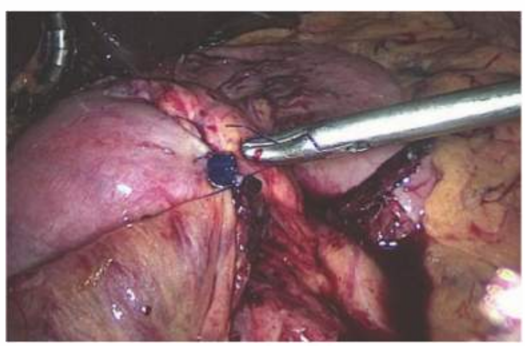


FIG 14 ● The anterior suture is secured with a second Lapra-Ty™ and the anterior and posterior sutures are tied.

TECHNIQUE 2: END-TO-SIDE, DUCT-TO-MUCOSA (BLUMGART) ANASTOMOSIS

- There are two technical challenges to laparoscopically performing this proven approach to PJ.[3]
  - The surgeon must maintain an organization system for the multiple, interrupted sutures that are placed and not immediately tied.
  - Orienting the course of the needle during the placement of the duct-to-mucosa sutures with the standard trocar placement can prove difficult. The strategic placement of an additional 5-mm trocar(s) (often best positioned in the midline, below the xiphoid) can overcome this challenge.
- The anastomosis is initiated by the placement of a series of 3-0 polyglactin sutures on an SH-1 needle. These interrupted sutures are placed full thickness as depicted in **FIG 15**. The suture passes anterior to posterior through the full thickness of the pancreas. A longitudinal, seromuscular bite of jejunum is taken posterior to the intended duct-to-mucosa anastomosis at the antimesenteric border, and the suture is brought back through the full thickness of the pancreas. Care is taken not to traverse the pancreatic duct with these sutures. Typically, five to six sutures are required. To maintain organization of the suture pairs, clips should be applied across the paired strands. This approach will also maintain proximity of the bowel to the pancreas as the duct-to-mucosa sutures are placed. Varying the length of each suture can also be helpful in maintaining organization.

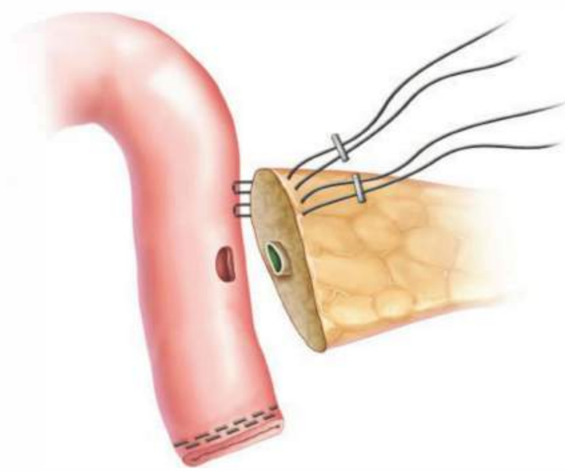


FIG 15 ● An end-to-side, duct-to-mucosa PJ is initiated by placing a posterior row of sutures. This row opposes the posterior aspect of the pancreas to the reconstructive jejunal limb. The sutures are placed through the full thickness of the pancreas to allow all of the sutures to be thrown prior to tying the sutures. This provides additional exposure during subsequent steps but does mandate that an organizational system is employed to prevent confusion regarding the paired strands.

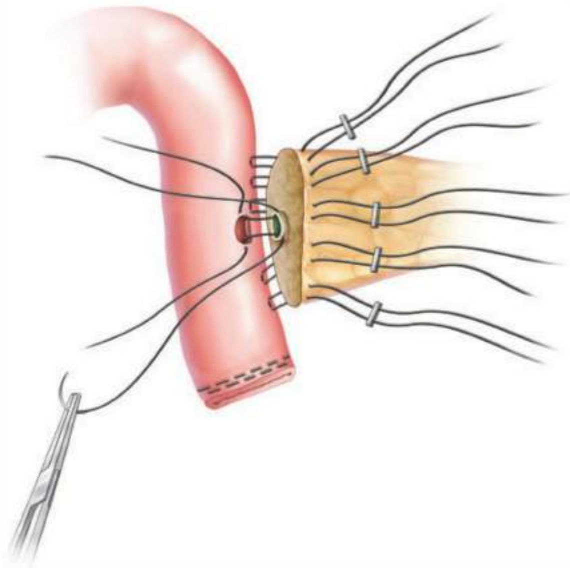


FIG 16 ● Typically, two sutures are placed to initiate the posterior aspect of the duct-to-mucosa anastomosis. As shown, the knots are positioned outside of the lumen. Some surgeons place these sutures so that the knots are within the lumen.

- Two 4-0 polyglactin sutures on an RB-1 needle are then placed in a duct-to-mucosa fashion as shown in **FIG 16**. Once both are placed, these sutures are tied down, bringing the bowel and pancreatic duct into apposition. Care must be taken to prevent any tension to the anastomosis at this point, as these sutures will easily tear through the soft pancreatic duct.
- The anterior row of duct-to-mucosa anastomosis is then fashioned with additional interrupted 4-0 polyglactin sutures (**FIG 17**). Some surgeons favor the placement of a silastic stent prior to this step to prevent accidentally

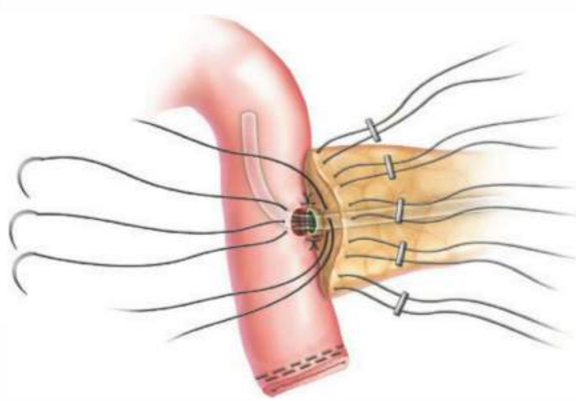


FIG 17 ● The anterior duct-to-mucosa sutures are placed. An optional silastic stent can be placed to prevent inadvertently incorporating the posterior wall of the anastomosis. This may be particularly useful when the pancreatic duct is of small caliber. The stent should be removed prior to completion of the anastomosis.

incorporating the back wall of the anastomosis in one of these sutures. Once all sutures are in place, these are then all tied. If used, the stent should be removed prior to this step to avoid inadvertent retention and the need for subsequent endoscopic retrieval.

- The sutures placed as shown in **FIG 15** are tied (**FIG 18**).
- The anterior row of sutures is oriented longitudinally in the pancreatic parenchyma and then a seromuscular bite of the jejunum is taken. The pioneer of this anastomotic technique advocates incorporating the tied suture from the posterior sutures to minimize laceration of the often soft pancreas tissues (**FIG 19**).

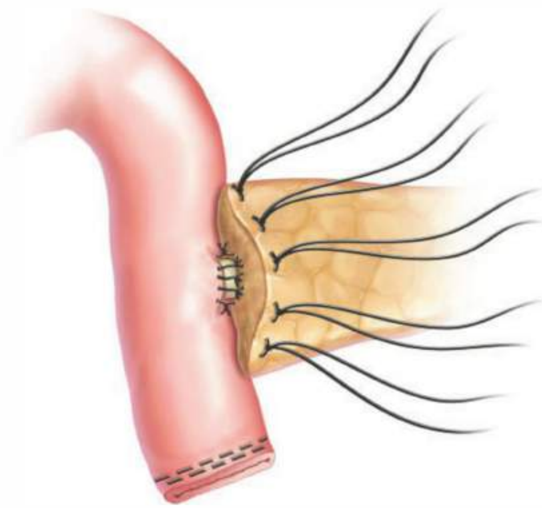


FIG 18 ● The posterior interrupted suture line is tied.

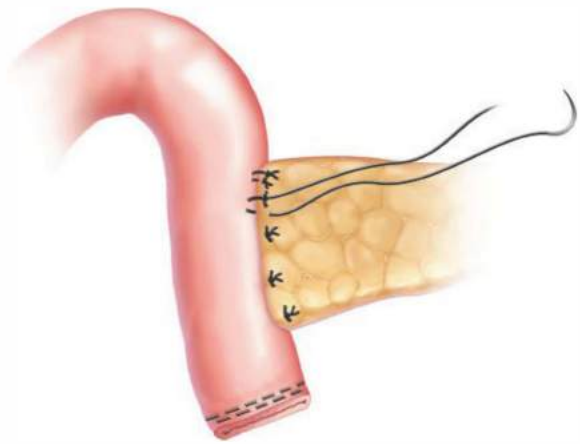


FIG 19 ● Construction of the anterior suture line to approximate the anterior aspect of the pancreas to the jejunum. Note the incorporation of the tied suture placed as shown in **FIGS 15** and **18**.

PEARLS AND PITFALLS

Patient history and physical findings	■ Anticipate a soft-textured pancreas in the clinical setting of neuroendocrine, intrapancreatic bile duct, and duodenal neoplasms. A soft-textured gland is associated with higher complication rates.
Surgical management	■ Adequate mobilization of the pancreatic remnant is essential for placement of posterior sutures. ■ Attention to restrictive fluid resuscitation and minimizing clamp time on the portal vein when necessary can dramatically impact bowel edema and thus the technical challenge of the anastomosis. ■ Place additional 5-mm trocar(s) in the subxiphoid space or elsewhere if the orientation of the stitch cannot be optimized with the standard trocar placement. ■ If using the interrupted suturing technique, keep the sutures as short as possible and strictly adhere to an organization method; that is, clip paired strands together. ■ Neither tissue sealants nor stents have been shown to reduce pancreatic fistula.
Postoperative care	■ Bleeding (either intraluminal or via operatively placed drains) that occurs after 5–7 days in the setting of a pancreatic fistula is due to a life-threatening pseudoaneurysm until proven otherwise. ■ Delayed gastric emptying should be assumed to be due to an evolving pancreatic fistula.

POSTOPERATIVE CARE

- Patients typically require admission postoperatively to a closely monitored setting.
- Drain amylases are obtained on postoperative days 1 and 4.
- Drains can be removed provided the amylase content is less than 1,000 IUD on postoperative day 4.
- Drains rich in amylase content should be left in place until the content returns to that of serum, or the drain output is less than 10 mL per day.
- Sandostatin therapy does not reduce rates of pancreatic fistula but may shorten the time required for a fistula to close.
- Delayed gastric emptying often accompanies evolving pancreatic fistula. If a surgical feeding system was not placed at the time of the operation, a nasojejunal feeding tube can be placed, understanding that this is associated with increased risk given the recent enteric anastomosis. Alternatively, total parental nutrition may be necessary. Nutritional support should be in place by postoperative day 7.

Table 1: Pancreatic Fistula Rates following Pancreaticojejunostomy

Grade	n	%
Intussuscepting PJ[a]	**31**	
A	5	16.1
B	1	3.2
C	1	3.2
Duct-to-mucosa PJ (open series)[b]	**187**	
A	25	13.4
B	7	3.7
C	6	3.2

[a]*Unpublished data from the author's experience over a recent 6-month-period.*
[b]*Adapted from Grobmyer SR, Kooby D, Blumgart LH, et al. Novel pancreaticojejunostomy with a low rate of anastomotic failure-related complications.* J Am Coll Surg. *2010;210(1):54–59. doi:10.1016/j.jamcollsurg.2009.09.020.*
PJ, pancreaticojejunostomy.

COMPLICATIONS

- Fistula[4]
- Delayed gastric emptying
- Hemorrhage (pseudoaneurysm)
- Sepsis
- Death

OUTCOMES

- Expected outcomes with respect to pancreatic fistula are summarized in Table 1. The overall fistula rate should be approximately 25% (range of 15% to 40%) over a large series and typically correlate with the percentage of soft glands in the series.[5,6]

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Chapter **39**

Portal Vein Resection and Reconstruction

Steven J. Hughes   Kevin E. Behrns

DEFINITION

- Borderline resectable pancreatic cancer is defined by tumor involvement of mesentericoportal venous axis.[1]
- En bloc portal vein (PV) resection with immediate reconstruction is now routinely performed by most high-volume pancreatic surgery centers. Large clinical series have demonstrated that this additional operative complexity does not result in increased morbidity.[2,3]
- Arterial resection and reconstruction is not indicated because existing data do not show a favorable benefit-to-risk ratio.

PATIENT HISTORY AND PHYSICAL FINDINGS

- Most borderline resectable patients will ultimately be staged with N1 disease.[4] Thus, these patients have a 5-year survival that is very close to the operative mortality.
- Previous central venous access or venothromboembolic events may be a contraindication to venous reconstruction because of venous hypertension.
- A history of hypercoagulability must be considered as an additional risk and factored into consideration for surgical therapy and potential for postoperative anticoagulation.
- Lower extremity edema is a contraindication for use of the deep femoral vein as conduit.

IMAGING AND OTHER DIAGNOSTIC STUDIES

- A high-quality, multidetector, thin-slice, triphasic computed tomography (CT) scan is essential (**FIG 1**). Pay particular attention to the PV phase; loss of the fat plane for greater than 180 degrees or narrowing of the mesentericoportal complex are predictive of PV involvement by neoplasm.[5]
- Obtain bilateral duplex ultrasound studies of the deep femoral and jugular veins. Surface mapping of deep femoral vein assists in harvesting the conduit but is not required for success.

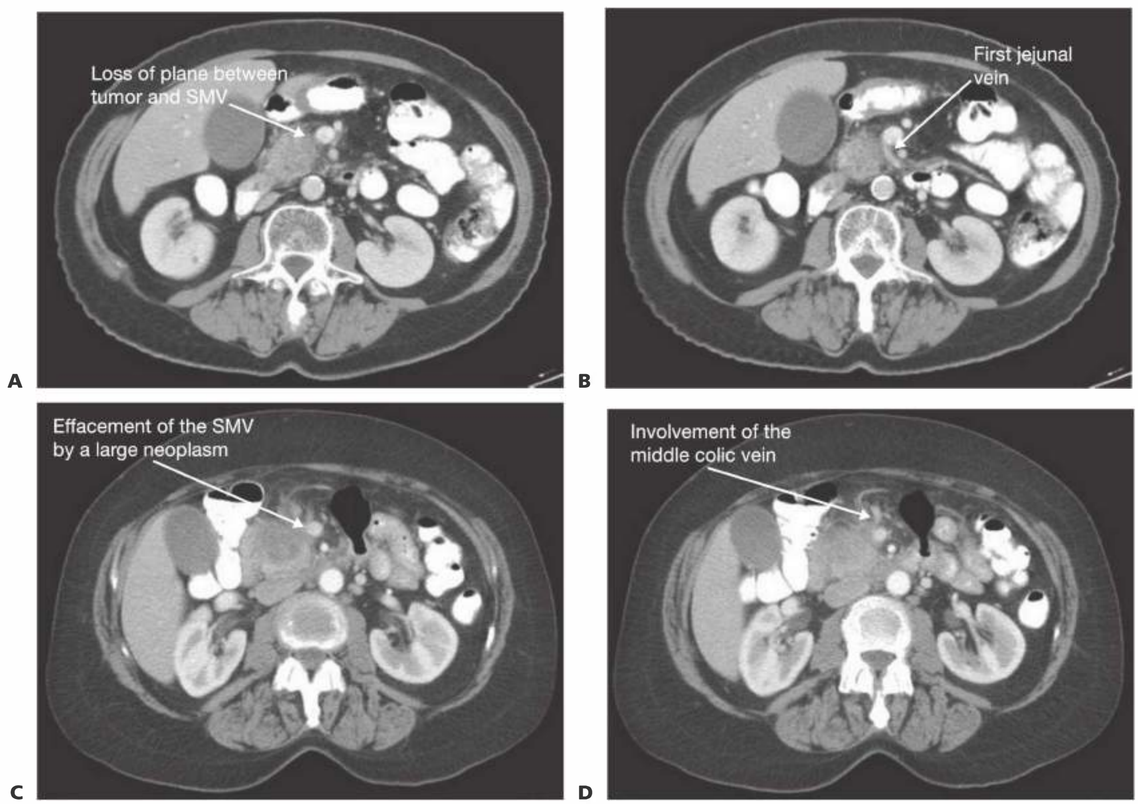

FIG 1 ● **A.** CT of a patient with pancreatic cancer demonstrating SMV involvement. **B.** The insertion of the first jejunal branch proved to be involved. The resulting lateral wall defect was repaired with a bovine pericardial patch. **C.** CT of a patient with large pancreatic cancer demonstrating 180-degree effacement of the SMV and **(D)** middle colic vein involvement. An interposition graft was planned and ultimately required to obtain an R0 resection and perform the subsequent reconstruction.

PREOPERATIVE PLANNING

- Key to success is the accurate, preoperative determination that an interposition graft will be required.
- If the vein is narrowed, plan for a circumferential excision with primary repair versus interposition graft. Using the CT scan, estimate the length of the PV involved and the resulting defect requiring reconstruction (**FIG 2**).
- A defect measuring less than 2 cm can usually be repaired primarily.
- A defect 2 to 4 cm typically can be reconstructed using an interposition graft.
- Defects measuring more than 4 cm will result in a long-segment conduit; the risk of graft thrombosis is proportional to the length, and longer segment reconstructions may preclude surgical therapy.

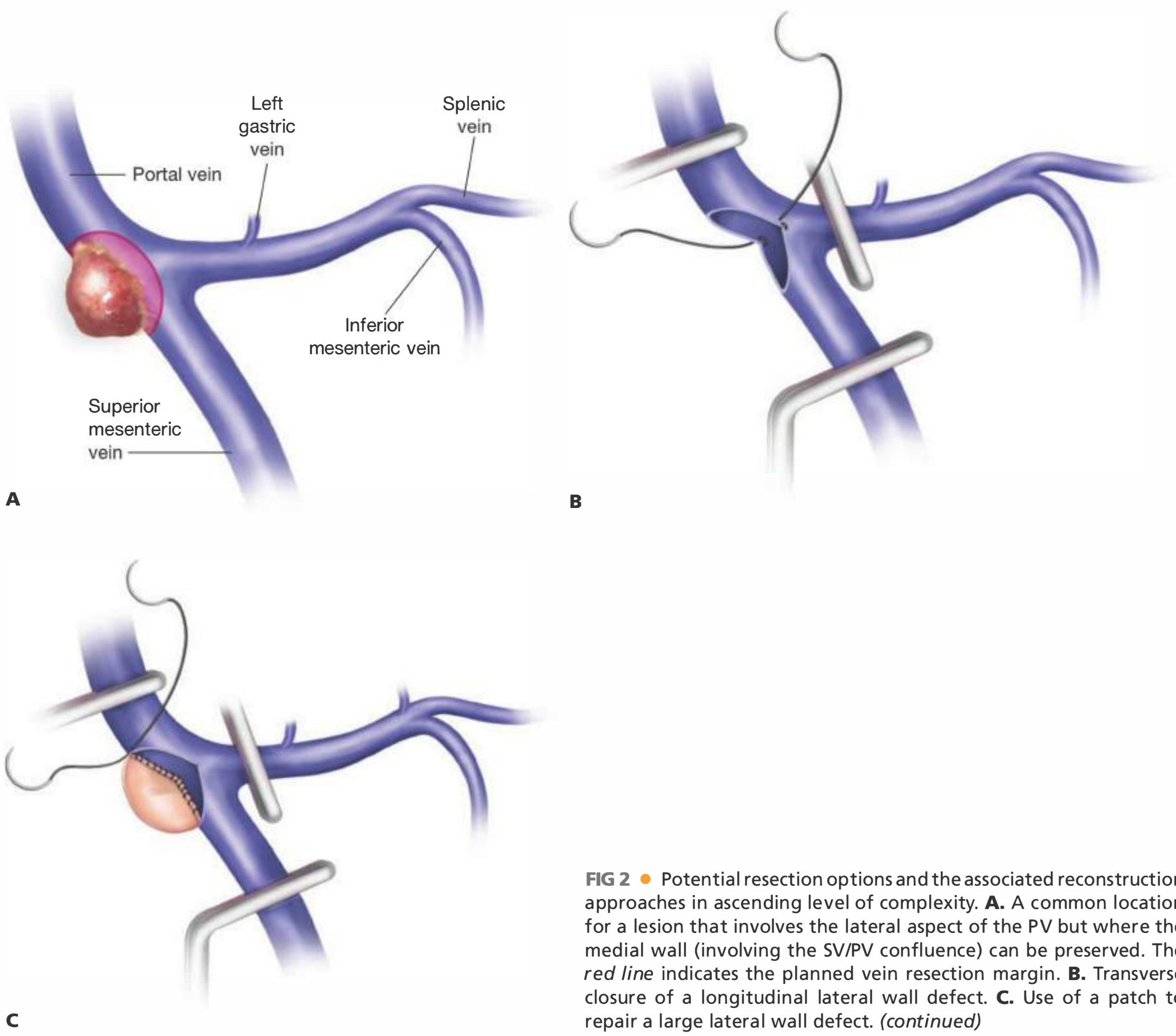

FIG 2 ● Potential resection options and the associated reconstruction approaches in ascending level of complexity. **A.** A common location for a lesion that involves the lateral aspect of the PV but where the medial wall (involving the SV/PV confluence) can be preserved. The *red line* indicates the planned vein resection margin. **B.** Transverse closure of a longitudinal lateral wall defect. **C.** Use of a patch to repair a large lateral wall defect. *(continued)*

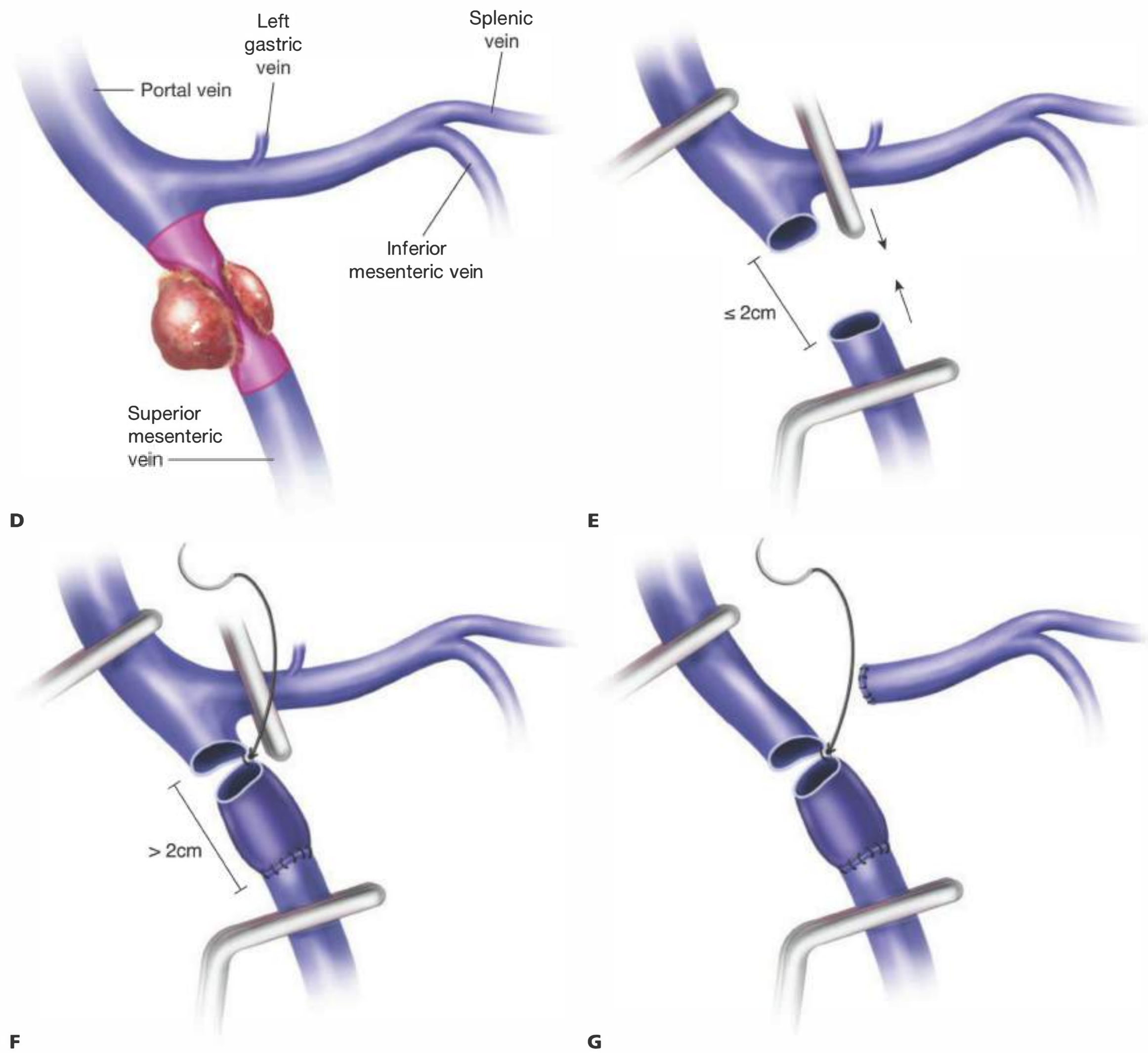

FIG 2 ● *(Continued)* **D.** A lesion resulting in significant narrowing of the SMV requiring excision of the vein. The *red areas* represent the planned resection margin. **E.** Primary end-to-end venous anastomosis for reconstruction. This approach is appropriate when the vein defect is less than a 2-cm gap or with mesenteric mobilization; the ends can be approximated without tension. **F.** Reconstruction using an autologous vein graft (gap in excess of 2 cm or under tension). **G.** If the SV confluence with the SMV is involved, reconstruction of SV inflow is optional.

- Tumor involvement with respect to the splenic vein (SV) and superior mesenteric vein (SMV) confluence must be considered.
  - If the lateral wall is involved, a primary transverse repair or patch repair is ideal.
  - If a circumferential vein resection is required and a primary end-to-end anastomosis or interposition graft planned, most experienced surgeons do not reinsert the SV—this significantly increases the complexity of the procedure. Rather, the SV is ligated proximally. The risk of sinister portal hypertension leading to symptoms is acceptably low.
- Consider initiating or continuing a daily enteric-coated aspirin (81 mg) through the perioperative period.
- Have a bovine pericardium patch available.
- Most centers have abandoned the use of cadaveric vein grafts.
- Strongly consider a neoadjuvant approach for all patients with borderline resectable disease. An R1 resection confers no survival benefit over a nonsurgical, palliative therapeutic approach.
- Neoadjuvant therapy should be offered to all patients in whom there is a loss of the fat plane around the superior mesenteric artery (SMA).

POSITIONING

- Tuck the left arm. This will provide better access to the left neck should the jugular vein need to be procured as a graft (**FIG 3**).
- Place either an upper or lower body active warming device; this decision is driven by the planned source of conduit.
- Prepare the patient's skin. Then, isolate the left neck or left thigh and abdominal operative fields with sterile towels (**FIG 4**). Ensure that these towels create a sterile field between these isolated sites. Use ¾ sterile drapes as indicated to achieve this objective. The authors support the use of iodine-containing, self-adhesive barriers to secure these fields under the additional overlying draping and reduce the risk of surgical site infections.
- To minimize the risk of hypothermia, drape the patient such that only the abdominal operative field is exposed. This drape will be cut to expose the graft harvest site when indicated.

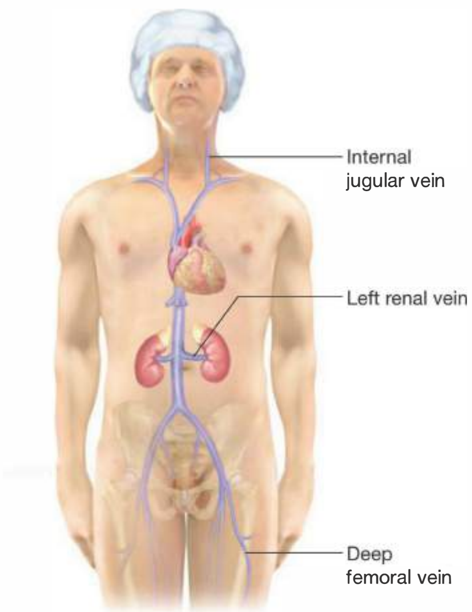

FIG 3 ● Autologous sources of interposition vein grafts include the jugular, left renal, and deep femoral veins.

FIG 4 ● The patient is positioned supine with the left arm tucked. The left leg is prepared and draped with towels, then the abdomen is prepped and draped in a way that should access need to be obtained for the left leg, the draping can be removed or exposed by cutting through the overlying drape without compromising either aseptic operative field.

INCISION AND EXPOSURE

- Either a midline or bilateral subcostal incision can provide adequate exposure. In addition to exposing the upper abdomen, the incision must allow for complete mobilization of the right colon and retroperitoneal attachments of the small bowel mesentery.

DISSECTION

- The dissection proceeds for the most part as presented in detail in Part 3, Chapter 33 but may include limiting particular portions of the dissection; *most importantly, the uncinate process/SMA dissection is performed prior to dissection of the SMV/PV*.
  - Perform a complete Cattell-Braasch maneuver, fully mobilizing the retroperitoneal attachments of the cecum, right colon, and small bowel mesentery to the left of the aorta and up to the third portion of the duodenum.
  - As part of the Kocher maneuver, establish a plane between the third portion of the duodenum and the aorta and extend this dissection cephalad to the origin of the SMA (**FIG 5**).
  - Mobilize the ligament of Treitz and derotate the small bowel such that the cecum is in the left upper quadrant.
  - These maneuvers will provide excellent exposure and mobility of the mesentery to facilitate primary reconstruction without undue tension following mesentericoportal resections up to 2 to 3 cm in length.
- This mobilization will also expose the anterior aspect of the left renal vein—a potential source of reconstruction conduit.
- Open the lesser space and expose the pancreatic head. Assess the root of the transverse mesocolon and bimanually palpate the lesion. Also, palpate the course of the SMA with respect to the palpable lesion.
- Proceed with the dissection of the inferior and superior borders of the pancreas, identifying the anterior borders of the SMV and PV proximal and distal to the area of tumor involvement, respectively.
- By palpation and visualization, identify the relationship of the tumor with respect to the SV/SMV confluence.
- Establish the plane between the root of the mesentery and the third and fourth portions of the duodenum and uncinate process.
- Determine resectability with respect to involvement of the SMV/PV and the extent of resection required (**FIG 2**).
  - A very small segment of the lateral wall of the SMV/PV is involved—a side-bite clamp placed longitudinal to the vein will provide adequate

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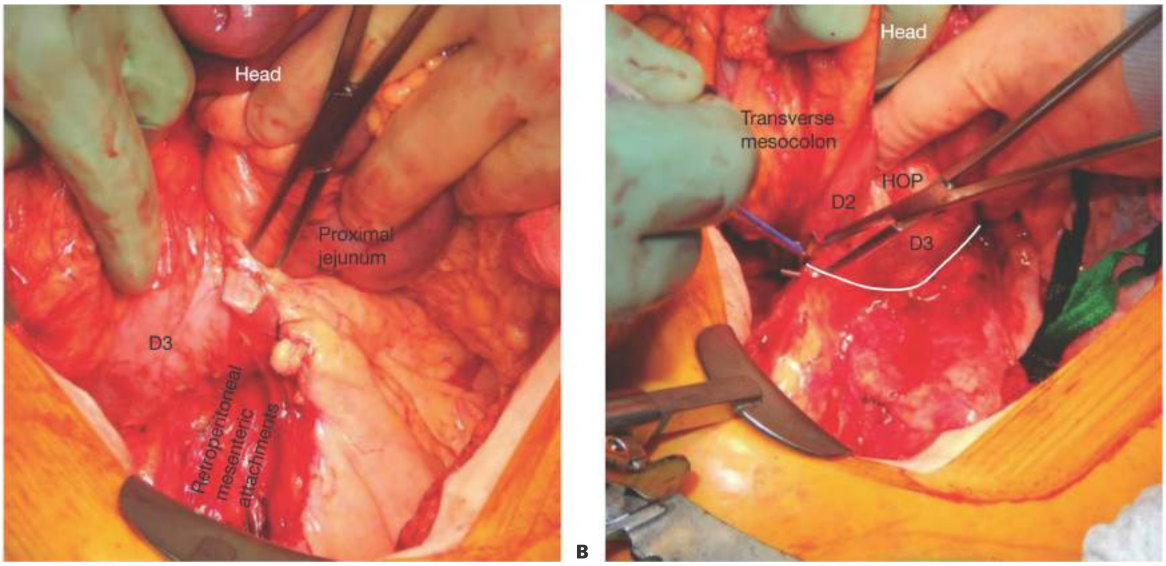


FIG 5 ● **A.** Completely mobilize the right colon and the retroperitoneal attachments of the small bowel. **B.** Extend the dissection by mobilizing the retroperitoneal attachments of the duodenum and pancreatic head to the origin of the SMA (*white line* represents plane of dissection). *D2*, second portion of the duodenum. *D3*, third portion of the duodenum. *HOP*, head of pancreas.

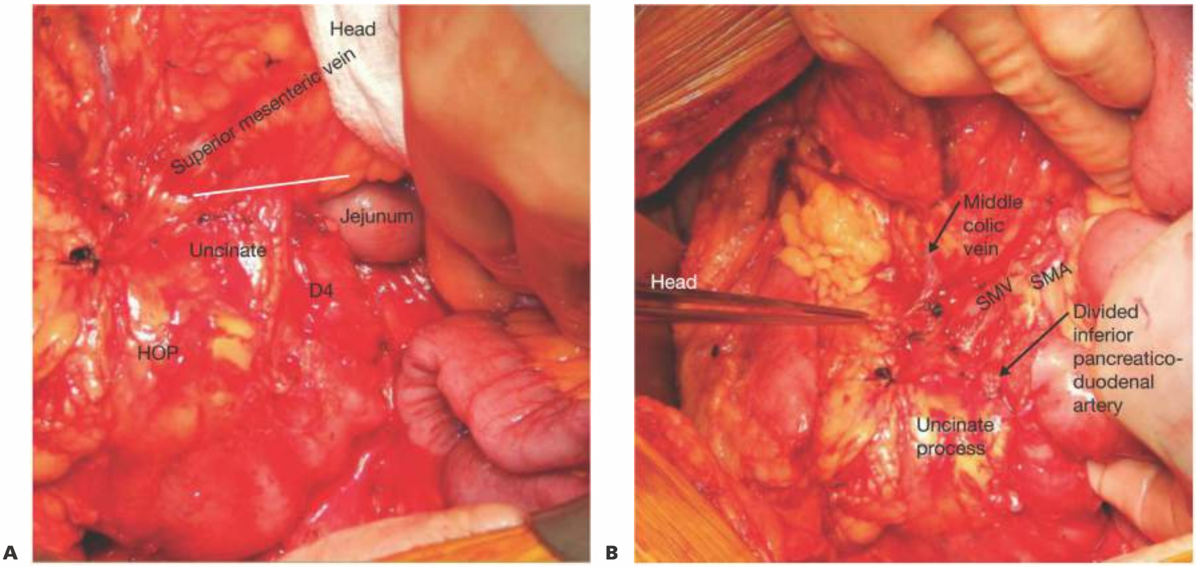


FIG 6 ● Establish the plane between the root of the mesentery and the third and fourth portions of the duodenum and uncinate process. **A.** Mobilize the uncinate process along the adventitia of the SMA (*white line* represents plane of dissection). **B.** Control the inferior pancreaticoduodenal arteries with ligatures. *HOP*, head of pancreas. *D4*, fourth portion of duodenum.

resection margin (2 to 3 mm) and vascular control. Note: A longitudinal clamp will not allow a transverse closure of the resulting defect due to tension; the clamp will typically need to be repositioned transversely. Thus, the authors rarely use a side-biting clamp technique and usually obtain circumferential, proximal, and distal control.

    - Unless a plane can be readily established anterior to the SMV/PV confluence (i.e., only the lateral wall of the vein is involved), save division of the pancreatic neck for later.
  - Proceed with the other steps of the dissection.
    - Dissect the porta hepatis and divide and control the bile duct and gastroduodenal artery.
    - Divide the proximal gastrointestinal (GI) tract (duodenum or stomach).
- Approaching from the posterior–inferior, dissect the uncinate process and duodenal mesentery from the SMA, hugging the adventitial plane while working caudad to cephalad until the lateral aspect of the SMA has been fully dissected up to its origin from the aorta. An energy device can be used for much of this dissection, but the authors recommend ligation or suturing of any identified inferior pancreaticoduodenal artery (**FIG 6**).
- Alternatively, the SMA dissection can be facilitated by approaching it from the anterior aspect, inferior to the takeoff of the middle colic artery but superior to the arborization of the artery. First, isolate and encircle with a vessel loop the SMV well inferior to the tumor (**FIG 7**). Dissect down to the adventitia and then continue dissecting along the right lateral border until you break through to the posterior dissection plane. Once this maneuver has been performed, continuing the dissection cephalad is straightforward from the posterior–inferior approach described earlier.
- Confirm the resection plan and required reconstruction. Particularly, determine if an interposition graft will be required. Harvesting of this graft *should be performed first* to minimize vascular clamp time and the resultant bowel edema that impacts reconstruction of intestinal continuity.

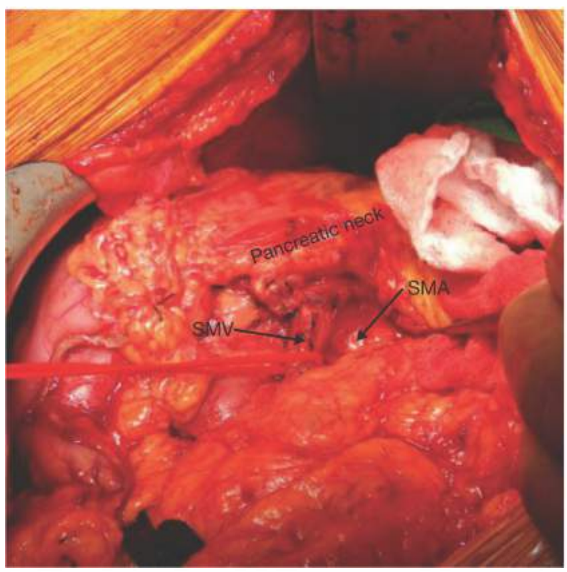


FIG 7 ● Circumferentially dissect the SMV and control it with a vessel loop. This also provides and anterior approach to the distal SMA. This approach also provides safe access to the adventitial plane of the SMA.

PROCURE THE RECONSTRUCTION CONDUIT

- Intravenously administer unfractionated heparin sulfate (50 IU/kg) and allow time for the drug to circulate.
- Have a basin with heparinized normal saline (100 IU/mL) available to store the conduit.

Left Renal Vein

- When of adequate length, the left renal vein is an ideal source of conduit as it can be procured without establishing another surgical field, is typically of appropriate caliber, and has a relatively thick wall that holds sutures well.
- Assess the left renal vein for caliber and length (from the insertion of the left gonadal vein to the inferior vena cava) and determine if it is suitable as the conduit for reconstruction. If the interposition graft is anticipated to need to be 3 cm, the length of conduit should be longer, that is, 5 cm.
- Circumferentially dissect the vein and control it with vessel loops. Using vascular clamps, control the vein proximally and distally and sharply excise the conduit. Place it in heparinized saline (100 IU/mL).
- Use a running 5-0 Prolene to control the proximal renal vein and vena cava.

Femoral Vein

- The deep femoral vein is also an excellent source of conduit as it is relatively thick walled, of good caliber and never inadequate in length, and complications associated with the procurement site are surprisingly rare.[6]
- Prepare the surgical field for conduit procurement by cutting the overlying draping. Use additional towels as indicated.
- Use a clean set of instruments and keep them separate from those used for the abdominal surgical field.
- The left thigh is more readily available.
- See Lee et al.[7] for details of the exposure and other details of the technique.

Jugular Vein

- The left jugular vein is the preferred conduit for PV reconstructions at some centers.
- The exposure and surgical anatomy are available in Part 6, Chapter 3.

VASCULAR CONTROL AND RESECTION

- If the pancreatic neck has not been divided, establish a plane posterior to the pancreas at the level of planned transection (this is often at the level of the pancreatic body to the left of the SMV/PV confluence). Divide the pancreas and obtain hemostasis on the cut surface.
- Isolate and control the SV with a vessel loop (**FIG 8**). During this dissection, be mindful of the left gastric vein. It typically inserts into the cephalad aspect of the SV approximately 1 cm proximal to the SMV/PV confluence. It is at risk for injury during isolation of the SV or inserting distal to the point of control; this will lead to a lack of hemostasis after clamping during the vein resection. The authors typically ligate and divide this vein.
- The insertion of the IMV into the SV is quite variable. It may need to be independently isolated if it inserts in close proximity to the SMV/PV confluence.
- Circumferentially dissect the SMV proximal to the area of venous involvement. Control it with a vessel loop. Be mindful of the first jejunal branch of the SMV. This vessel usually receives a larger tributary vein from the uncinate process and injury or loss of control can be quite challenging. Furthermore, obtaining control proximal to the vessel will not lead to a hemostatic field.
- Get control of the PV above the planned level of vein resection. Identify the superior uncinate vein (vein of Belcher) and isolate, ligate, and divide it.

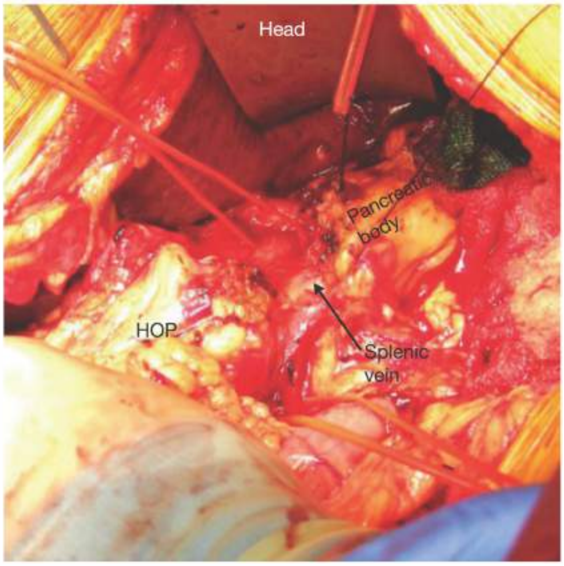


FIG 8 ● If indicated, isolate and control the SV. In this circumstance, the tumor is attached to the lateral aspect of the SMV/PV confluence. The pancreas has been divided to the left of the pancreatic neck to provide an adequate margin and expose the anterior surface of the SV. During this dissection, be mindful of the left gastric vein. It typically inserts into the cephalad aspect of the SV approximately 1 cm proximal to the SMV/PV confluence. It is at risk for injury during isolation of the SV or inserting distal to the point of control; this will lead to a lack of hemostasis after clamping during the vein resection.

- At this point, proximal and distal control has been achieved (FIG 9).
- If a conduit was not procured, intravenously administer unfractionated heparin sulfate (50 IU/kg); allow at least 1 minute for the drug to circulate prior to placing clamps. The authors prefer to have the clamps relatively remote from the planned resection planes; this length provides better exposure and mobility of the vessels during the construction.
- Mark the anterior surface of the vessels using a marking pen. This will facilitate maintenance of the vessels' orientation. Alternatively, consider marking the anterior aspect of the vein with a fine monofilament suture. Loss of this orientation is surprisingly easy and can result in torsion and narrowing of the reconstruction. Sharply divide the vein(s) along the planned resection plane.
- Orient the pathologist to the specimen using sutures. One or more of these sutures should identify the venous margins.

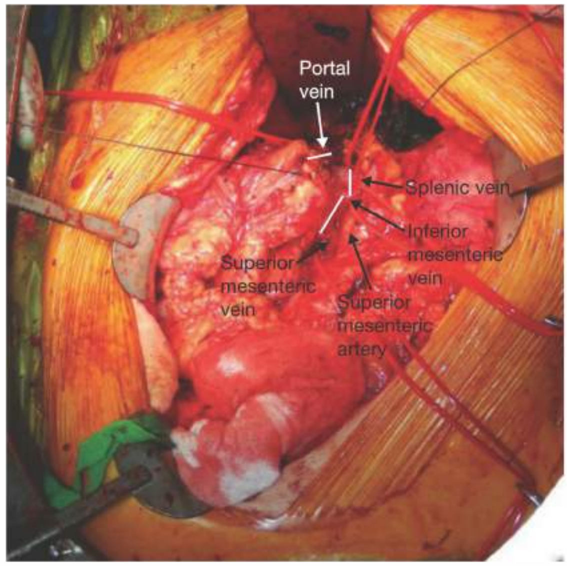


FIG 9 ● Proximal and distal control with complete mobilization of the uncinate process off of the superior mesenteric artery. The *white lines* represent the planned venous resection lines. This plan includes a tangential proximal anastomosis that incorporates and aberrant IMV insertion into the SMV and ligation of the SV.

RECONSTRUCTION

- The vascular reconstruction proceeds immediately.
- Place moistened white towels around the field and over the fixed retractor blades/arms to better see the fine reconstructive suture and avoid tangling it on the retractor.
- Use 6-0 Prolene on a fine vascular needle for the repair.
- The authors do not reverse the systemic anticoagulation effects of the heparin unless necessary to control nonsurgical bleeding at the completion of the procedure.

Primary Transverse Closure

- Place single-armed 6-0 Prolene sutures at the (1) anterior and (2) posterior longitudinal midpoints of the venotomy (FIG 10). The two stitches are placed longitudinally, 1 mm from the cut edge from outside in and then immediately back inside out so that they can be tied and result with the knot outside the lumen.
- Begin with the posterior suture, advancing 1 mm cephalad from outside the lumen into the lumen.
- Run the posterior suture visualizing the placement of the sutures from inside the lumen until the anterior suture can be used to complete the anastomosis with visualization from outside the vessel lumen.
- Release the PV clamp to allow retrograde blood flow. Allow the vessel to fill, thus degassing the anastomosis. Hold minimal tension on the sutures to allow the suture line to maximally expand before tying the two sutures together to complete the anastomosis.
- Place interrupted repair sutures as necessary to obtain a hemostatic anastomosis.
- Hemostatic agents such as cellulose may facilitate control of oozing from needle tracts.
- Release the remaining clamps.

Patch Closure

- When a lateral defect in the vein cannot be transversely closed without undue tension, employ a patch venoplasty using bovine pericardium (FIG 11).
- Cut the patch to size. Leaving the patch about 80% of the length of the defect and twice as wide as the defect will minimize the risk of narrowing the vessel.
- Initiate the double-armed suture line at the apex of the venotomy. The assistant retracts the patch caudally and laterally to expose the posterior suture line from the lumen side (FIG 11B).
- Use care to align the patch with the vein—bites of the vein should be spaced further apart to prevent a size mismatch.
- Place a second double-armed suture at the heel of the repair and then tie the posterior suture to this second suture.
- Alternatively, this suture can be placed at the same time as the apex suture and each suture can be run toward the middle. This approach reduces the risk of a significant size mismatch but limits the exposure.
- Run the anterior suture line to the midpoint of the repair and then use the heal suture to complete the anastomosis. Do not tie down the suture until retrograde restoration of blood flow has been accomplished.

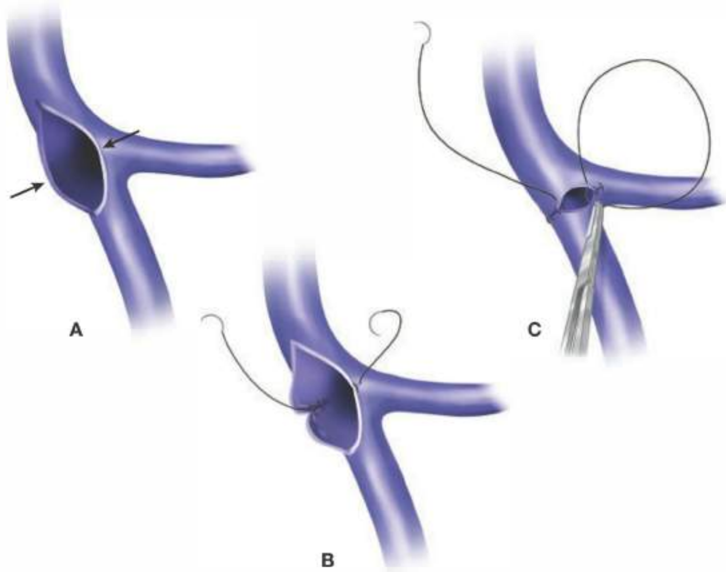


FIG 10 ● A transverse closure of a longitudinal defect. **A.** The suture line is initiated at the anterior and posterior mid-points of the longitudinal venotomy *(arrows)*. **B.** The posterior suture is run first, visualizing the repair from inside the lumen of the vessel. **C.** The anterior suture completes the anastomosis.

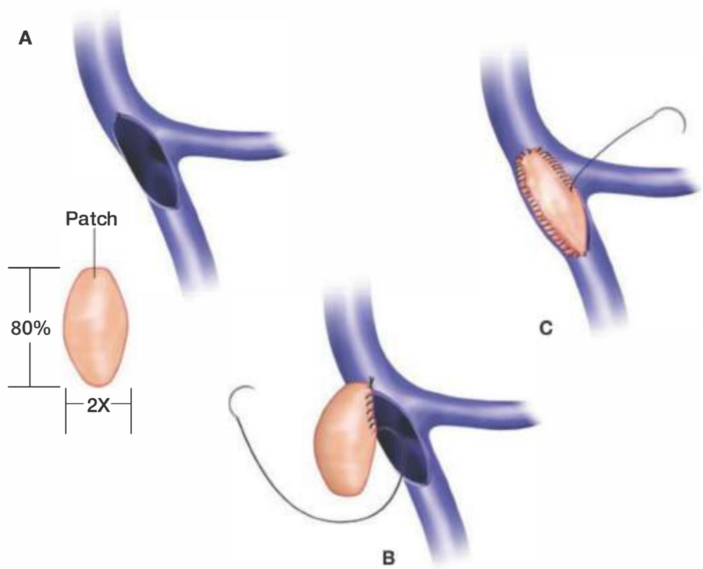


FIG 11 ● A pericardial patch repair of a large lateral wall defect. **A.** Estimate the width of the patch, and then double it to prevent narrowing. The authors prefer to also shorten the length of the defect by purposely shortening the patch. **B.** The lateral posterior suture line is placed first with exposure from the lumen side of the vein. The "heal" of the patch can be anchored to the proximal wall of the venotomy to assist in alignment (not shown). **C.** The anterior suture line is then placed to complete the patch repair.

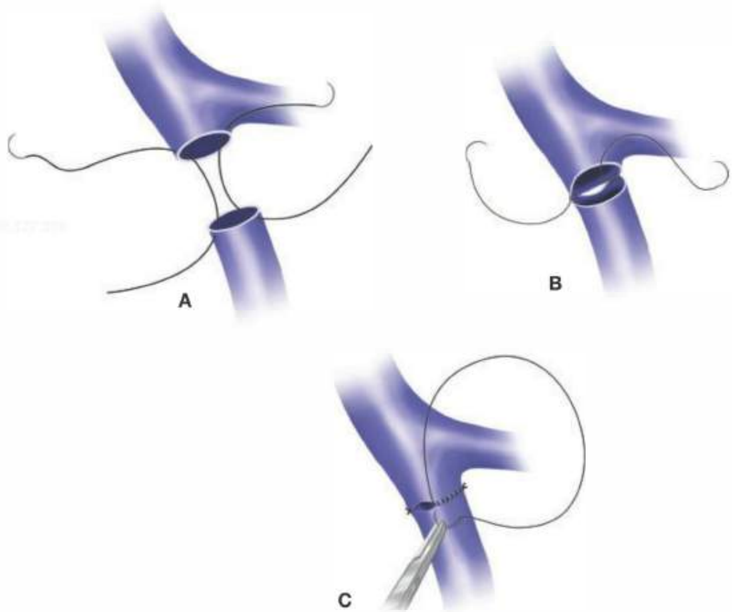


FIG 12 ● End-to-end native vein reconstruction. Size mismatch is often an issue; the authors recommend interrupted sutures in this clinical setting. When compared to interrupted sutures, a running suture takes less time and is more hemostatic but puts the anastomosis at risk for narrowing by producing a purse-string effect. **A.** Double-armed, 6-0 Prolene sutures are placed at the 3 o'clock and 9 o'clock positions. **B.** The posterior suture line is placed under visualization from inside the lumen. The suture line is completed at the 9 o'clock position by tying the sutures together. **C.** The anterior suture line is then placed.

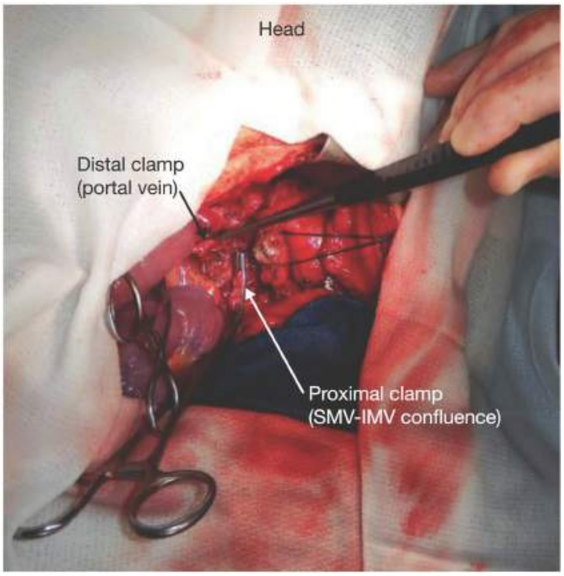
- Release the remaining clamps; place repair sutures as needed.

Primary End-to-End Anastomosis

- When the vein has been circumferentially excised to obtain a margin, a primary repair can often be accomplished. Typically, gaps of even greater than 2 cm can be closed by cephalad mobilization of the root of the mesentery.
- Begin by placing double-armed sutures at 3 o'clock and 9 o'clock positions (**FIG 12**). If there is a significant size mismatch, consider using interrupted sutures. The vein can usually be "rolled" 180 degrees to expose the posterior wall so that these sutures can be placed with good exposure.
- Begin a running suture line using one of the 3 o'clock position strands. Pass this outside in the distal (hepatopedal) vein orifice. Then, run the suture using exposure from the lumen side. At 9 o'clock position, pass the suture outside the lumen on the proximal side (hepatofugal) and tie it to one of the 9 o'clock position suture arms. Use care not to "purse-string" this posterior suture line. Some surgeons advocate not tying this suture until portal blood flow has been restored, thus allowing the suture line to "parachute" open and minimize the risk of narrowing the lumen.
- Run the anterior suture line from both the 3 o'clock and 9 o'clock positions so that the anastomosis is completed at the 12 o'clock position.
- Release the proximal clamp to degas the vessel and allow the suture line to parachute. Then, tie the sutures to complete the anastomosis and place repair sutures as needed.

Interposition Graft

- When the gap cannot be closed without undue tension, an interposition graft is indicated (**FIG 13**).
- Do not cut the conduit to length until the proximal anastomosis is completed.
- Each anastomosis is fashioned as described for the primary repair. The assistant maintains cephalad tension on the graft to facilitate the exposure.
- Minimize trauma to the endothelium of the conduit. When possible, only grasp the adventitia of the conduit with fine, atraumatic forceps.
- If the defect involves the splenoportal confluence, oversewing the SV is a reasonable option with acceptable morbidity. Reimplantation can be considered to avoid sinister portal hypertension and augment flow through the conduit thus theoretically reducing the risk of thrombosis.



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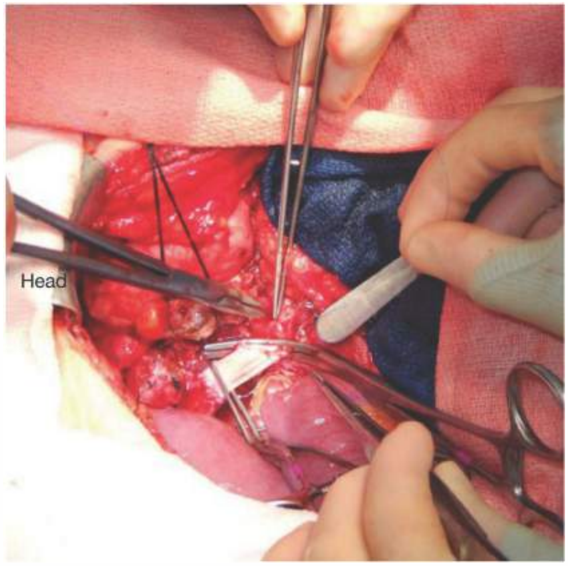

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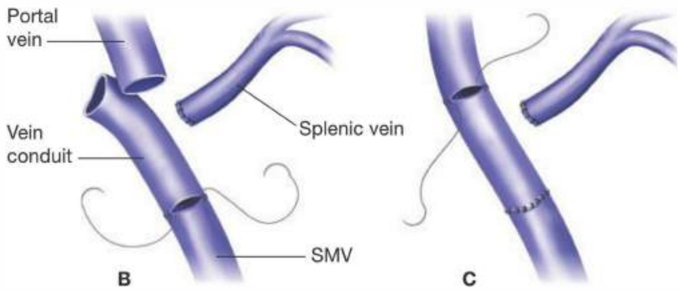
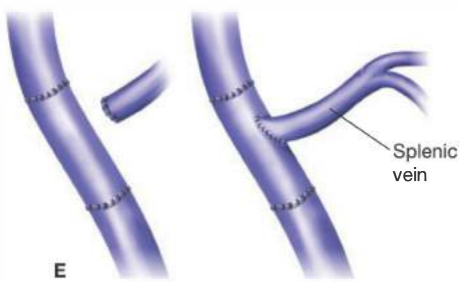
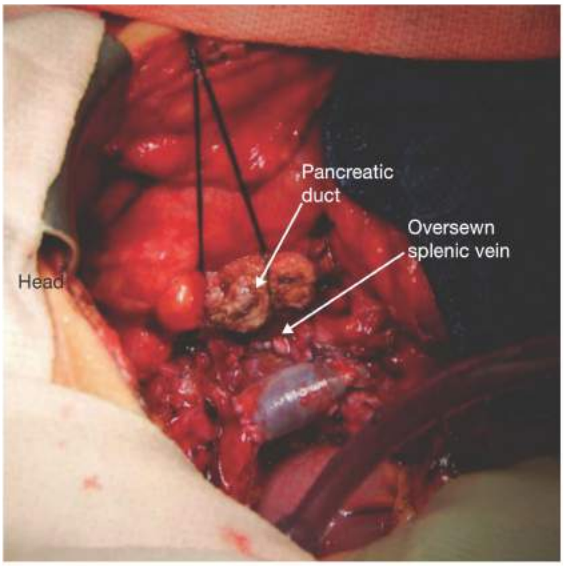




B,C,E

E

FIG 13 ● An interposition graft repair of the SMV/PV using a deep femoral vein conduit. In this example, the SMV/PV confluence has been resected. **A.** Intraoperative photograph of proximal and distal control with vascular clamps prior to placement of an interposition graft. The SV has been oversewn and is not visualized. As nearly 4 cm of vein was resected, an interposition graft will be required but will only be 2 cm in length. This is facilitated by the mobilization of the retroperitoneal attachments of the mesentery. **B.** Reconstruction begins with the proximal anastomosis using identical technique to that depicted in **FIG 12**. **C.** The distal anastomosis is then constructed. **D.** Intraoperative photograph during performance of a proximal anastomosis. **E.** Reimplantation of the SV is at the surgeon's discretion. If it is performed, portal flow can be re-established prior to beginning the anastomosis by placing a side-biting clamp on the conduit. *(continued)*



F

FIG 13 ● *(Continued)* **F.** Reperfused interposition graft—the SV has been ligated by oversewing with Prolene.

PEARLS AND PITFALLS

Preoperative planning	■ The key to successful PV resection and reconstruction is being prepared to perform the procedure. ■ Assess potential conduit and inform the patient of the possible need for a second surgical incision.
Operative technique	■ Dissect the uncinate process from the SMA prior to controlling and dividing the vein. This provides superior exposure to the posterior aspect of the vein, minimizes clamp time, and avoids the tedious and occasionally bloody dissection of the uncinate while the PV is clamped. ■ Gain early control of the SMV and PV. ■ Procure the reconstruction conduit prior to clamping the mesoportal vessels and completing the resection.
Postoperative care	■ Prescribe antiplatelet therapy.

POSTOPERATIVE CARE

- Administer an aspirin suppository in the recovery room and continue daily antiplatelet therapy at least until discharge. The authors continue enteric-coated aspirin (81 mg) indefinitely after surgery.
- Admit the patient to a monitored environment capable of frequent assessment of vital signs, drain output, and so forth.
- Instruct nursing team to immediately contact the service for a sudden increase in drain output; this can be the first sign of spontaneous thrombosis of the graft—early recognition of thrombosis is essential for any reasonable attempt at surgical revision.
- Bedside ultrasound with Doppler assessment is the first diagnostic modality to assess flow in the PV. Portal venous-phase CT can reliably assess patency of the PV.
- Return to the operating room or angiographic maneuvers to restore patency of a thrombosis have been reported but are rarely employed—reported patency rates of PV reconstruction exceed 90%.

OUTCOMES

- Morbidity, mortality, and disease-free and overall survival do not differ between standard resection and resection requiring a PV/SMV resection/reconstruction.[8]

COMPLICATIONS

- Bleeding
- PV thrombosis
- Deep venous thrombosis
- Venous insufficiency
- Harvest site wound morbidity

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Chapter 40 Open Distal Pancreatectomy

Susanne G. Warner Rebecca M. Minter

DEFINITION

- Distal pancreatectomy is defined as resection of the body and tail of the pancreas with or without splenectomy with transection at any point distal to (left of) the superior mesenteric vessels. This chapter will discuss techniques and indications for open distal pancreatectomy and will focus predominantly on resection for malignancy.

PATIENT HISTORY AND PHYSICAL FINDINGS

- In the era of minimally invasive surgery, there are fewer indications for open distal pancreatectomy than ever before. Whenever possible, minimally invasive techniques for distal pancreatectomy should be pursued. Indications for open distal pancreatectomy are dictated either by the clinical circumstance mandating resection or by a comorbidity or contraindication to laparoscopy. Both can be identified during a thorough history and physical (Table 1). Patients suffering ductal rupture as a result of trauma or those with extensive adhesions or anatomic anomalies resulting from prior surgery are two such examples. Other conditions include a history of peripancreatic inflammation in the setting of acute or chronic pancreatitis or a malignant diagnosis with known vascular involvement. Local advancement into the retroperitoneum without evidence of distant spread is yet another indication.
- In an elective practice, the majority of distal pancreatectomies will be precipitated by suspicion for malignancy,[1] and those being performed open will likely have been selected as such, secondary to local extension of disease. This chapter will thus focus on oncologic principles of resection.
- A relevant history and physical examination in the setting of potential malignancy should include a detailed past medical history with discussion of known pancreatic cancer risk factors such as family history of pancreatic cancer, chronic pancreatitis, history of diabetes, obesity, and smoking. Character, duration, and mitigating factors of any abdominal or back discomfort or sensations should be discussed and considered carefully to guide differential diagnosis.

Table 1: Indications for Distal Pancreatectomy

Indications for Open Distal Pancreatectomy	Contraindications for Minimally Invasive Procedure
• Malignancy with concern for vascular involvement or substantial retroperitoneal local invasion	• Unable to tolerate pneumoperitoneum (i.e., severe cardiopulmonary disorder)
• Trauma/pancreatic duct disruption	• Untreated coagulopathy or liver failure
• Sequelae of acute/chronic pancreatitis (e.g., stricture or disconnected pancreatic tail)	• Documentation of hostile abdomen

- Medical comorbidities as well as cardiovascular and pulmonary functional status should be evaluated, and any relevant testing needed for preoperative clearance such as stress echocardiograms or pulmonary function tests should be performed in accordance with anesthesia guidelines.[2]
- A detailed past surgical history and special attention to family history can help identify patterns of hereditary malignant disease, which can in turn guide preoperative decision making, postoperative surveillance, and genetic testing of the patient and their families. If a neuroendocrine tumor is suspected, symptoms of functional tumors such as rash, diabetes, diarrhea, hypoglycemia, and signs of peptic ulcer disease should be discussed.
- A thorough physical exam should evaluate for any abdominal abnormalities such as organomegaly. Splenomegaly should raise concern for segmental portal hypertension, which could be precipitated by tumor thrombosis or vascular invasion. Hepatomegaly can imply the presence of hepatic metastases. Special attention should also be paid to a patient's nodal basins, specifically left supraclavicular and periumbilical nodes to evaluate for any palpable nodal metastases that would prompt a workup.

IMAGING AND OTHER DIAGNOSTIC STUDIES

- The nature of preoperative testing depends heavily on the nature of the diagnosis. Most conditions will warrant further definition with laboratory evaluations and contrasted, cross-sectional imaging, at times, in conjunction with endoscopic ultrasound for tissue diagnosis and for definition of a pancreatic lesion as it relates to surrounding structures.
- Laboratory testing should include a complete blood count and a comprehensive metabolic panel, including evaluation of liver enzymes and amylase. A preoperative carbohydrate antigen 19-9 (CA 19-9) level is important for postoperative surveillance and can contribute to decision making when neoadjuvant therapy is being considered. When an endocrine tumor is suspected, functional urine and relevant hormone stimulation tests should be performed. If a patient has experienced substantial weight loss, a prealbumin level can be helpful in establishing nutritional status and can guide recommendations for perioperative supplemental alimentation, if appropriate.
- Preoperative workup of a pancreatic mass or injury should almost always include a contrasted, cross-sectional imaging study. Although there is some debate regarding the optimal choice of imaging modality, the most common standard is a computed tomography (CT) "pancreas protocol," which is a triple-phase CT that allows evaluation of arterial, pancreatic, and portal venous phases, and is critical to determining resectability and to establishing an appropriate operative plan. Three-dimensional reconstruction, where available, can also add insight regarding resectability. **FIG 1** demonstrates a lesion with adrenal involvement that would be appropriate for radical antegrade distal pancreatectomy.

FIG 1 ● CT scan showing distal pancreatic mass with adrenal involvement.

- In the case of cystic neoplasms of the pancreas, many surgeons use magnetic resonance cholangiopancreatography (MRCP) in order to assess cystic nature and communication with the main pancreatic duct or side branch ducts in order to further characterize risk of cystic lesion.
- Endoscopic ultrasound (EUS) is another available tool that can elucidate possible lymph node metastases and confirm spatial relationships between a mass and peripancreatic vasculature. EUS can also secure a tissue biopsy of the mass and any suspicious lymphadenopathy as relevant. EUS is not always needed if surgical planning can be completed with cross-sectional imaging, and the results of the EUS would not change the surgical plan. Multidisciplinary collaboration between surgeons and gastroenterologists is important to ensure the appropriate information is gathered and conveyed.
- The role of positron emission tomography (PET)-CT in pancreatic cancer staging for consideration of resection is currently poorly defined and is not currently considered standard of care.

SURGICAL MANAGEMENT

Preoperative Planning

- Preoperative imaging guides surgical treatment. Location of a tumor to the left of the superior mesenteric vessels obviates the possibility of successful disease eradication with a distal or subtotal pancreatectomy. The imaging studies mentioned earlier should be reviewed thoroughly. Close attention should be paid to the planned resection margins, as they relate to surrounding organs and vasculature; particular attention must be given to the retroperitoneal margin, major mesenteric and celiac vessels, left adrenal gland, and left renal vasculature and kidney. If a portion of the colon is involved, a bowel preparation should be considered in anticipation of en bloc colonic resection.
- The anesthesiology team should be informed in advance if a surgeon anticipates an arduous dissection that poses a risk for significant hemorrhage. A type and screen should be drawn on all patients to facilitate blood availability in case of emergent need.
- In addition to adequate peripheral or central intravenous access, a Foley catheter, nasogastric tube, and arterial line should be placed.
- Preoperative antibiotics should be administered within 1 hour of incision. Coverage should be broad spectrum and should include gram-positive skin flora as well as gram-negative and anaerobic intestinal pathogens.
- The entire abdomen from nipples to pubis should be shaved including flanks, even if a midline incision is anticipated. This facilitates subcostal and perixiphoid incisional extension if needed.

Positioning

- The patient is positioned supine with arms out unless precluded by patient shoulder mobility. The secure placement of the post of a self-retaining retractor should be considered.

INCISION

- Left subcostal and midline incisions are both reasonable choices; obesity and costal margin angularity should influence the exposure. Incision location varies based on patient body habitus, tumor location, and surgeon preference. Generally, a slender patient or a patient with a sharp costal margin angle is appropriate for a midline incision as this incision is less morbid. Other candidates for a midline incision are patients with previous midline incision and those with tumors closer to the midline. In obese patients or those with a particularly high splenic flexure or a tumor that is quite distal on the pancreas, a subcostal incision may provide enhanced visualization of the left upper quadrant.
- A vertical midline incision is made from xiphoid to just below the umbilicus.
- A left subcostal incision is made two fingerbreadths below the costal margin and is carried from the midline, obliquely to approximately the anterior axillary line.

INITIAL SURVEY AND EXPOSURE

- The abdomen is explored for signs of extrapancreatic metastases. The liver and peritoneal surfaces are visually examined and palpated. The omentum is examined for caking or nodularity. The gastrohepatic ligament and lymphatic tissues around the celiac plexus are inspected for any evidence of metastasis. Any unexpected findings should be biopsied and sent for frozen section analysis prior to an extensive dissection. When a distal pancreatectomy is anticipated, the head of the pancreas should also be examined and palpated in order to confirm the absence of major abnormalities.
- A self-retaining Omni-Trak or Bookwalter retractor should be placed. Our institutional preference is the Omni-Trak retractor as this provides superior exposure in the upper abdomen using the sternal retractors to elevate the costal margin.
- The splenic flexure is mobilized and reflected downward. In select patients, one may consider laparoscopic mobilization of the splenic flexure and division of the short gastric vessels prior to open distal pancreatectomy to allow for a more limited incision.

EXPOSURE OF THE PANCREAS

- The gastrocolic ligament is divided to gain entry into the lesser sac. The transverse colon is gently retracted inferiorly, taking care not to avulse the middle colic vein as it inserts into the superior mesenteric vein (SMV) at the inferior neck of the pancreas.
- The short gastric vessels are divided with an energy device, or rarely between clamps and ties. Any posterior gastric attachments to the pancreas are divided and the stomach is retracted superiorly to expose the anterior surface of the pancreas.
- In the case of a small lesion that is not readily visualized, the inferior attachments of the pancreas can be freed to facilitate posterior palpation. At the inferior border of the pancreas, gentle separation of pancreatic parenchyma from posterior attachments can be achieved. The splenic vein can be identified and isolated just to the left of its union with the portal vein (PV) usually beneath the pancreas. Intraoperative ultrasound can also be used to locate small lesions in the tail of the pancreas that are not readily identified.
- More typically, the celiac trunk is identified at the superior border of the pancreas and the hepatic and splenic arteries are identified and followed to their origins. The splenic artery is then ligated and divided using either a vascular stapler or silk ties, double securing with a stick tie (3-0 silk) followed by free tie (**FIG 2**).

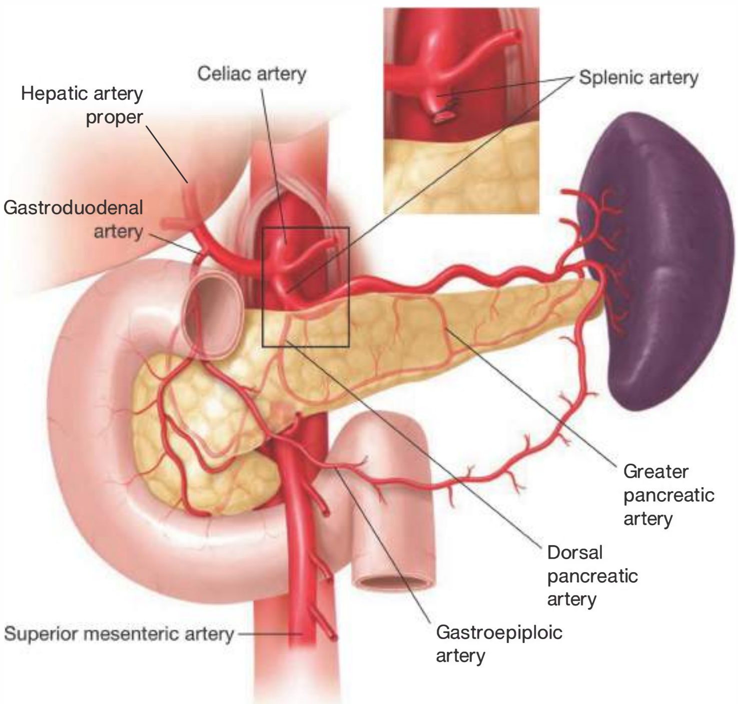

FIG 2 ● Splenic artery division.

CHOICE OF PANCREATIC DISSECTION TECHNIQUE

- As with any operation, there are a wide variety of techniques available to achieve the intended resection. One should decide preoperatively whether to undertake a lateral to medial (retrograde) or a medial to lateral (antegrade) resection and whether a spleen-preserving procedure is appropriate to consider. In the setting of malignancy, our preferred practice is typically a radical antegrade resection with N1 resection.

Splenectomy with Lateral to Medial (Retrograde) Dissection

- Beginning at the inferior pancreatic border, the posterior pancreatic attachments to the retroperitoneum are divided until the inferior mesenteric vein (IMV) and SMV are visualized (**FIG 3**). The pancreas is gently retracted anteriorly, which should help develop the avascular plane between the pancreas and retroperitoneum. The IMV is divided and the splenic vein is elevated with the specimen along the posterior aspect of the pancreas.

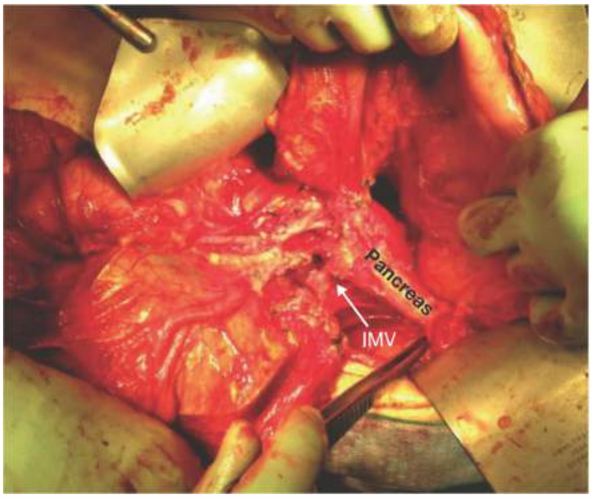

FIG 3 ● Exposure of inferior pancreatic border—SMV and IMV.

- With the body and tail freed, the lienorenal and lienophrenic attachments can be divided, and the spleen should be freed from the posterior abdominal wall. Posterior mobilization should be predominantly complete and the spleen and distal pancreas can be reflected medially. At this point, the splenic artery is identified, typically running along the superior border of the pancreas, although there can be significant anatomic variability including an intraparenchymal location. The splenic artery is isolated 2 cm proximal to the mass lesion at the site of planned parenchymal transection or just distal to its origin and divided between clamps. It is doubly secured with a stick tie and a free tie. The splenic vein can then be clearly followed to its confluence with the PV and can be divided and oversewn at the level of the PV.
  - With the distal pancreas now entirely mobilized, it should be palpated to ensure that anticipated point of transection is in fact free from the mass of interest or any other abnormalities. If the point of transection needs to occur proximal to the splenic vein/PV confluence and the PV is free of tumor, a plane on the anterior surface of the vein can be developed to facilitate pancreatic parenchymal transection closer to the pancreatic neck.
- Pancreatic transection is now performed (see "Pancreatic Transection" for details).

Splenectomy with Medial to Lateral (Antegrade) Dissection

- This is our preference for patients with locally advanced pancreatic cancer in the body or tail of the pancreas. This procedure may be more time consuming but facilitates early vascular isolation and enhanced lymph node procurement as well as early and safe establishment of margin status. With this technique, early pancreatic transection is necessitated.
- Once the greater omentum is elevated and the colon retracted inferiorly, the lesser sac is opened and the common hepatic artery is traced to the proper hepatic. The gastroduodenal artery is identified and occasionally requires division if a more proximal point of transection at the neck of the pancreas is required.
- Lymph nodes are dissected free of the left border of the proper hepatic artery, PV, and common hepatic artery. The avascular plane between the PV and posterior pancreatic neck is developed and the pancreatic neck is divided.
- The celiac trunk is identified and a celiac lymph node dissection is carried out from the superior border of the pancreas, ultimately exposing the origin of the splenic artery, which is then ligated as previously shown (**FIG 2**). The artery is typically ligated with a 2-0 silk free tie and a 3-0 silk stick tie but can also be stapled if the angle is appropriate and there is no compromise to the celiac trunk. Rarely, the left gastric artery warrants ligation at this juncture in order to facilitate complete lymph node dissection. However, this is not an option in the case of a replaced left hepatic artery, and it is very important to carefully review the preoperative CT angiogram preoperatively to be fully aware of any aberrant arterial anatomy.
- The splenic vein is encircled and divided at the junction with the PV. Dissection in a sagittal plane then proceeds until the superior mesenteric artery (SMA) is identified. The periaortic lymph tissue between the celiac trunk and SMA is then removed. An adequate dissection exposes the left side of the aorta from the origin of the SMA superiorly to the origin of the celiac trunk (**FIG 4**).
  - This dissection can be carried down onto the diaphragm, if necessary, to include the adrenal gland as part of the resected specimen if needed.
  - The left renal vein should be the inferior border of dissection. The adrenal vein is identified and remains undisturbed if the adrenal gland is not part of the specimen. Gerota's fascia is resected from the superior pole of the kidney in the case of more lateral malignancies.

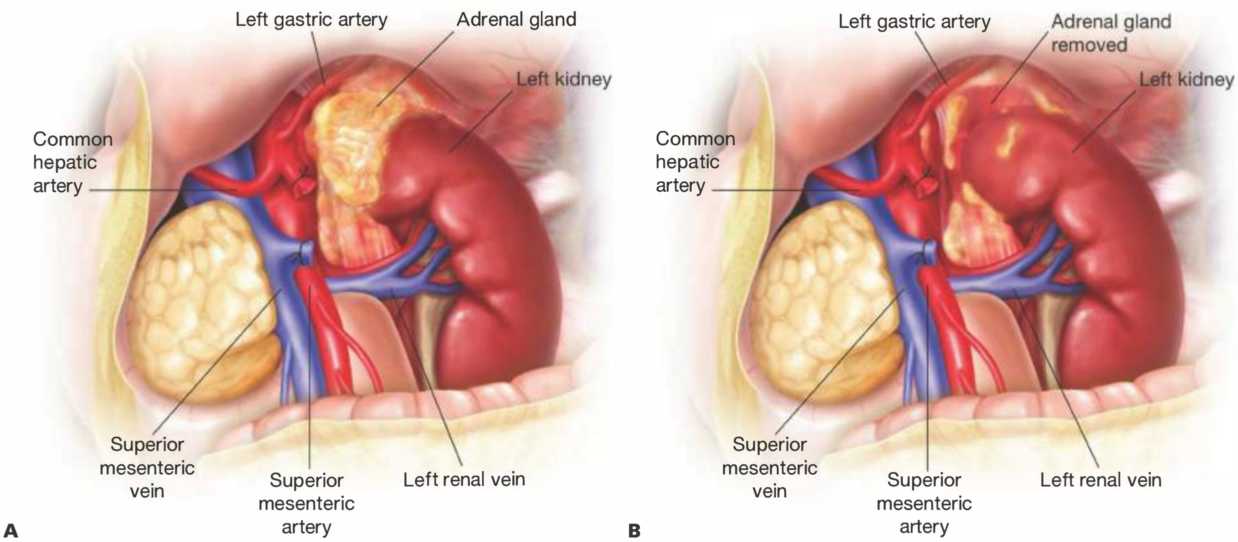

FIG 4 ● Exposure of left aorta from SMA to celiac trunk **(A)** with left adrenal in place, **(B)** with left adrenal removed.

- The superior and inferior pancreatic peritoneal attachments are then divided and dissection proceeds laterally. The IMV is ligated and transected and the spleen is separated from the kidney as the final operative step prior to specimen removal.
  - Although rare, adrenal resection is sometimes necessary and has been described in detail by Strasberg et al.[3]

Spleen-Preserving Distal Pancreatectomy

- Splenic preservation can be considered in the case of cystic lesions or small well-differentiated neoplasms for which a large radical excision is oncologically unnecessary.
- There are several techniques for splenic preservation:
  - The Warshaw[4] technique of dividing the splenic artery and vein proximal to the tumor and then again at the splenic hilum, leaving the short gastrics and as the primary blood supply for the spleen is occasionally attempted but is less commonly performed secondary to the severity of complications that can occur, namely splenic infarcts, splenic abscess, and gastric varices.
- The more common method of splenic preservation involves preservation of the splenic vessels and careful dissection of the vessels away from the posterior pancreas until the splenic hilum is reached. The small arterial and more numerous venous branches are isolated between clamps and ligated or controlled with a surgical energy device. FIG 5 shows the resection bed following spleen preserving distal pancreatectomy.

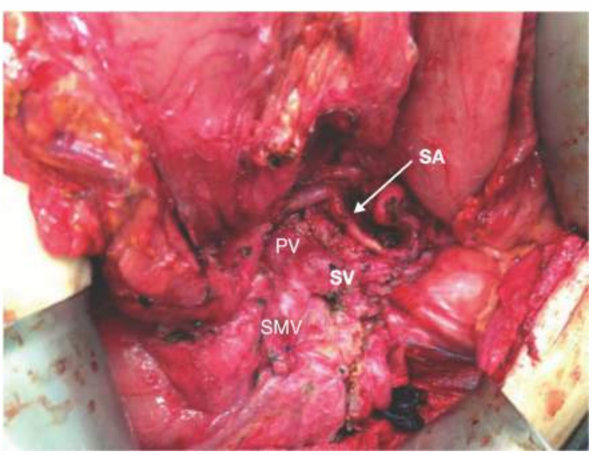

FIG 5 ● Resection bed following spleen preservation. SV, splenic vein; SA, splenic artery.

PANCREATIC TRANSECTION

- In cases of relatively nonedematous or nonfibrotic pancreatic parenchyma that is typically not greater than 1.5 cm in thickness, an Endo GIA stapler can be used to transect the pancreas (3.0-mm load). In cases of pancreatic edema or a thicker gland, an energy device can be used for parenchymal transection, and the line of transection is then oversewn using a running, locking 3-0 Prolene stitch. **FIG 6** shows pancreatic transection using a thoracoabdominal (TA) stapler.
- The specimen is removed and marked for margins on a back table. The surgeon may wish to walk to pathology personally to ensure specimen orientation and discussion of margins.
- The transected specimen should be sent to pathology for margin assessment—typically, the pancreatic margin is assessed and, if in question and there is the possibility of additional retroperitoneal clearance, then a frozen section on the retroperitoneal margin may be obtained as well. Serial sections may be required to establish adequate margins.
- The resection bed may be marked with clips for postoperative radiation if procedure is for a malignancy, particularly, if there is a margin which is felt to be in question following radical resection. A closed suction drain is left in the resection bed near the pancreatic stump. Size and type of drain are based on surgeon preference. In general, our practice is to use a 10-Fr flat Jackson-Pratt drain. The colon and stomach are placed in their usual anatomic position.

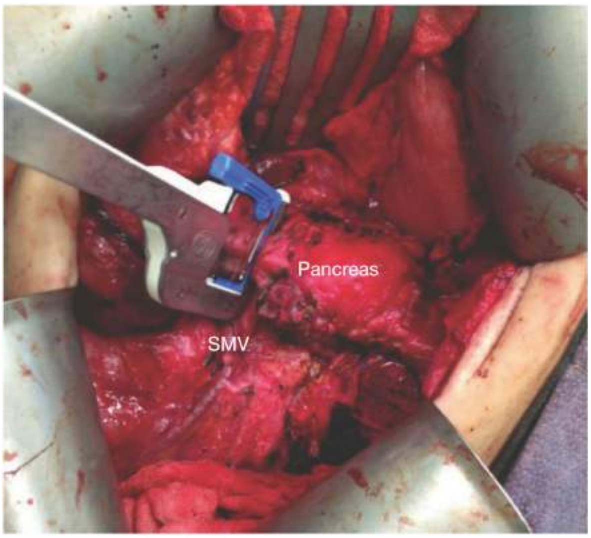

FIG 6 ● Pancreas division using TA stapler.

CLOSURE

- Midline fascial incision is closed using running looped 0 or 1-0 polydioxanone (PDS) suture. Skin is then reapproximated with interrupted 3-0 Vicryl deep dermal sutures and 4-0 Monocryl suture in a running subcuticular fashion.
- Subcostal fascial incision is closed in one or two layers using 0 or 1-0 PDS suture depending on surgeon preference.

PEARLS AND PITFALLS

Indications	▪ A complete history and physical and review of imaging must be performed to ensure the patient is an appropriate surgical candidate and to review for any aberrant anatomic considerations. If appropriate, minimally invasive techniques are preferred.
Incision	▪ Midline incision is preferred for more slender patients or those with a sharply angled costal margin. The splenic flexure can be mobilized laparoscopically for enhanced ease of dissection and potentially a more limited midline incision. ▪ Patients with high splenic flexure or those undergoing a splenic-preserving procedure may benefit from left subcostal incision.
Initial survey and exposure	▪ Retractor placement (Omni-Trak) ▪ Any unanticipated lymphadenopathy outside the planned plane of dissection or unexpected suspected metastases should be biopsied and sent for frozen section prior to any dissection. Be certain to examine the head of the pancreas.
Exposure of the pancreas	▪ When mobilizing the posterior stomach away from the anterior pancreas, vessels encountered between the gastrum and mesocolon should be ligated with care taken not to injure the middle colic vessels. Do not apply undue tension in retracting the colon down as the middle colic vein can be avulsed off the SMV.
Lateral to medial (retrograde) dissection	▪ If the point of transection needs to occur proximal to the splenic vein/PV confluence and the PV is free of tumor, a plane on the anterior surface of the vein can be developed to facilitate pancreatic parenchymal transection closer to the pancreatic neck. This may require ligation of the gastroduodenal artery.
Medial to lateral (antegrade) dissection	▪ During splenic arterial ligation, control is obtained proximal to anticipated site of ligation prior to tie or stapler placement. ▪ Prior to ligating the splenic artery, encircle and occlude it, then verify that the proper hepatic is still pulsatile to verify ligation of the correct structure. ▪ If needed, secondary to extensive posterior involvement, dissection can be carried down onto the diaphragm to include the adrenal gland as part of the resected specimen. ▪ If transverse colon involvement is suspected, a full bowel preparation is recommended in anticipation of possible en bloc resection.
Splenic preservation	▪ Splenic preservation can be considered in the case of cystic lesions or small well-differentiated neoplasms for which a large radical excision is oncologically unnecessary.
Pancreatic transection	▪ In cases of severe edema or fibrosis or a thicker gland (>1.2 to 1.5 cm), hemostasis and pancreatic duct closure can be incomplete with the use of a stapler. In this instance, our preference is to use and energy device to transect the pancreas. ▪ Regardless of transection method, the pancreatic stump is always oversewn using a running, locking 4-0 Prolene suture.
Specimen analysis	▪ It is important to work with pathology colleagues both on specimen orientation and to encourage appropriate nodal retrieval analysis. Inking of margins by the surgeon is encouraged.

POSTOPERATIVE CARE

- Blood glucose should be closely monitored postoperatively. Development of diabetes in the postoperative setting is widely variable, ranging from 9% to 40% and may depend on the preoperative pancreatic function and severity of chronic pancreatitis.[5] Whichever the case, blood glucose must be closely monitored in the perioperative setting and at regular intervals in the long term.
- A transient elevation of pancreatic enzymes may be noted but should trend down within several days. Closed suction drainage should remain in place until the patient's diet has been advanced, and drain output should be monitored for signs of pancreatic fistula. Although there is a trend toward drainless pancreatic surgery, it remains our preference to use a closed suction drain to monitor for postoperative fistula. The reported incidence of fistula is 9% to 35%, regardless of pancreatic transection technique. If there is persistent amylase-rich output at 4 weeks postoperatively, the patients are treated with pancreatic duct stenting, which typically resolves the fistula and allows for drain removal.
- We typically begin clear liquid diet on postoperative day 2, depending on patient status. From there, diet is advanced in the standard fashion, based on patient distension and abdominal comfort level. Postoperative nasogastric tube placement is not used as a standard, although in the case of a longer operative duration with retraction of the stomach upward and more extensive dissection, it may be used for 24 to 48 hours after surgery.
- Once diet is advanced, providers should be vigilant for symptoms of pancreatic insufficiency even if blood glucose control remains adequate. Many patients will benefit from perioperative pancreatic enzyme supplementation, particularly if they had any underlying chronic pancreatitis preoperatively. Approximately 17% will need supplementation in the long term.[6]

- For any patients undergoing pancreatic resection, it is important that they are monitored by their primary care physicians for vitamin D deficiency and osteoporosis in the long term at their health maintenance exams, which can result from long-standing pancreatic exocrine insufficiency. The surgeon should communicate this surveillance need to the patient's primary care physician, as they may otherwise be unaware of this possible disease-specific deficiency.

OUTCOMES

- An R0 resection should be the goal in every oncologic resection. Long-term results for distal pancreatectomy vary significantly based on pathology. With adenocarcinoma of the body and tail of the pancreas, long-term results of the antegrade technique have shown improved negative margin rates with only 9% positive tangential margins in recent years as compared to the more traditionally observed approximate 25% R1 resection rate seen with the retrograde method.[7] With the antegrade method, Strasberg and colleagues[3] are reporting an actual 5-year survival of 30.4% with an actuarial survival of 35.5%. However, one must bear in mind that most of the evidence surrounding open distal pancreatectomy for malignancy is underpowered, single-institution, and retrospective in nature.

COMPLICATIONS

- Most of the available outcomes data for distal pancreatectomy exists as retrospective case series or large reviews of case series. Therefore, reporting of certain complications is highly variable.
- Overall complication rates are reported as high as 40% for open distal pancreatectomy in large series.[5,8]
- The data regarding pancreatic bed and subphrenic abscesses is conflicting with some authors demonstrating increased abscess formation following spleen-conserving surgery, and others reporting the opposite.[9,10] With increasing popularity of splenic preservation as more solid and cystic pancreatic lesions are identified incidentally, a more clear picture of benefit and risk of splenectomy versus splenic preservation will hopefully emerge.

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Chapter **41**

Minimally Invasive Distal Pancreatectomy

Paul D. Hansen   W. Cory Johnston

DEFINITION

- Laparoscopic and robotic approaches to distal pancreatectomy were initially reserved for small, benign lesions of the pancreatic body and tail. As surgical expertise and refinements of the techniques progressed, indications have expanded to include larger lesions and invasive malignancies.
- Minimally invasive resections are now commonly performed in cases of malignant neoplasms with oncologic outcomes equivalent to open resection in experienced hands.
- The decision to attempt splenic preservation is dictated by the underlying pathology, the size and location of the lesion, and its relationship to the spleen and splenic vasculature.

DIFFERENTIAL DIAGNOSIS

- Pancreatic adenocarcinoma
- Pancreatic neuroendocrine tumors
- Cystic pancreatic lesions
- Pancreatic metastases
- Sequelae of chronic pancreatitis

PATIENT HISTORY AND PHYSICAL FINDINGS

- Tumors of the pancreatic body and tail are typically asymptomatic and are, therefore, more likely to manifest in the later stages of disease progression. Consequently, regional and distant disease is commonly encountered during the initial evaluation or at the time of surgical exploration.
- Careful attention should be made in the history and physical examination to elicit symptoms and signs of advanced disease including back pain from invasion of the celiac plexus, nausea and early satiety from invasion or compression of the stomach or duodenum, and splenomegaly caused by thrombosis of the splenic vein.

IMAGING AND OTHER DIAGNOSTIC STUDIES

- The primary imaging modality is pancreatic protocol, multiphase computed tomography (CT) scans including precontrast, arterial, and portal venous phases. 1- to 3-mm cuts with coronal and sagittal reconstructions allow a detailed analysis of the pancreas, the pathologic target, and the surrounding vasculature and viscera (**FIGS 1–3A**). Abdominal and pelvic CT is also useful in identifying the presence of lymphadenopathy, metastatic peritoneal or omental implants, and hepatic metastases. In patients with known or suspected pancreatic adenocarcinoma, a staging chest CT is also recommended.
- Abdominal magnetic resonance imaging (MRI) is slightly more sensitive in identifying liver metastases but provides less anatomic soft tissue detail regarding the pancreas and vasculature. Magnetic resonance cholangiopancreatography (MRCP) can be helpful in grossly examining ductal anatomy but does not provide fine detail. MRI requires a higher degree of patient cooperation but may be helpful in patients with contrast allergies or other contraindication to contrast-enhanced CT.
- Endoscopic ultrasound (EUS) is operator-dependent but can result in a more accurate assessment of tumor size and relationship to the portal and superior mesenteric veins (SMV) (**FIG 1B**). Assessment of superior mesenteric artery (SMA) and celiac involvement is no better than CT. Tissue sampling via ultrasound-directed fine needle aspiration (FNA) of primary tumor or regional lymph nodes may provide confirmatory tissue diagnosis. EUS-guided sampling of fluid from pancreatic cystic lesions may help distinguish between benign and premalignant tumors.
- Endoscopic retrograde cholangiopancreatography (ERCP) can be useful in providing fine details of pancreatic and bile duct anatomy, such as dilatation, strictures, luminal defects, or masses.

A

B

FIG 1 ● **A.** Venous-phase CT showing a hypodense mass in the pancreatic body adjacent to the splenic artery. The distal pancreatic duct is dilated. **B.** EUS showing the pancreatic body mass with direct abutment with the splenic artery (SA).

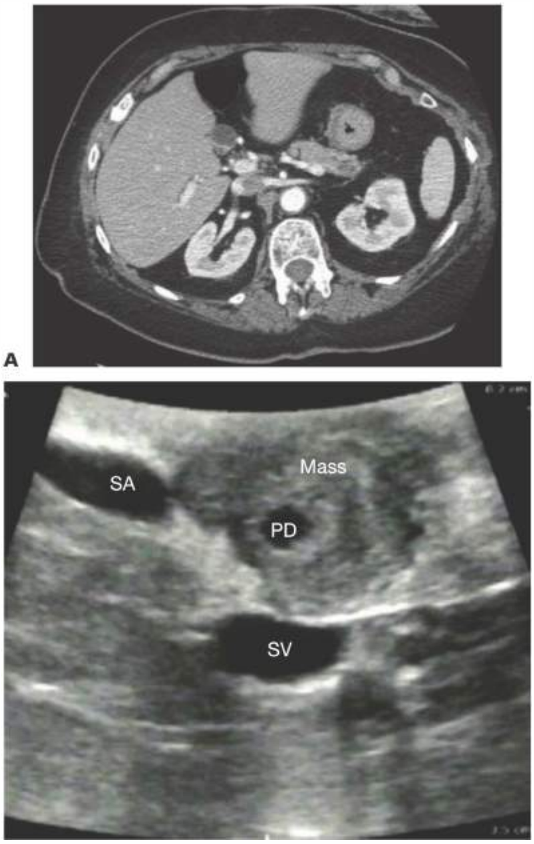


FIG 2 ● **A.** Venous-phase CT showing an irregular hypodensity in the pancreatic tail. This was proven to be a ductal adenocarcinoma on EUS/FNA. **B.** IOUS image showing an irregular, hypoechoic mass in the pancreatic tail around the pancreatic duct (PD). The mass abuts both the splenic vein (SV) and the splenic artery (SA).

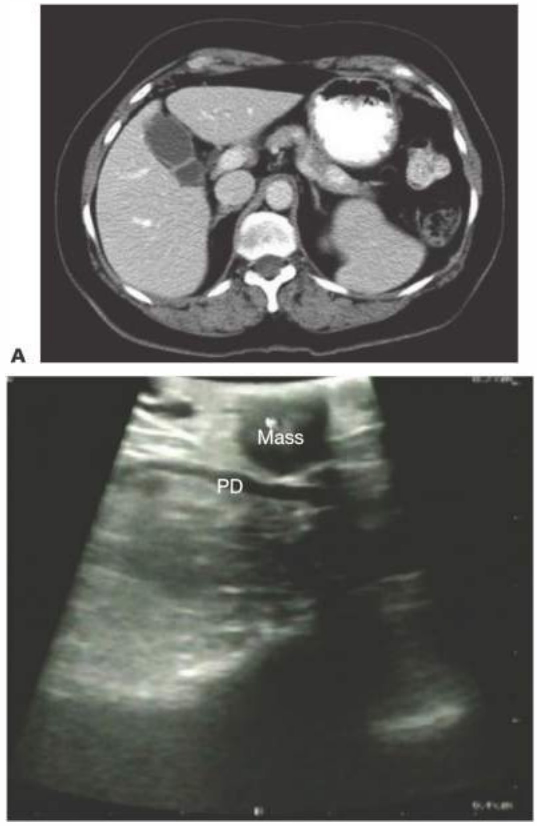


FIG 3 ● **A.** Venous-phase CT showing a rounded hypervascular mass in the pancreatic tail. The patient presented with symptomatic hypoglycemia. The tumor was proven to be an insulinoma by EUS/FNA. She was treated with a spleen-preserving distal pancreatectomy. **B.** IOUS showing the insulinoma at the time of resection. The deep margin was within 2 mm of the pancreatic duct (PD).

- Intraoperative ultrasound (IOUS) is used routinely to define the relevant pathology, to identify important vascular structures, and to determine resectability during operative staging (**FIGS 2B** and **3B**).

SURGICAL MANAGEMENT

Preoperative Planning

- Feasibility of resection should be determined preoperatively based on cross-sectional imaging and EUS. We use National Comprehensive Cancer Network (NCCN) guidelines for resectability based on the tumor's relationship to the SMA and celiac trunk.[1] Portal, superior mesenteric, splenic, and left renal vein involvement do not preclude resection but may suggest a role for neoadjuvant therapy.[2] Resection of the celiac trunk with reconstruction of the hepatic artery has been described in numerous series, but most major American centers have not adopted this approach.[3]
- The extent of gland resection is variable and should be directed by tumor location within the pancreas and its relationship with relevant blood vessels. Lesions in the tail of the pancreas can be resected with preservation of the neck and body, whereas more proximal lesions may require division of the gland closer to the portal vein. The gastroduodenal artery (GDA) is generally considered the landmark for the proximal limit of transection, as division of the pancreas more proximally places the intrapancreatic bile duct at risk of injury.
- The decision to include the spleen in the resection is typically made preoperatively based on surgeon preference and the characteristics of the tumor. If malignancy is suspected, the spleen and lymphatic tissue along the splenic vessels should be resected en bloc with the pancreas. Cystic lesions that are considered low risk for malignancy can be considered for a spleen-preserving approach. Intraoperative findings may alter plans for spleen preservation.
- Central venous access is typically not necessary as long as reliable, large-bore peripheral intravenous (IV) lines are established. An arterial blood pressure catheter can be placed at the discretion of the anesthesiologist.

Positioning

- The patient is positioned supine or, in some cases, in a gentle right semilateral decubitus position on a padded mattress.

The arms are supported on arm boards at just under 90 degrees to prevent stretch of the brachial plexus. Alternatively, the arms may be tucked at the patient's side to facilitate placement of fixed retractors.

- During the dissection, the operating table is positioned in reverse Trendelenburg with the left side slightly elevated so that the hollow viscera fall caudad and to the right, away from the operative field.
- The position of the operating surgeon depends on the position of the tumor within the pancreas and may change during the procedure. During mobilization of the stomach and colon, the surgeon is typically on the patient's right with the assistant on the patient's left. Once the body and tail of the pancreas are exposed, the surgeon's position depends on tumor location. If the tumor is distal and the transection of the pancreas will be in the body, the surgeon stays on the patient's right. If the tumor is in the proximal body and the point of transection will be at the pancreatic neck, the dissection may be easier by having the surgeon stand on the patient's left. This facilitates the surgeon's ability to dissect along the superior mesenteric and portal veins and create the window behind the neck of the pancreas.
- We typically use a 10-mm high-definition (HD) laparoscope to ensure optimal visualization. Alternatively, a 5-mm HD laparoscope may be used.
- We prefer to use dual carbon dioxide (CO_2) insufflation devices. This can be valuable in cases where bleeding occurs, as laparoscopic suction devices can rapidly decompress pneumoperitoneum.

DIAGNOSTIC LAPAROSCOPY

Port Placement

- For exploratory laparoscopy, we start with two ports. The first is typically 11 or 12 mm and placed just below the umbilicus. The second is an 11 or 12 mm and placed just lateral to the left rectus muscle, at the level of the umbilicus. These ports facilitate peritoneoscopy and laparoscopic ultrasound examination.
- Two or three additional ports are placed, depending on the complexity of the procedure and on the position of the tumor within the pancreas (**FIG 4**).
- A high, right 5-mm subcostal port will ultimately serve to retract the stomach cephalad to expose the pancreas. Additional 5-mm ports may be placed just lateral to the right rectus muscle above the level of the umbilicus or laterally along the left subcostal margin. Which ports are used for the camera, surgical dissection, or assistant's retraction will depend on the position of the tumor as described earlier.

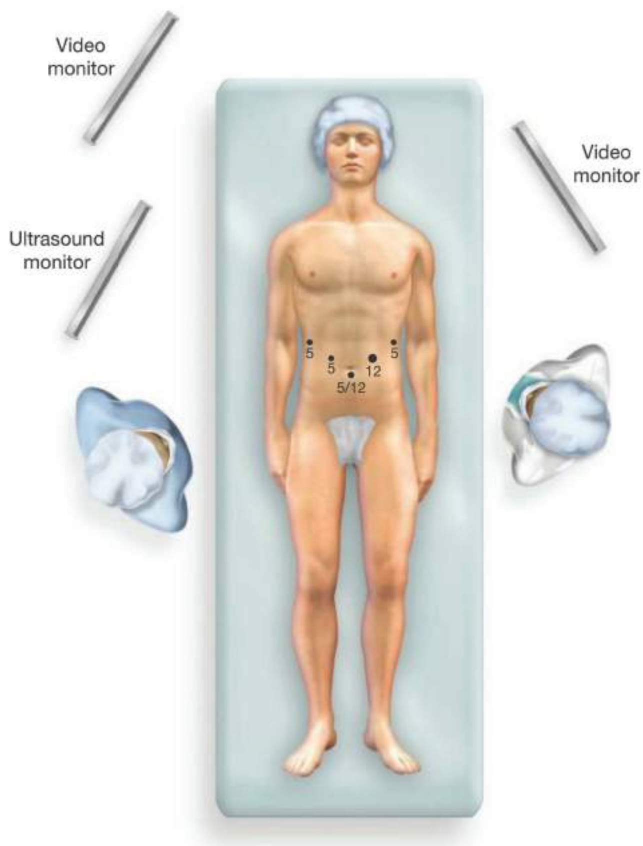


FIG 4 ● Illustration showing port positions. The patient is positioned supine with the left side bumped slightly with a padded wedge. The arms can be tucked or extended. The surgeon can stand on either side; typically, patient's right for distal tumors and patient's left for proximal tumors.

- A hand port may be used at the surgeon's discretion. Hand assistance can be very useful for large tumors that invade the surrounding viscera, inflammatory masses, and proximal tumors that abut the celiac axis. The optimal position of the port is variable. Right-handed surgeons will prefer to have the left hand in the port, and a lower midline position is preferred. Left-handed surgeons typically prefer to have their right hand in the port, which should be positioned laterally beneath the left costal margin.

Examination of Peritoneum and Viscera

- The entire peritoneal surface is examined for carcinomatosis. Suspicious lesions are biopsied and sent for immediate pathologic analysis.
- The abdominal viscera are likewise examined and any suspicious lesions are sampled. Although we look at the omentum and easily accessible viscera, we typically do not "run the bowel" unless otherwise indicated.
- The root of the small bowel mesentery and the undersurface of the transverse mesentery are examined in cases of large malignant tumors and those located in the central pancreas.
- Ascitic fluid is sent for cytology.

Intraoperative Ultrasound

- The liver is systematically examined for evidence of metastases. Surface lesions are wedged out with a small margin and sent for frozen section analysis. Intraparenchymal nodules are biopsied with a coring needle and sent for immediate pathologic analysis.
- The pancreatic parenchyma is examined. The exact location and dimensions of the tumor are determined as well as its relationship to the duct (**FIG 3B**).
- The relationship of the tumor to the SMA, SMV, splenic vessels, and left renal vein is determined (**FIG 2B**). The intended location of pancreatic gland transection is estimated.
- Paraaortic lymph nodes as well as those along the origins of the celiac trunk and the SMA are examined. Suspicious lymph nodes outside the limitations of the proposed resection should be biopsied and sent for frozen section.
- The procedure is terminated or a predetermined palliative bypass is performed if diagnostic laparoscopy reveals metastatic or locally unresectable disease.

LAPAROSCOPIC DISTAL PANCREATECTOMY AND SPLENECTOMY

Mobilization of the Splenic Flexure

- With the patient in reverse Trendelenburg position with the left side rotated up, the lateral peritoneal reflection is incised and the proximal descending colon is medialized. The distal transverse colon and splenic flexure are brought down away from the inferior splenic pole. This dissection occurs in the avascular plane between Gerota's fascia and the mesocolon.
- The inferior pole of the spleen is mobilized by dividing the avascular retroperitoneal attachments.
- The lesser sack can be entered anterior to the tail of the pancreas during this dissection. This "clockwise approach" is described by Asbun and Stauffer[4] and can be useful for exposure of the pancreatic body via a left to right division of the gastrocolic ligament (**FIG 5A,B**).

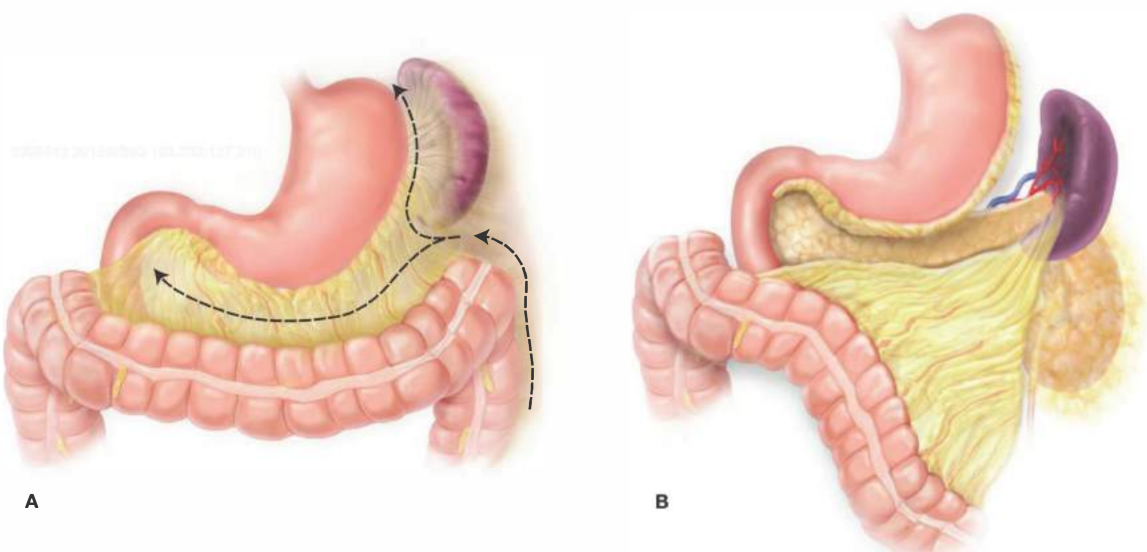


FIG 5 ● Illustration showing "clockwise" technique for exposure of the distal pancreas. **A.** The left colon and splenic flexure are mobilized from left to right. The lesser sack is entered in the plane between the pancreatic tail and the transverse mesocolon. **B.** The gastrocolic and gastrosplenic ligaments are then divided to expose the pancreas and to drop the transverse colon out of the field of dissection.

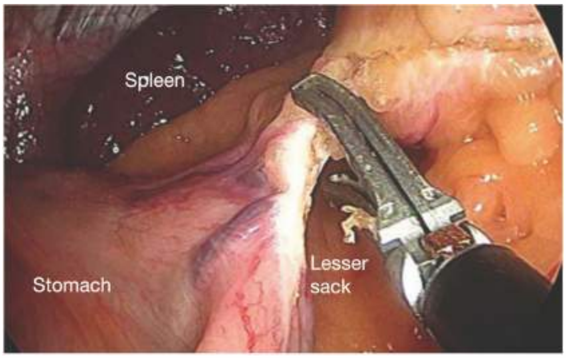


FIG 6 ● Operative image showing division of the short gastric vessels between the greater curvature and the spleen. These vessels can be taken safely with bipolar or ultrasonic coagulating devices unless they are engorged due to splenic vein thrombosis.

Entry into the Lesser Sack and Division of the Short Gastric Vessels

- Preserving the right gastroepiploic arcade, the lesser sack is traditionally entered through the gastrocolic ligament just below the greater curve of the stomach. The gastrocolic and gastrosplenic omentums are then divided from right to left using ultrasonic shears or a bipolar electrocautery device (**FIG 6**).
- Enlarged venous collaterals may be present in this area if the splenic vein is invaded or thrombosed. A linear stapler or individual vessel ligation with clips or ties is often preferred for division of varices greater than 3 mm in diameter.
- Mobilization of the fundus continues all the way to the left crus. The posterior wall of the stomach is mobilized anteriorly to completely expose the body and tail of the pancreas. Avascular congenital adhesions are frequently present between the stomach and pancreas and can be divided bluntly or with electrocautery (**FIG 7**).
- For proximal tumors of the pancreatic body, the dissection continues toward the patient's right. The transverse mesocolon is swept caudally in an avascular plane that exposes the middle colic and gastroepiploic vessels, which are followed to their confluence with the SMV. The anterior surface of the SMV is cleared cephalad in its adventitial plane up to the inferior margin of the pancreas.

Mobilization of the Pancreatic Body and Tail

- The stomach is retracted anteriorly, away from the pancreas using a liver retractor or by suturing the greater curve to the abdominal wall (**FIG 8**).
- Using electrocautery or ultrasonic energy, the retroperitoneum is incised along the inferior border of the pancreas from medial to lateral. Gentle retraction is used on the pancreas, as it is prone to tearing and bleeding.
- The line of transection of the pancreas is dictated by the location of the pathology. Tumors from the tail to the midbody can be resected with a generous margin by transecting the proximal pancreatic body. Tumors involving the proximal body require subtotal distal pancreatectomy with gland transection of the pancreatic neck anterior to the SMV. Tumors involving the pancreatic neck require transection to the right of the SMV. The most proximal resection plane is where the GDA passes anterior to the pancreatic head. Attempts to resect further to the right may result in injury to the intrapancreatic bile duct.
- The plane between the posterior wall of the pancreas and the retroperitoneal fat is entered and the gland is mobilized anteriorly with blunt dissection or electrocautery.
- The pancreatic tail is mobilized anteriorly, taking care not to enter the splenic hilum. The plane of this dissection will intersect in the lesser sack with the plane previously opened during mobilization of the splenic flexure of the colon.
- The retroperitoneum along the superior margin of the pancreas is divided along the length of the gland. The splenic artery is frequently seen in a superficial retroperitoneal plane and can be dissected and encircled with a vascular loop.

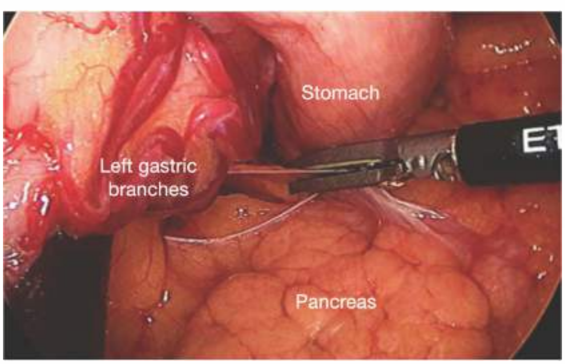


FIG 7 ● Operative image demonstrating the division of the congenital adhesions from the posterior wall of the stomach to the pancreatic body.

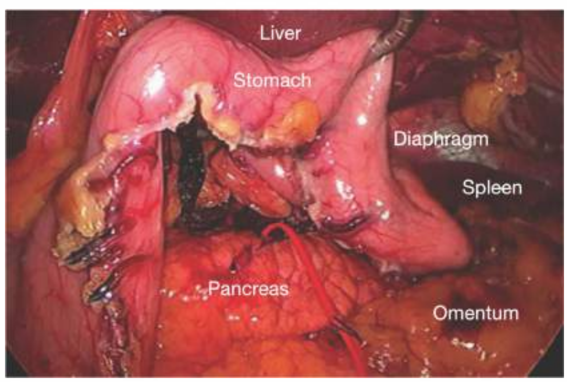


FIG 8 ● Operative image showing excellent exposure of the pancreatic body after division of the gastrocolic omentum and elevation of the stomach with a retractor placed through a right upper quadrant port.

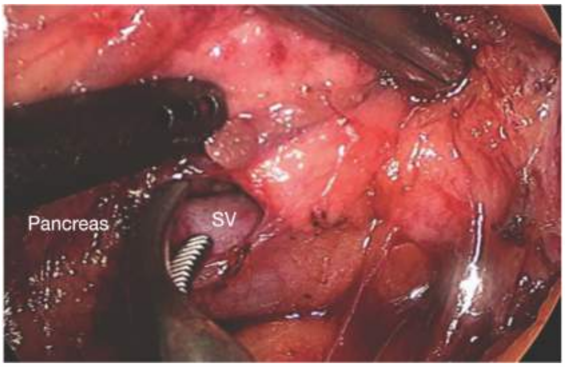


FIG 9 ● Operative image demonstrating dissection of the splenic vein behind the posterior aspect of the pancreatic body. A window is created between the splenic vein and the superior edge of the pancreas. The splenic artery is often seen behind the vein from this perspective.

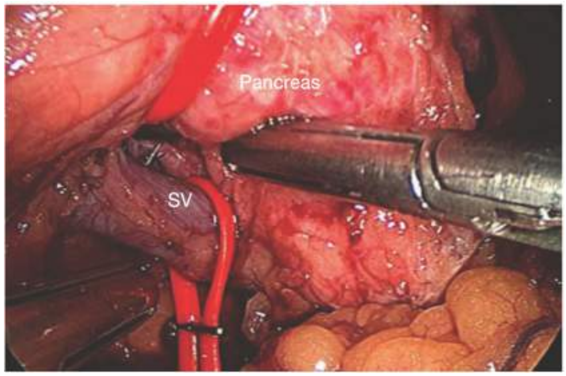


FIG 11 ● Mobilization of the splenic vein (SV) away from the posterior wall of the pancreas, and encirclement of the vein with a vascular loop to facilitate retraction.

Isolation and Division of the Splenic Vein

- Ultrasound is used to confirm the location of the tumor and to select an appropriate line of gland transection. The splenic vessels are also visualized and their relationship to the pancreas is noted (**FIG 2B**). For distal tumors, the vein is dissected and divided behind the pancreatic body. For proximal tumors, the SMV/splenic vein confluence is dissected behind the pancreatic neck and the splenic vein is divided here.
- With the pancreas reflected anteriorly and cephalad, the splenic vein is located behind the pancreas in the intended region of transection. The vein may be partially or completely enveloped in pancreatic tissue, particularly at the more distal aspects of the gland.
- A curved dissector is used to enter the adventitial plane around the vein and create a tunnel between the vein and pancreas (**FIG 9**). The tunnel is extended cephalad and anteriorly up to the superior margin of the pancreas. The splenic artery may be encountered and exposed during this dissection.
- A short vessel loop may be passed around the pancreas and the tails retracted anteriorly, facilitating excellent exposure to the splenic vein (**FIG 10**).
- The splenic vein is dissected circumferentially and may be encircled with a second vessel loop. The loop is used for retraction as the vein is mobilized away from the pancreas along a sufficient length to provide passage of a linear stapler (**FIG 11**).
- The vein is divided with a linear vascular stapler or between locking clips or nonabsorbable ties. If the vein is closely opposed to the pancreas at the point of transection, it can be included in the staple line if a linear stapler is used.
- For proximal tumors, the anteromedial surface of the SMV is bluntly dissected away from the pancreatic neck to expose the confluence of the splenic vein (**FIG 12**),

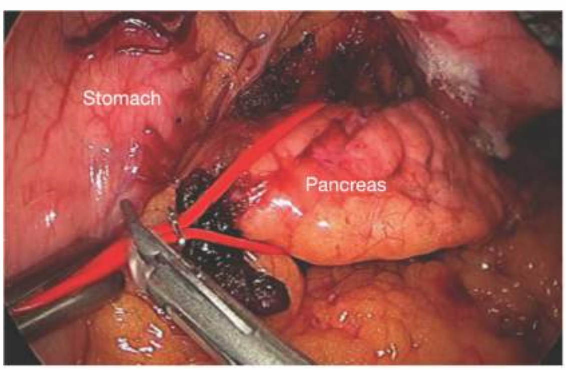


FIG 10 ● Operative image of the mobilized pancreatic body. Passage of a vascular loop around the pancreas helps with retraction during vascular dissection and positioning of the stapling device.

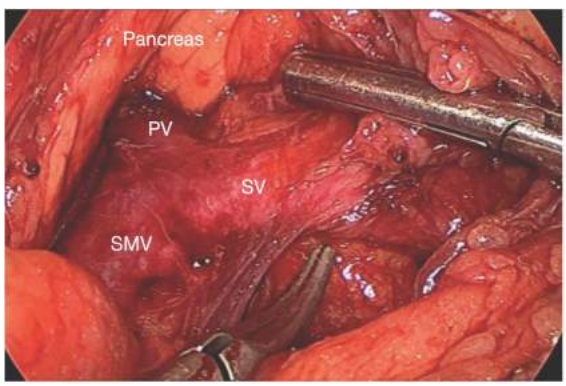
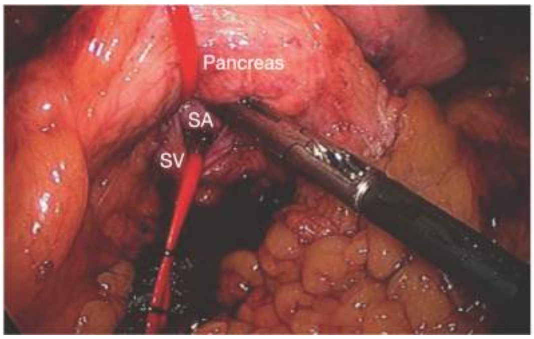
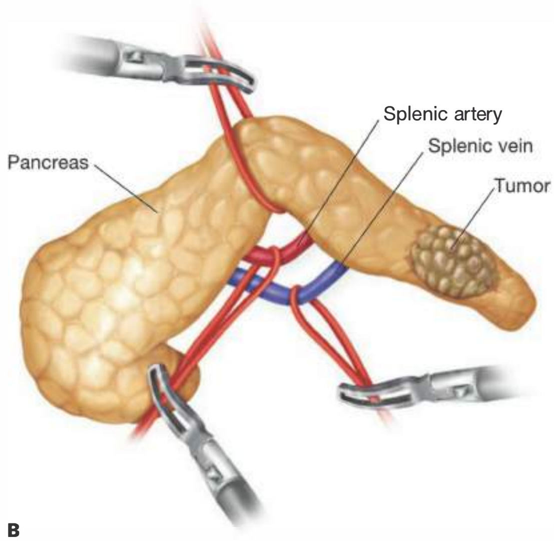


FIG 12 ● Operative image showing the dissection of the SMV/splenic vein (SV)/portal vein (PV) confluence behind the neck of the pancreas. This is the margin of transection for more proximal tumors of the pancreatic body. Pathology involving the pancreatic neck requires division of the pancreas even further to the patient's right in the region of the GDA.



A



B

FIG 13 ● **A.** Operative image demonstrating anterior retraction of the pancreas to expose the splenic vein (SV; looped and retracted posteriorly) and the splenic artery (SA). **B.** Illustration demonstrating anterior retraction of the pancreas to expose the SV (looped and retracted posteriorly) and SA.

which can then be encircled and divided either proximal or distal to the inferior mesenteric vein (IMV) confluence.

Isolation and Division of the Splenic Artery

- The splenic artery is typically encountered cephalad to the splenic vein along the superior edge of the pancreas, although it is a tortuous vessel and its course can be unpredictable (**FIG 13**).
- As with the splenic vein, the region of dissection and division of the splenic artery varies with tumor location. For tumors of the tail and midbody, the artery is divided distal to its origin from the celiac. For tumors of the proximal body and neck, the artery is divided at its origin.
- The artery is cleared circumferentially and encircled with a vessel loop (**FIG 14**). We recommend routine use of IOUS in proximal transections to confirm isolation of the splenic artery, as inadvertent division of the celiac trunk and common hepatic artery have been reported (**FIG 15A–C**).
- The artery is divided with a linear vascular stapler, between locking vascular clips or between permanent suture ligatures (**FIG 16**).
- Alternatively, the splenic artery can be included in the pancreatic staple line for distal transections. We do not recommend this for more proximal tumors, as the celiac trunk or hepatic artery may be at increased risk of inadvertent incorporation into the staple line.

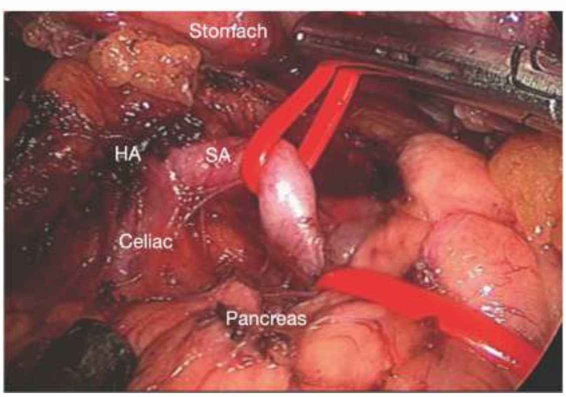


FIG 14 ● Operative image showing the splenic artery (SA) just distal to its origin from the celiac axis. The artery is looped to assist with retraction during vascular dissection. *HA*, hepatic artery.

Division of the Pancreas

- Once sufficiently mobilized away from the splenic and mesenteric vessels, the pancreas can be transected at any point in the operation. We prefer to divide the gland early on, as this will greatly enhance exposure of the underlying vascular structures.
- The line of gland transection is determined by the location of the pathology. A minimum 1-cm margin is desirable for malignant tumors, and this can be confirmed with immediate frozen tissue examination. The proximal (or right-sided) limit of transection is typically the plane where the GDA crosses the anterior aspect of the pancreatic head.
- The perfect method of dividing the gland and controlling the pancreatic duct remains elusive. Numerous techniques have been applied with similar rates of leakage from the pancreatic stump.
- Soft glands that are relatively thin (<2.0 cm in thickness) are best divided with a linear stapler (**FIG 17**). Biologic or synthetic Seamguard have been used with mixed results. We recommend slow compression of the gland prior to division, as this minimizes parenchymal lacerations that can result in postoperative leaks.

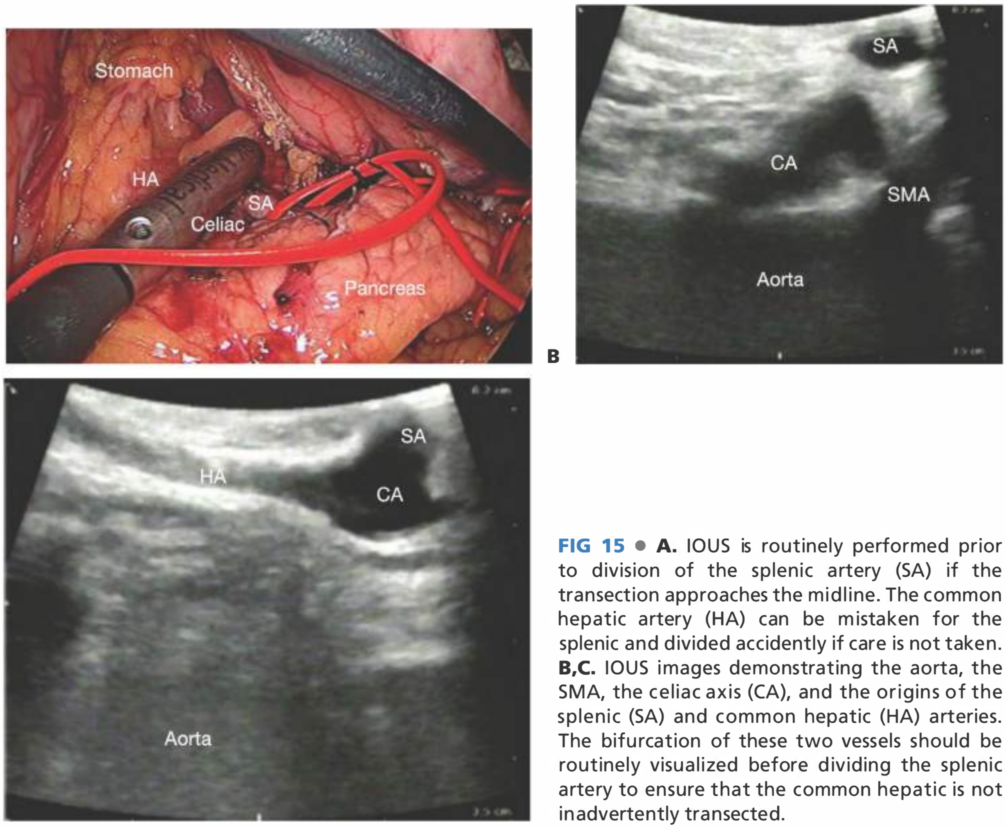


FIG 15 ● **A.** IOUS is routinely performed prior to division of the splenic artery (SA) if the transection approaches the midline. The common hepatic artery (HA) can be mistaken for the splenic and divided accidently if care is not taken. **B,C.** IOUS images demonstrating the aorta, the SMA, the celiac axis (CA), and the origins of the splenic (SA) and common hepatic (HA) arteries. The bifurcation of these two vessels should be routinely visualized before dividing the splenic artery to ensure that the common hepatic is not inadvertently transected.

- Fibrotic or thick glands can be divided with linear staplers, electrocautery, saline-enhanced monopolar cautery, or Harmonic scalpel. The pancreatic duct should be identified during the division.
- The pancreatic duct can be secured with either mattressed sutures or a bipolar tissue-sealing device.

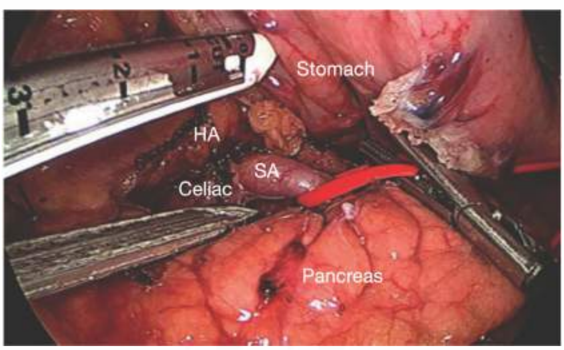


FIG 16 ● Operative image showing placement of a vascular stapler across the splenic artery (SA) near its origin from the celiac axis. A vascular loop around the artery helps with retraction during positioning of the stapler. *HA*, hepatic artery.

Dissection of the Specimen off the Retroperitoneum

- After division of the pancreas and splenic vessels, the specimen is swept off the retroperitoneum in an avascular plane anterior to the left adrenal gland and Gerota's fascia, typically using hook electrocautery or an ultrasonic dissector.
- The remaining retroperitoneal and diaphragmatic attachments to the spleen are divided, completing the mobilization of the specimen.

Extent of Lymphadenectomy

- In the setting of suspected malignancy, en bloc distal pancreatectomy and splenectomy should be performed with the intention of harvesting the lymphatic tissue within the splenic hilum and along the splenic vessels.
- For pancreatic neuroendocrine tumors, cystic neoplasms, and small (<3 cm) pancreatic adenocarcinomas, the earlier description typically results in an adequate lymphadenectomy.
- For larger adenocarcinomas, a more extensive lymphadenectomy may be desired. Laparoscopic D1 lymph node dissection with skeletonization of the celiac trunk, SMA, and lateral aorta along with resection of the left adrenal

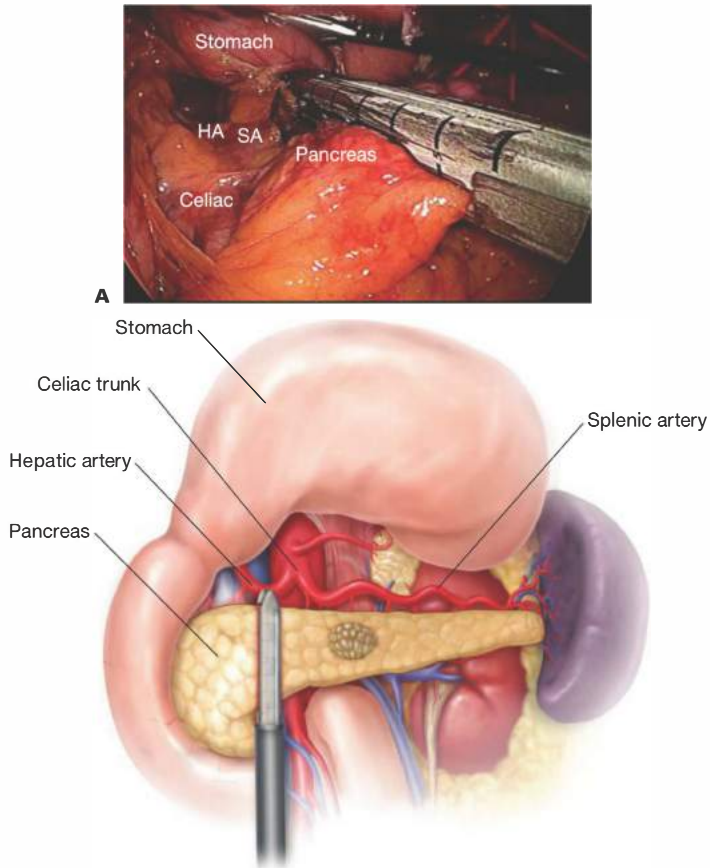


FIG 17 ● **A.** Operative image showing stapled transection of the pancreatic body for a tumor in the tail. Slow compression of the stapler is important to avoid crushing and fracturing the pancreatic parenchyma. The celiac axis, common hepatic artery (HA), and splenic artery (SA, divided with staples) are seen to viewer's left of the pancreas. **B.** Illustration showing stapled transection of the pancreatic body for a tumor in the tail. Slow compression of the stapler is important to avoid crushing and fracturing the pancreatic parenchyma. The celiac axis (CA), common HA, and SA are seen to viewer's left of the pancreas.

gland (radical antegrade modular pancreaticosplenectomy [RAMPS] procedure) can be performed by experienced surgeons.[5] However, we recommend an open approach to these lesions as is warranted in most situations, which is described in Part 3, Chapter 40.

Specimen Extraction, Placement of Drains, and Port Site Closure

- The specimen is placed into a large extraction bag, spleen first with the pancreas on top. The wound is slightly enlarged. The pancreas is removed and divided from the splenic hilum extracorporeally. The spleen is then morcellated and removed.
- Alternatively, if the site of pathology is not in the distal pancreas, the spleen can be separated from the pancreas intracorporeally once the dissection is complete. The pancreas is placed in a separate bag and removed intact through the 12-mm port site. The spleen is placed in a reinforced extraction bag, morcellated, and removed.
- In cases of malignancy, the transection margin should be shaved and sent for frozen section examination to ensure a negative margin.
- A closed suction drain may be placed selectively adjacent and posterior to the pancreatic stump. We do not routinely use drains, but this remains a controversial issue.
- After irrigation of the abdominal cavity and thorough sweep for foreign bodies, the port sites are closed using Vicryl suture.

SPLEEN-PRESERVING LAPAROSCOPIC DISTAL PANCREATECTOMY

Preservation of the Gastroepiploic Arcade and Short Gastric Vessels

- Initial steps for access and exposure are identical to that described earlier.
- Care is taken to preserve the right gastroepiploic arcade during division of the gastrohepatic ligament, as these vessels will provide perfusion to the spleen.
- The gastric fundus is not mobilized, and the short gastric vessels are preserved.

Retrograde Division of Splenic Vein Tributaries

- The splenic vein is separated from the pancreas as described earlier and encircled with a vessel loop, which is used for both retraction and vascular control.
- The vein is dissected away from the body and tail of the pancreas in a retrograde fashion from right to left using blunt or sharp dissection but avoiding monopolar cautery, as desiccating heat can easily injure small splenic vein tributaries.
- Venous tributaries from the pancreas are skeletonized and divided between clips or with bipolar energy along the length of the splenic vein (**FIG 18**).

Antegrade Division of Splenic Artery Branches

- The splenic artery is skeletonized along the superior border of the pancreas.

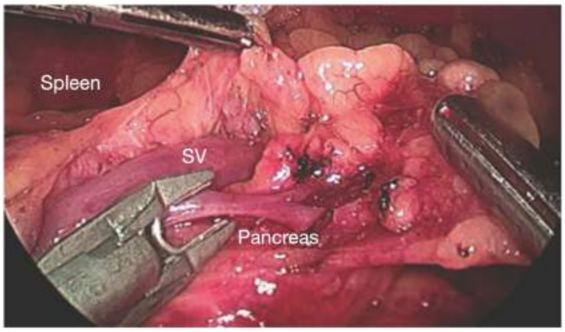


FIG 18 ● Operative image showing clips being placed across a splenic vein (SV) tributary along the distal pancreas during a spleen-preserving distal pancreatectomy. Small tributaries can be controlled with energy bipolar energy devices, but those larger than 3 to 5 mm should be controlled with clips or ties.

- Feeding branches to the pancreas are divided between clips, typically in an antegrade fashion proceeding from right to left.

Warshaw Technique

- In the technique described by Warshaw,[6,7] the splenic vessels can be ligated and divided at the proximal transection margin and again distally near the splenic hilum.
- The midportion of the splenic vessels is included with the resected specimen, whereas the spleen is left in situ to be perfused by the short gastric vessels. Preservation of the right gastroepiploic arcade and short gastrics are essential with this approach.

ROBOTIC DISTAL PANCREATECTOMY

General Concepts

- The robotic approach to a distal pancreatectomy is largely the same as the laparoscopic approach.
- The potential advantage of a robotic approach includes increased dexterity, possibly beneficial in cases where splenic preservation is prioritized.[8]
- The potential downside to a robotic approach include the loss of haptics, difficulty with altering the field of view, the complexities involved in docking and limited access to the patient, and cost.[9]

Patient Positioning

- The patient positioning is the same as a laparoscopic approach.
- The optimal position for the camera during the dissection again depends on where the anticipated area of most difficult dissection lies. Most commonly, the camera will be in the infraumbilical port and the direction of surgical approach will be from the patient's right, looking toward the spleen.
- Retraction of the stomach may be performed with the third robotic arm or may be via a bed-mounted fixed retraction.
- The assistant will stand on the opposite side of the bed from the camera for additional retraction and suction/irrigation.

Port Placement and Docking of the Robot

- Ports being used by the robot are typically better placed slightly farther away from the target than those used in a laparoscopic approach. This reduces the chance that ports will be inadvertently dislodged and allows the ports to be placed slightly farther away from each other, reducing the conflict between the robotic arms outside the patient.

Mobilization of the Colon and Pancreas

- The individual steps of colonic mobilization and exposure of the body and tail of the pancreas are the same as those described earlier for the laparoscopic approach.

TECHNIQUES

Mobilization of the Pancreas and Control of the Vasculature

- The individual steps of pancreatic mobilization and control of the vasculature are the same as those described earlier for the laparoscopic approach.

Splenic Preservation Using a Robotic Approach to Distal Pancreatectomy

- The primary advantage of a robotic approach to a distal pancreatectomy is thought to be the increased dexterity by which the vasculature of distal pancreas and spleen can be dissected away from the tail of the pancreas.
- Using the three-dimensional (3-D) visualization, the small branches of the splenic vein and artery are identified, dissected, and individually divided using monopolar or bipolar technology.

Specimen Extraction

- The individual steps of specimen extraction are the same as those described above for the laparoscopic approach.

PEARLS AND PITFALLS

Sequence and details of dissection can be altered based on individual anatomic characteristics.	■ Dissection of the splenic vein deep to the superior pancreas margin may result in difficult-to-control bleeding. The vein is more safely approached inferiorly from below the pancreas.
Bleeding from splenic vessels controlled with vascular loops, topical hemostatic agents, or nonabsorbable sutures.	■ The distal pancreatic duct is suture ligated with a U stitch if visualized when dividing the pancreas without duct-sealing technology.
Suction device recommended to maintain dry operative field. Consider dual insufflation systems to maintain pneumoperitoneum while suctioning.	■ Method of gland transection should be individualized based on thickness and texture of the pancreas. Vascular staplers are generally appropriate for glands up to 2.0 cm in thickness. Saline-linked monopolar cautery, ultrasonic energy, and radiofrequency ablation are alternative methods of transection.
Individualized port placement based on abdominal length and body habitus. Ports should be moved cephalad in large and obese patients.	■ Placement of drains is optional and should be individualized based on texture of the pancreas and confidence in the closure of the pancreatic stump.
A hand port is useful for central tumors with abutment of the celiac vessels and for bulky tumors that are difficult to mobilize laparoscopically.	■ The common hepatic artery should be visualized with IOUS prior to ligating the splenic artery to prevent inadvertent injury.

POSTOPERATIVE CARE

- Coverage with 24 hours of prophylactic antibiotics, as determined by institutional standards
- Initiation of low-molecular-weight heparin deep vein thrombosis (DVT) chemoprophylaxis, typically starting on postoperative day (POD) 1 in the absence of evidence of hemorrhage
- Clear liquid diet on POD 1, advance as bowel function resumes.
- Early mobility commencing on the day of surgery
- Drain amylase on POD 4 if a closed suction drain was used. Remove if within normal range of serum amylase.
- CT scan if patient develops leukocytosis, fever, prolonged ileus, or other signs of pancreatic fistula or intraabdominal infection.
- Percutaneous interventions are typically sufficient for management of postoperative fistulas and abscesses.
- Discharge on POD 4 or 7 in the absence of complications.

OUTCOMES

- Overall survival not related to minimally invasive surgery (MIS) versus open approach[10]
- Oncologic resection not compromised by MIS approach[11]
- Decreased blood loss compared to open resection[12]
- Increased length of surgery compared to open approach[13]
- Decreased average length of hospital stay compared to open approach[14]
- Morbidity and mortality equivalent or better than open surgery[15]

COMPLICATIONS

- Pancreatic fistula 15% to 30%
- Intraoperative/postoperative hemorrhage
- Intraabdominal abscess
- Pancreatic pseudocysts
- Splenic infarction
- Splenic vein thrombosis
- Overwhelming postsplenectomy sepsis (OPSS)

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Chapter **42**

Distal Pancreatectomy with Splenic Preservation

Adam S. Brinkman *Sharon M. Weber*

DEFINITION

- Distal pancreatectomy with splenic preservation (DPSP) is the complete removal of the distal pancreas (lateral to the superior mesenteric vein/portal vein [SMV/PV] confluence) while preserving the spleen via meticulous dissection and preservation of the splenic artery (SA) and splenic vein (SV), or with sacrifice of these vessels (Warshaw technique) with preserved blood flow to the spleen through the short gastric vessels.
- Indications for DPSP include benign tumors for which local excision is inadequate (neuroendocrine tumors), pancreatic cysts, chronic pancreatitis limited to the distal pancreas, and selected cases of distal pancreatic trauma. DPSP for distal pancreatic malignancies (adenocarcinoma) is controversial as body and tail lesions may have lymphatic drainage to the splenic hilum.
- The majority of cases performed in the United States are accomplished either open or laparoscopically, whereas fewer are performed using robotic assistance or with a hand port. Variation in surgical technique with respect to preservation of the splenic vessels versus ligation of the vessels exists.

DIFFERENTIAL DIAGNOSIS

- Premalignant or malignant lesions a DPSP may be considered:
  - Solid pancreatic tumors
  - Functional and nonfunctional neuroendocrine (NE) tumors
  - Cystic pancreatic tumors
    - Intraductal papillary mucinous neoplasms (IPMNs)
    - Mucinous cystadenomas (MCN)
    - Solid pseudopapillary tumors
  - Benign conditions
    - Congenital cysts
    - Serous cystadenomas (SCA)
    - Chronic pancreatitis pancreatic pseudocysts can also be theoretically resected with a DPSP
- The location of the lesion and the anatomic relationships of the splenic vasculature are the major factors that should be evaluated before considering a DPSP as the surgical procedure of choice.

PATIENT HISTORY AND PHYSICAL FINDINGS

- Patients being considered for DPSP should be evaluated with a thorough history and physical examination including a detailed past medical history, past surgical history (including previous foregut and pancreatic surgery), as well as personal and family history of pancreatic disease or malignancy.
- Particular attention should be paid to symptoms of pancreatic insufficiency, nutritional status, and ability to tolerate a pneumoperitoneum of 15 mmHg if a laparoscopic approach is chosen.
- Severely malnourished patients (more than 10% to 15% of ideal body weight [IBW] loss in the preceding 2 months) or serum albumin less than 3 g/dL should be considered for supplemental nutrition; enteral nutrition via Dobhoff tube or total parenteral nutrition through indwelling central venous catheter.

IMAGING AND OTHER DIAGNOSTIC STUDIES

- Pancreatic protocol helical computed tomography (CT) with oral and dual phase intravenous contrast is the preferred imaging modality for pancreatic diseases. The thin cuts through the pancreas allows for ideal delineation of vasculature, size of the lesion, involvement of surrounding structures, and evidence of local disease progression (**FIG 1**). Careful attention should be paid to the arterial and venous phases as well as the arterial blood flow to the spleen, as this can determine feasibility of splenic preservation.
- The relationship of the mass, cyst, or stricture should be noted and its anatomic relationship to the SV, inferior mesenteric vein (IMV), and SA should be noted in anticipation of potential intraoperative pitfalls.
- In addition to CT, consideration can also be given to endoscopic ultrasound (EUS) to better evaluate the pancreatic lesion and its relationship to the surrounding structures. In addition, sampling of the mass with fine needle aspiration for diagnostic purposes or aspiration of a cyst fluid for evaluation of carcinoembryonic antigen (CEA), amylase concentration, and mucin analysis may assist with diagnosis and operative planning. The presence of local disease discovered on CT imaging may be further investigated with EUS and suspicious masses (often lymph nodes) can be sampled.

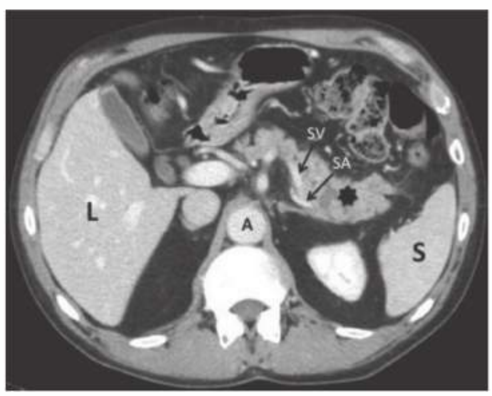


FIG 1 ● Pancreatic protocol helical CT scan of with dual phase intravenous contrast of the abdomen and pelvis demonstrating a solid 3.6 × 2.9-cm complex cystic lesion *(star)* in the tail of the pancreas concerning for malignant transformation of IPMN amenable for a DPSP. *A*, aorta; *L*, liver; *S*, spleen; *SA*, splenic artery; *SV*, splenic vein.

- Additional pathology can also be identified, including isolated gastric varices indicative of SV thrombosis and sinistral portal hypertension.
- Additional diagnostic testing that may be considered prior to a DPSP includes magnetic resonance imaging (MRI) or magnetic resonance cholangiopancreatography (MRCP), which may better define the pancreatic ductal anatomy.
- Consideration can also be extended to endoscopic retrograde cholangiopancreatography (ERCP), the gold standard to define pancreatic ductal anatomy, which also offers an opportunity for evaluation of communication with the main pancreatic duct for cystic lesions, which is diagnostic for IPMN.
- Additional imaging including a chest radiograph or chest CT scan may be obtained for complete staging and preoperative evaluation in patients with suspected malignancy.

SURGICAL MANAGEMENT

Preoperative Planning

- Prior to proceeding to the operating room (OR), all patients should be evaluated with a full history and physical examination with cardiovascular and pulmonary testing as medically needed. Patients scheduled to undergo a laparoscopic distal pancreatectomy should be made aware of the potential need to convert to an open approach during the operation.
- Consideration should also be given to vaccinating against encapsulated bacteria including *Neisseria meningitidis*, *Haemophilus influenzae*, and *Streptococcus pneumoniae*.
  - These vaccines should be given 1 to 2 weeks prior to operative intervention in the event splenic preservation is not possible.
  - Should a splenectomy be required in a nonvaccinated patient then vaccines should be administered within 2 weeks following surgical intervention to mitigate postsplenectomy sepsis.
- Patients should also obtain baseline laboratory function including type and screen, serum electrolytes, hemoglobin and hematocrit as well as pregnancy testing in reproductive-aged females.
- Preoperative antibiotics and deep venous thrombosis (DVT) prophylaxis should be ordered prior to patient arrival to the OR. Arterial lines and central venous catheters are placed selectively for high-risk patients.

Positioning

- Patients should be positioned supine on the OR table with arms extended wide with easy access to the OR table should a Bookwalter retractor need to be placed. Preoperative DVT prophylaxis with heparin should be administered subcutaneously prior to the induction of general anesthesia, bilateral lower extremity sequential compression devices should be placed, and a single dose of a second-generation cephalosporin should be administered within 60 minutes of skin incision.
- After the patient is intubated, a Foley catheter should be placed under sterile technique and a nasogastric tube should be placed for gastric decompression.
- The abdomen is shaved, prepped, and draped, with the xiphoid process, umbilicus, and right and left anterior superior iliac spines exposed.
- An adequate prep will allow for easy incision planning should there be a need to convert to the open technique.
- Some surgeons prefer a semilateral positioning in a relaxed right lateral decubitus position to assist with visualization of the left upper quadrant, whereas others prefer a split leg (Nissen) table to allow the surgeon to stand between the patient's legs.
- Standard laparoscopic instruments (including 0- and 30-degree laparoscopes), ultrasonic dissector or bipolar electrocautery, laparoscopic staplers (vascular and bowel staple loads), and clip appliers should be available.

LAPAROSCOPIC APPROACH

Port Placement

- Access to the abdominal cavity can be accomplished with either a supraumbilical Veress needle or Hassan trocar depending on surgeon preference and a pneumoperitoneum is established at 15 mmHg.
- Three to four additional ports are placed under direct visualization, usually with one in the upper midline or just right of midline, depending on the patient's anatomy. Two additional ports (a 5 mm and a 10 mm to accommodate the laparoscopic stapler) can be placed in the left middle or lower quadrant (**FIG 2**).
- Once all ports are placed, a thorough diagnostic laparoscopy is performed to rule out metastatic disease. If abnormal lesions are identified, they should be biopsied and sent for frozen sectioning. Adhesions are freed to allow full visualization of the left upper quadrant.

Opening the Lesser Sac

- The lesser sac is then opened along the greater curvature of the stomach inferior to the gastroepiploic vessels through the gastrocolic ligament. This allows visualization of the posterior stomach and the anterior surface of the pancreas (**FIG 3**).
- The short gastric vessels along the superior aspect of the fundus should be preserved, as they may be required for splenic preservation if the SA and SV are divided (Warshaw technique).
- If splenectomy is planned, all short gastric vessels will need to be transected.

Identification of the Pancreatic Lesion

- Every effort should be made to identify or palpate the pancreatic lesion and its relationship to the pancreatic neck. Lesions amenable to a DPSP are those to the left of the SMV/PV confluence (**FIG 4**). If the lesion cannot be identified then employment of the laparoscopic ultrasound or EUS can be performed to assist with localization.

Dissection of the Pancreas

- Dissection along the inferior border of the pancreas begins above the ligament of Treitz and should be extended toward the splenic hilum.

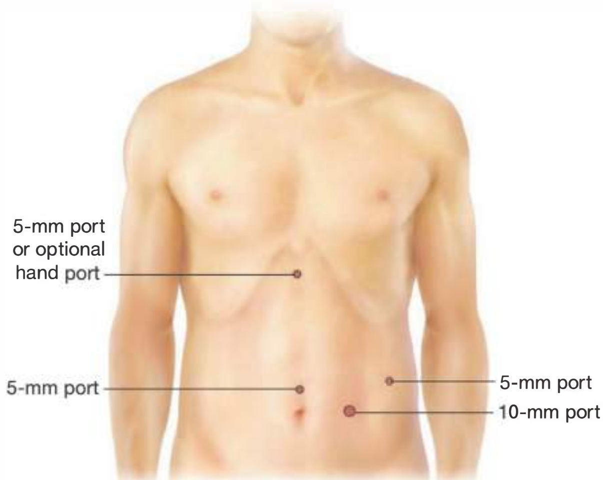


FIG 2 ● Port placement for a laparoscopic DPSP includes three 5-mm ports, one 10-mm port, and an occasional hand port placed in the upper midline to assist with specimen retraction and dissection.

- Careful attention is paid to opening just the thin peritoneum inferior to the pancreas and to elevate the pancreas from the retroperitoneal tissue by assuring the plane of dissection stays within the fibroareolar plane. If this is done correctly, the SV will usually be elevated with the pancreas and will result in mobilization of the pancreas anteriorly (**FIG 5**).
- Careful attention is required to avoid lacerating or transecting the posterior SV.
- The IMV should be identified and ligated if it enters the SV to the left of the mass or preserved if it enters the SV to the right of the planned pancreatic transection plane. Neoplastic involvement of the IMV requires ligation and resection.
- Some surgeons advocate for placement of a hand port in the left upper quadrant to assist with tissue manipulation and aid with dissection during this step.

Dissection and Control of the Splenic Artery

- With splenic vessel preservation
  - Attention should then be focused on identification of the serpiginous SA located on the superior aspect of the pancreas. The SA can then be carefully dissected from the pancreas using suture ligation or clipping plus energy-assisted ligation and division of small arterial branches running to the pancreatic tail until the pancreas is completely separated from the SA.

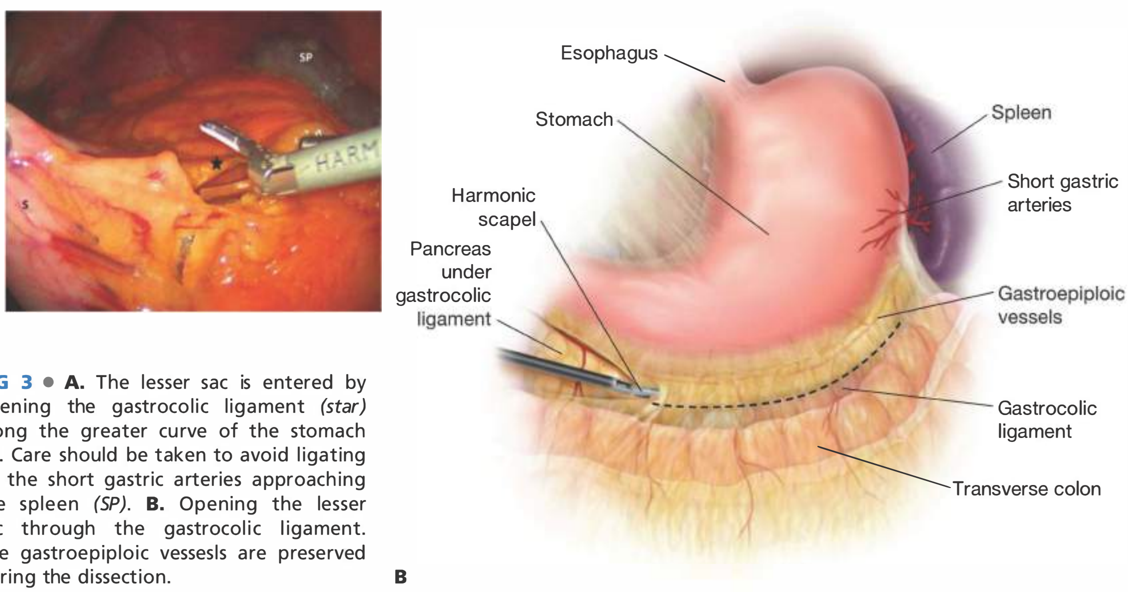


FIG 3 ● **A.** The lesser sac is entered by opening the gastrocolic ligament *(star)* along the greater curve of the stomach *(S)*. Care should be taken to avoid ligating all the short gastric arteries approaching the spleen *(SP)*. **B.** Opening the lesser sac through the gastrocolic ligament. The gastroepiploic vessesls are preserved during the dissection.

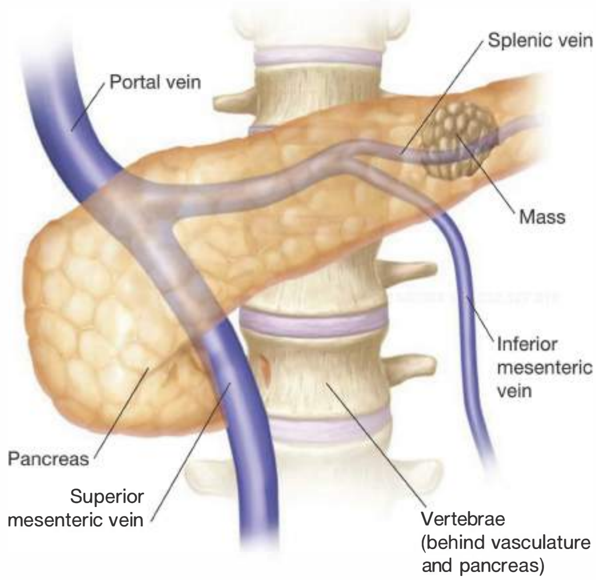


FIG 4 ● Lesions amenable to a DPSP are those left of the SMV/PV confluence.

- Without splenic vessel preservation (Warshaw technique)
    - The SA is dissected and controlled, followed by ligation using a vascular load of the laparoscopic stapler. The authors suggest additional, subsequent control of either ligation or clipping to minimize risk of pseudoaneurysm in the setting of pancreatic fistula. The SA (inflow) should be controlled before SV (outflow) to decrease bleeding.

Transection of the Pancreas

- With splenic vessel preservation
    - A tunnel should be created to the right of the lesion to free the pancreas from the vasculature for transection (**FIG 6**).
    - The pancreas can then be transected with a laparoscopic Endo GIA stapler, Harmonic scalpel, or LigaSure device.
        - In patients with thick pancreas, the pancreatic parenchyma can be thinned out with the ultrasonic dissector while avoiding the pancreatic duct, which usually is positioned posteriorly in the pancreas approximately one-third inferior to the superior border. This enhances the ability of a stapler to appropriately control the pancreatic duct.
- Without splenic vessel preservation (Warshaw technique)
    - Alternatively, the pancreas can be transected with the laparoscopic stapler incorporating the SA and SV in the staple line. Alternatively, the pancreas, SA, and SV can be dissected and transected individually. In most cases, it is simplest to ligate the SV with the pancreas using a stapler.

Dissection of the Distal Pancreas

- With splenic vessel preservation
    - The SV is identified and dissected off the pancreas posteriorly. This is often expedited by transection of the pancreatic parenchyma, with a right-to-left mobilization.
    - Small venous branches into the pancreas should be carefully dissected and either divided between clips, ties, or with the ultrasonic dissector (**FIG 7**). Often,

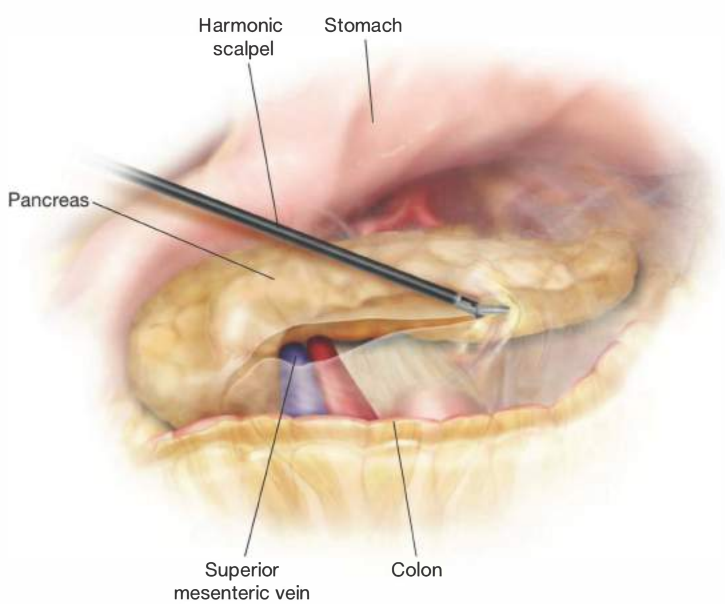


FIG 5 ● Dissecting and opening the peritoneum along the inferior aspect of the pancreas in a medial to lateral direction. The SV is posterior to the pancreatic body and at risk for injury during dissection if the posterior fibroareolar plane is violated.

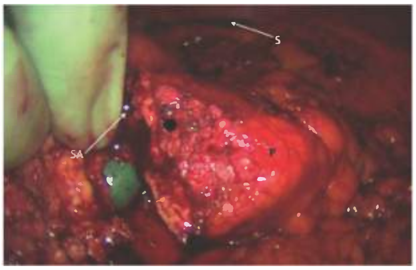
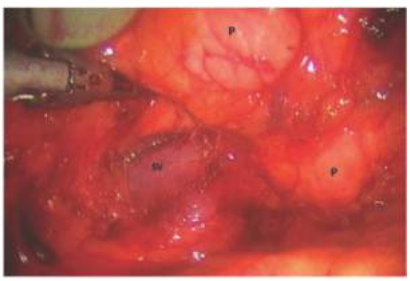


FIG 6 ● Transection of the pancreas *(P)* at the confluence of the SV and portal vein left of midline using a hand port. The SA is dissected circumferentially and stapled. The cut edge of the pancreas *(star)* is reflected anteriorly and toward the spleen *(S)* to assist with further posterior dissection.

small bleeding veins can be controlled through direct pressure for a short time; however, persistent bleeding may require ligation with a Prolene suture.

- Without splenic vessel preservation (Warshaw technique)
  - An additional fire of the laparoscopic stapler using a vascular load is needed to control the splenic vasculature at the splenic hilum.
  - Great care should be taken to avoid lacerating or puncturing the splenic parenchyma during control of the hilar vessels.
  - Once accomplished, the specimen can be removed from the abdomen using a specimen bag through the largest port site, leaving the spleen to obtain its vascular supply from the short gastric vessels.



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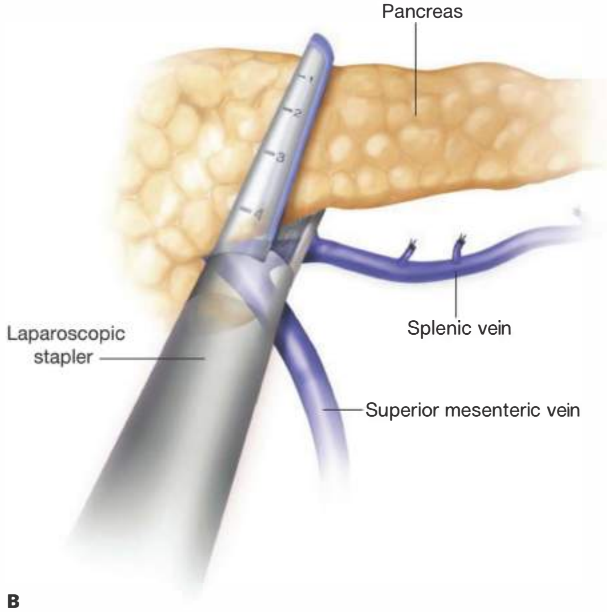

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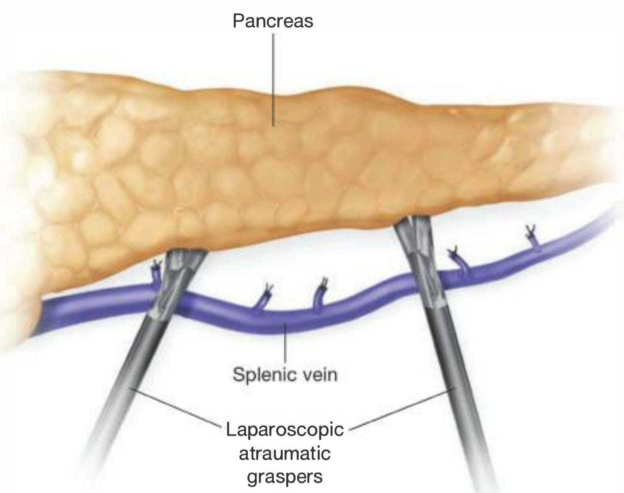

C

FIG 7 ● **A.** Dissection of the pancreas *(P)* from the underlying splenic vein *(SV)* in a medial to lateral direction. Small venous branches are controlled with fine suture, clips, or staples. **B.** Medial to lateral dissection of the pancreas from underlying SV. **C.** The pancreas is transected to the right of the lesion using a laparoscopic Endo GIA stapler

Management of the Residual Gland

- Once the specimen is removed, careful attention should be paid to assuring meticulous hemostasis. The surgical bed should be irrigated with warm sterile saline and the SA and SV should be investigated to ensure hemostasis. Attention should also be directed to the spleen to ensure adequate perfusion and no evidence of ischemia or bleeding.
- Placement of a soft closed suction drain to monitor for pancreatic leaks in the postoperative period is indicated.

Closure

- Following specimen removal, the spleen should be inspected to assess perfusion and bleeding. When using the Warshaw technique, if a completely ischemic or partially ischemic spleen is identified, a splenectomy should be performed, as ongoing ischemia will often result in significant left upper quadrant abdominal pain and bleeding.
- The fascia is closed for 10-mm or larger port sites and the skin is closed with 4-0 dissolvable sutures. If a hand port is placed, the fascia is closed.

OPEN TECHNIQUE

Incision Choice

- The incision of choice for a DPSP depends on the patient's body habitus and previous abdominal surgery.
- Either an upper midline or left subcostal incision can be used. Patients with previous upper midline incisions can be used although in obese patients and those with a narrow subcostal angle, it may be difficult to reach the pancreatic tail with a midline incision. Additionally, locally advanced malignancies, large tumors, or those where oncologic endpoints may be compromised should be approached with the open technique.
- Once inside the peritoneal cavity, careful palpation of the abdominal cavity should be performed to ensure no evidence of metastatic disease. A self-retaining retractor (Bookwalter) can be placed with cephalad retraction of the left costal margin to allow for visualization.
- The remainder of the operative steps in the open technique are identical to those used for the laparoscopic technique, although sometimes it is easier to perform a left-to-right mobilization first, allowing the spleen to be elevated into the operative field. If performing the Warshaw technique, the SA and SV on the posterior aspect of the pancreas are transected, followed by pancreas transection. The transected edge of the pancreas should be investigated after the specimen is removed and the pancreatic duct ligated with a 2-0 or 3-0 polypropylene suture, or other techniques of pancreatic stump closure can be used, such as the stapler, ultrasonic dissector, or LigaSure.
- A soft closed suction drain should be placed along the cut edge of the pancreas and brought out through a separate stab incision on the abdominal wall. The fascia is then closed in several layers.

PEARLS AND PITFALLS

Preoperative considerations	■ A complete history and physical examination should be performed to ensure the patient is a candidate for surgery. ■ Evaluate for pancreatic insufficiency and malnutrition; consider preoperative nutritional support. ■ Vaccination against encapsulated organisms
Open vs. laparoscopic technique	■ Ability to tolerate pneumoperitoneum and previous foregut surgery ■ Laparoscopic is the preferred approach for lesions amenable to this technique. ■ Consider placement of hand port to assist with dissection or specimen removal. ■ Midline or left subcostal incision can be used for the open approach.
Management of short gastric arteries (Warshaw technique only)	■ Maintain short gastrics and avoid excessive traction.
Control of splenic artery and vein	■ Small branches of the SV should be controlled with direct pressure, clips, or suture ligation. ■ IMV should be ligated and divided if it enters the SV to the left of the target lesion and preserved if it enters the SV to the right of the lesion or enters the SMV. ■ If the lesion involves the SA, SV, or IMV—ligate and resect the vessels with the specimen (Warshaw technique). ■ Careful dissection of the thin-walled SV can avoid bleeding and postoperative SV thrombosis.
Splenectomy	■ Splenic preservation is an option except in cases of adenocarcinoma, unclear diagnosis, or direct involvement of the splenic hilum. ■ Unexpected bleeding or splenic ischemia may require unplanned splenectomy.
Management of the residual pancreas	■ Soft closed suction drain placed and output monitored for several days.

POSTOPERATIVE CARE

- Following an uncomplicated DPSP, the patient should be admitted to the general care floor. Routine nasogastric decompression is per surgeon's discretion but may not be needed.
- Assuming stable hemodynamics and hematocrits, patients may begin a clear liquid diet the following day and diet may be advanced as tolerated.
- On postoperative day 1, drain amylase should be checked to assess the risk for pancreatic fistula formation. Attention should be paid to the volume, consistency, and color of the soft closed suction drain and changes in any of the three should prompt further investigation for a developing pancreatic fistula.
- Patients are encouraged to ambulate often and discharged home 4 to 5 days following surgery.

OUTCOMES

- With adequate laparoscopic training and a solid anatomic understanding, this approach can be safely performed with similar rates of morbidity, mortality, and pancreatic fistula development. As with the majority of laparoscopic techniques, patients often experience less postoperative pain, narcotic use, shorter hospital stay, and nearly identical rates of operative blood loss. Several studies have indicated that when comparing splenic vessel ligation (Warshaw technique) to splenic vessel preservation, there was a greater incidence in splenectomy with splenic vessel ligation, although this technique is easier to perform with shorter operative times. Despite similar outcomes compared with the open technique, a DPSP should be performed by those surgeons with advanced laparoscopic skills after careful patient selection.[1–19]

COMPLICATIONS

- Hemorrhage
- Infection—often subdiaphragmatic
- Pancreatic leak/fistula
- Splenic vein thrombosis
- Thrombocytosis
- Hyperglycemia—potential to develop diabetes mellitus
- Pancreatic exocrine insufficiency
- Splenic ischemia (Warshaw technique)

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Chapter 43 Central Pancreatectomy

Daniel J. Delitto Jose G. Trevino

DEFINITION

- Central pancreatectomy (occasionally referred to as median or middle pancreatectomy) is a conservative resection of the neck and body of the pancreas in order to conserve endocrine and exocrine pancreatic function. This segmental resection also preserves surrounding structures including the duodenum, spleen, biliary tract, and gallbladder. Central pancreatectomy has been described for benign, premalignant, and low malignant potential tumors located in the pancreatic neck and proximal portion of the pancreatic body.

DIFFERENTIAL DIAGNOSIS

- Pancreatic neuroendocrine tumors (PNETs) are most commonly nonfunctional, but approximately 15% of PNETs actively secrete insulin, glucagon, vasoactive intestinal peptide (VIP), pancreatic polypeptide (PP), somatostatin, or gastrin. Neuroendocrine tumors have known malignant potential and resection is indicated in appropriate surgical candidates. PNET is the most frequent diagnostic indication for central pancreatectomy.
- Mucinous cystadenomas (MCAs) account for 2% of all pancreatic neoplasms and approximately 25% of cystic neoplasms.[1,2] These tumors tend to be larger than SCAs, contain a mucin-secreting epithelial lining, and have no communication with the pancreatic ductal system. MCAs are considered dysplastic lesions with premalignant potential and resection is indicated in suitable surgical candidates.
- Pseudopapillary tumor (SPT) is a rare cystic-appearing neoplasm with malignant potential in approximately 5% of cases. The hypodense areas seen on imaging represent necrosis of solid papillary vascular stalks that slough as the tumor grows. Resection is indicated upon diagnosis. As these rare lesions are typically large at the time of diagnosis, central pancreatectomy as a viable surgical approach will be incredibly unusual.
- Serous cystadenomas (SCAs) represent approximately 1% of all pancreatic neoplasms and 33% of pancreatic cystic neoplasms.[2] These lesions contain a true epithelium and do not communicate with the pancreatic duct. Indications for surgical intervention for SCAs include symptomatic lesions or rapid growth with solid components. Otherwise, observation of SCAs is recommended. As with SPT, these lesions tend to be large at the time of diagnosis; central pancreatectomy will rarely be a viable option.
- Intraductal papillary mucinous neoplasms (IPMNs) are continuous with the pancreatic ductal system. These lesions may be classified as either branch-type or involving the main pancreatic duct. Main duct neoplasms may be invasive in up to 50% of cases and central pancreatectomy is not appropriate. Branch-type IPMNs should be resected if they are symptomatic, contain concerning radiographic findings (e.g., a mural nodule, thickened septae, or a ductal stricture), high-grade atypia, strong family history of pancreatic cancer, or size greater than 3 cm. As surgical therapy for IPMN includes reduction of malignant potential, the authors do not advocate central pancreatectomy for IPMN—the surgical goal for these patients is not parenchymal preservation.

PATIENT HISTORY AND PHYSICAL FINDINGS

- Early symptoms of benign pancreatic lesions may include vague abdominal pain or bloating, nausea, and weight loss. More advanced lesions may present with gastric outlet obstruction, jaundice, or recurrent pancreatitis. However, most of these lesions are identified incidentally with cross-sectional imaging. In particular, lesions amenable to central pancreatectomy are typically small (~1 to 2 cm) and are generally asymptomatic.

IMAGING AND OTHER DIAGNOSTIC STUDIES

- Pancreatic protocol triple-phase (arterial, late arterial, and venous phase) contrast-enhanced, multiplanar, thin-slice computed tomography (CT) provides excellent imaging of pancreatic parenchymal and ductal anatomy and is typically the diagnostic method of choice for characterizing pancreatic tumors. Magnetic resonance imaging (MRI) or magnetic resonance cholangiopancreatography (MRCP) may further characterize the relationship of the lesion to the pancreatic duct (**FIG 1**). Endoscopic ultrasound (EUS) may allow for fine needle aspiration (FNA) biopsies. Diagnostic characteristics of each lesion are described.
- PNETs appear as hypervascular lesions on thin-slice CT or MRI scans. Somatostatin receptor scintigraphy (SRS) has a high sensitivity for most PNETs, with the exception of insulinomas. EUS may further characterize lesions near the pancreatic head, which typically have a hypoechoic appearance compared to normal pancreatic parenchyma. FNA or core needle biopsy sampling can confirm the presence of PNETs with immunohistochemical staining of cell block or tissue for chromogranin. Functional tumors are diagnosed on a biochemical basis.
- MCAs are typically seen in younger women and may contain loculated lesions with multiple septae. More commonly, however, these lesions are seen as larger unilocular cysts. EUS and FNA reveal viscous, mucinous fluid with high carcinoembryonic antigen (CEA) levels and low amylase.
- SCAs may contain a "starburst" or honeycomb pattern of central scarring on CT imaging. EUS reveals a characteristic thin-walled capsule with thin septae. If FNA is performed, it often yields serous fluid with low amounts of CEA and mucin.
- SPTs present in young females (mean age 25 to 30 years) typically as a large mass in the body or tail. These lesions contain hypodense areas representing sloughed, necrotic papillary stalks with internal calcifications. FNA with immunostaining may reveal neuron-specific enolase, vimentin, and α1-antitrypsinase expression. Aggressive surgical resection is

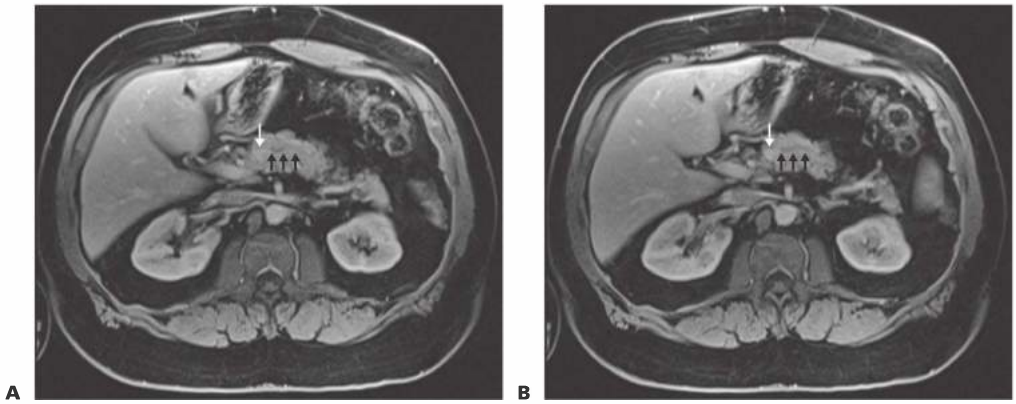

FIG 1 ● Contrast-enhanced MRCP of a PNET involving the pancreatic neck. The central location of the lesion and evidence of pancreatic duct (PD) involvement precludes safe enucleation; thus, central pancreatectomy was offered. **A,B.** The 1.2-cm lesion *(white arrows)* enhances as compared to the surrounding pancreatic parenchyma. The upstream PD is dilated *(black arrows)* and the surrounding parenchyma is edematous, consistent with inflammation.

warranted even in the presence of local invasion or metastatic disease.[3,4]

- IPMNs are diagnosed with CT or MRCP. EUS with FNA reveals high amylase and CEA levels. Additionally, K-*ras* mutation and loss of heterozygosity are malignant characteristics. Endoscopic retrograde cholangiopancreatography (ERCP) will show continuity with the main pancreatic duct.

SURGICAL MANAGEMENT

Preoperative Planning

- A complete history and physical of any patient undergoing central pancreatectomy is essential, paying close attention to signs of malignancy including weight loss or new-onset diabetes. A prior history of jaundice or pancreatitis should also be solicited. Basic blood chemistries should be obtained as well as a hepatic function panel, complete blood count, and coagulation studies. Serum tumor markers, including CEA, carbohydrate antigen (CA 19-9), and α-chromogranin should be obtained. When indicated, additional studies to characterize functional PNETs are warranted.
- Central pancreatectomy may be considered for lesions less than 3 cm located deep within the pancreatic neck or proximal body or situated near the main pancreatic duct; such lesions are not amenable for enucleation. The length of remnant distal pancreas should maximize functional endocrine tissue. To this effect, recommendations from Iacono et al.[5] include a minimum length of 5 cm for the distal pancreatic stump.
- Contraindications to resection include evidence of invasive malignancy and chronic or focal pancreatitis not involving the pancreatic neck or body. Importantly, central pancreatectomy is contraindicated when the tail of the pancreas receives its only blood supply from the transverse pancreatic artery, as this will be ligated during the operation.[5]

POSITIONING

- The patient is placed in supine position, with the table placed into slight reverse Trendelenburg. Two large-bore peripheral intravenous (IV) lines should be established and, if the patient has cardiovascular comorbidities, arterial blood pressure monitoring is advisable.

- Laparoscopic central pancreatectomy has been reported by experienced surgeons to be feasible and safe. Port site placement for a minimally invasive approach is shown in **FIG 2**. The minimally invasive operation proceeds in the order described in the following text.

FIG 2 ● Port placement for laparoscopic central pancreatectomy. The camera is placed through the umbilical port and a stomach/liver fixed retractor is placed through the left anterior axillary line port. During the dissection, the surgeon stands on the right side of the patient. For the pancreatic anastomosis, the surgeon moves to the left side of the patient and the fixed retractor is repositioned to the right anterior axillary line port.

EXPOSURE OF THE PANCREAS

- Obtain adequate exposure to the upper abdomen through a midline celiotomy or, alternatively, a bilateral subcostal incision. Thoroughly explore the abdomen to exclude metastatic or other disease.
- Divide the gastrocolic ligament to enter the lesser space. Preserve the gastroepiploic vasculature; this will lead you to the insertion of the right gastroepiploic artery into the superior mesenteric vein. Divide any congenital adhesions between the gastric antrum and the body of the pancreas. Continue this dissection working left to right until you reach the level of the gastroepiploic vein.
- Mobilize the proximal transverse mesocolon to fully expose the head of the pancreas (HOP) and the second and third portions of the duodenum. Then, establish the plane between the gastroepiploic vascular pedicle and the transverse mesocolon to expose the pancreatic neck and superior mesenteric vein (**FIG 3**).
- Dissect the superior border of the pancreas. Divide the hepatoduodenal ligament to expose the common hepatic artery (CHA) and the associated lymphatics. Sharply dissect down to the anterior adventitia of the CHA. Continue the dissection distally, establishing a plane between the CHA and the cephalad aspect of the pancreatic body and neck. The gastroduodenal artery is your landmark for the distal extent of the dissection. Beyond this landmark, pancreatic transaction risks injury to the intrapancreatic bile duct.

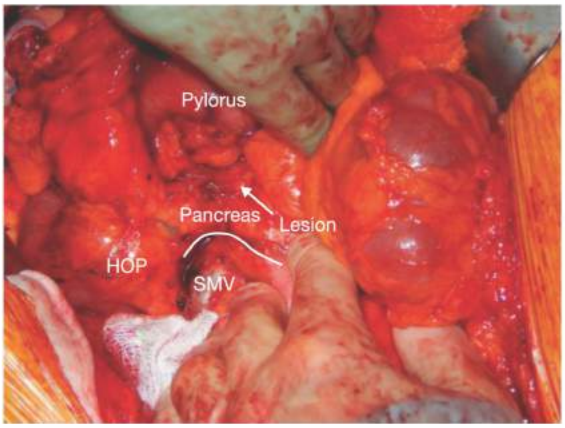

FIG 3 ● The HOP should be fully exposed by dividing the omentum and reflecting the antrum and pylorus toward the head. Dissect the inferior border of the pancreatic body and neck *(white line)*, and identify the anterior surface of the SMV. The lesion is readily palpable deep within the parenchyma of the pancreas and marked with an *arrow*—it is not readily visible on the surface of the gland.

PREPARING FOR RESECTION

- If the lesion is not visible or palpable, perform intraoperative ultrasound (IOUS) of the pancreas to localize the lesion. IOUS probes for liver imaging typically cannot visualize superficial structures and will not provide good imaging of the pancreas unless "stand-off" technique is applied. Fill the lesser space with saline as an ultrasonic conduit and position the transducer 2 to 3 cm away from the pancreatic parenchyma to visualize the superficial structures and lesion within the pancreas.
- Ligate and divide the gastroepiploic vein as it inserts into the superior mesenteric vein (SMV).
- Establish a plane between the pancreatic neck and the SMV/portal vein. Pass a vessel loop or umbilical tape to facilitate exposure of the posterior aspect of the pancreas. The authors do not perform extensive dissection of the pancreas off of the splenic vein until the pancreas is divided distally (toward the HOP). This dissection is straightforward once the distal (toward the HOP) pancreatic neck has been divided.
- At this point, identify the appropriate transection planes necessary to achieve appropriate margins and determine if central pancreatectomy is feasible or if pancreaticoduodenectomy or distal pancreatectomy are more appropriate (**FIG 4**).

Central Pancreatic Resection

- Transect the pancreatic neck to the side of the HOP. This margin can be stapled or the transaction may be performed with an energy device. For the latter, use 5-0 monofilament suture ligation for hemostatic control of the longitudinal pancreatic arteries (**FIG 5**).

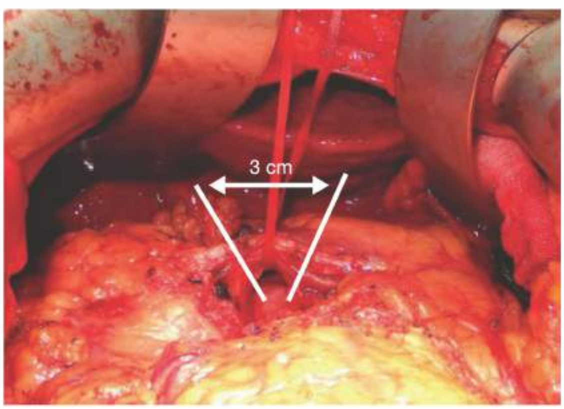

FIG 4 ● After dissecting the superior border of the pancreas to establish space between the hepatic artery and the pancreas, establish a broad plane between the pancreas and the splenic vein, SMV, and portal vein. A 1.5- to 2.0-cm space will allow for transections with adequate margins for most lesions amenable to central pancreatectomy (*white lines* represent planned transection planes).

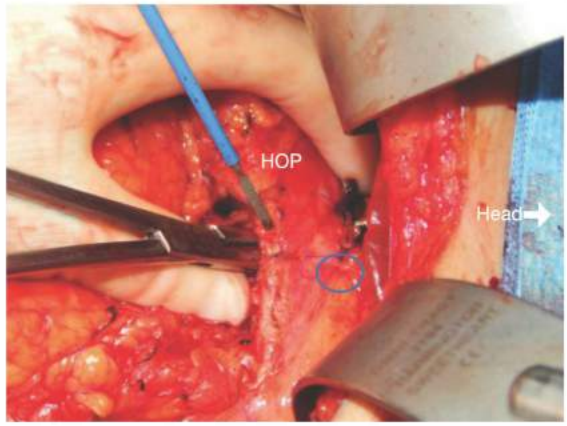

FIG 5 ● Transect the pancreas. Start to the HOP side of the lesion. A staple load can be used on this side. The authors prefer to divide the neck with electrocautery as it provides an excellent understanding of the margin. Use a clamp to protect the portal vein. Further mobilization of the body of the pancreas to take the proximal margin is facilitated once the distal margin has been taken. Do not deviate toward the HOP unless the margin mandates this; the smaller the transaction surface, the less likely the hemorrhage or the postoperative fistula. In this example, the distal margin could safely be taken at the surgical neck of the pancreas (*circle* marks the location of the palpable lesion). Note the placement of sutures to ligate the longitudinal pancreatic arteries.

- Dissect the body of the pancreas off the splenic vein as indicated to provide an adequate proximal margin and mobility for enteric reconstruction to the remnant pancreas.
- Place additional ligatures through the proximal pancreatic body (toward the spleen) for hemostasis and take the proximal margin with an energy device. When possible, divide the pancreatic duct sharply to minimize cautery artifact that can compromise pathologic assessment of the margin.
- When performing the procedure laparoscopically, retrieve the specimen through a separate incision (McBurney's incision is the author's preference) using a specimen retrieval bag. Personally assess the margins by visualization and palpation of the specimen.
- The specimen must then be transported to the pathologist for frozen section analysis to ensure clear margins and no evidence of invasive disease. In the case of malignancy or an involved margin, the operation of choice changes to a standard resection, either a pancreaticoduodenectomy or a distal pancreatectomy with splenectomy.
- The distal stump (HOP side) is then oversewn with 4-0 absorbable, monofilament sutures. If necessary, the distal pancreas (remnant) is then further mobilized anteriorly from the splenic vessels to ensure adequate space for anastomosis.

Reconstruction of Pancreatico-Intestinal Continuity

- Central pancreatectomy with pancreaticogastrostomy has gained popularity in the past decade as a means of

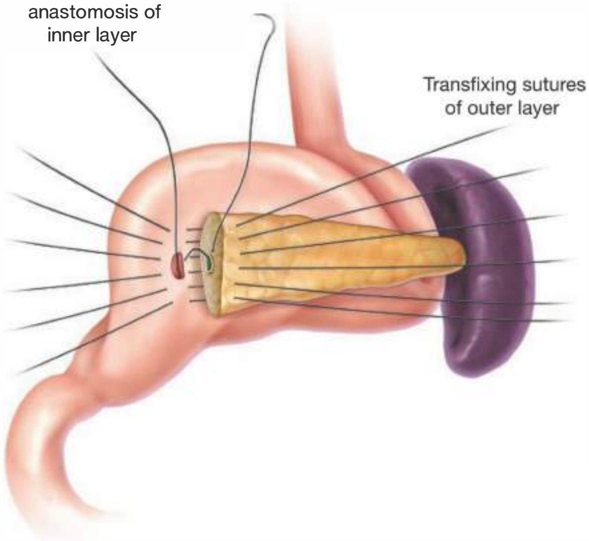

FIG 6 ● Reconstruction of pancreaticoenteric continuity via a pancreaticogastrostomy.

preserving pancreatic endocrine and exocrine function without disrupting intestinal continuity (**FIG 6**). This technique has been proven safe and effective in retrospective reviews in two major academic centers.[6–9] Major factors supporting this anastomosis include a generous blood supply to the posterior gastric wall and reduced anastomotic tension as the posterior gastric wall already lies in close proximity to the pancreatic tail. Critics note the inactivation of pancreatic enzymes by the low pH of the stomach potentially leading to reduced exocrine function. However, this result is not seen in studies evaluating central pancreatectomy.[1] Of note, a recent retrospective review showed a higher pancreatic leak rate with pancreaticogastric anastomosis.[9]

- Pancreaticogastrostomy is attractive as it eliminates the need to fashion a Roux limb; there is no separate jejunojejunostomy or the need for the creation of a tunnel through the colonic mesentery.
- Pancreaticogastrostomy is unattractive in that it requires additional mobilization of the pancreatic remnant and is rarely employed by most pancreatic surgeons.
- Alternatively, a Roux limb of jejunum is created by dividing the jejunum 15 to 30 cm distal to the ligament of Treitz. The mesentery is transected and the Roux limb is delivered to the pancreas in a retrocolic position. The pancreaticojejunal anastomosis may then be fashioned in an end-to-side or end-to-end manner to the distal pancreas (**FIG 7**).

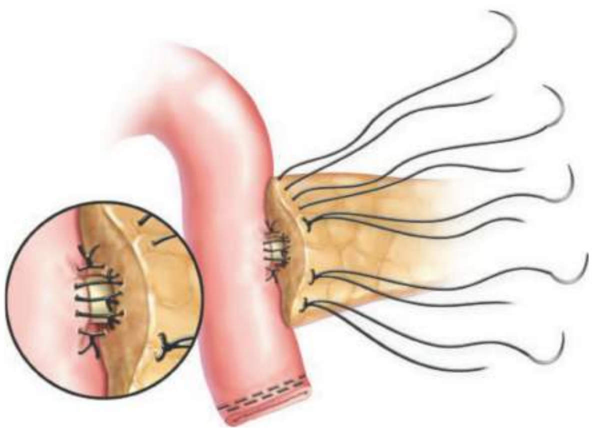

FIG 7 ● If the pancreatic remnant cannot be adequately mobilized (i.e., 3 cm) to provide a tension-free anastomosis to the posterior wall of the stomach or the surgical team is uncomfortable with the technique, Roux-en-Y pancreaticojejunostomy should be performed.

PEARLS AND PITFALLS

Patient selection	■ Rule out possibility of malignancy; central pancreatectomy is not an appropriate operation for malignant lesions especially adenocarcinoma. ■ Ensure adequate margins may be obtained. ■ Exclude chronic pancreatitis patients.
Head of pancreas margin	■ Ensure the main pancreatic ductal stump is visualized and suture ligated.
Pancreaticojejunostomy	■ Position the Roux limb retrocolic to the right of the middle colic vessels.
Pancreaticogastrostomy	■ Attractive option as it avoids the need to fashion a Roux limb. Ensure there is minimal tension on anastomosis; additional mobilization of the pancreatic remnant is necessary when compared to pancreaticojejunostomy.
Closure	■ Two closed suction drains placed in close proximity to anastomosis.

POSTOPERATIVE CARE AND COMPLICATIONS

- The patient should be admitted to a monitored setting for at least the first 24 hours postoperatively. Postoperative hemorrhage from central pancreatectomy is relatively uncommon but signs including unexplained tachycardia, hypotension, or oliguria must be explored.
- Pancreatic drain outputs are analyzed on postoperative day 3 for amylase content. Fistulas are identified based on these amylase levels and are graded based on the system from Bassi et al.[10] Drains with high amylase content remain in place until output is negligible or amylase content is low. Grade B fistulas include those with clinical impact and may include early signs of infection and radiographic findings. These fistulas typically require antibiotic treatment and further drainage procedures. Grade C fistulas have greater clinical impact, typically progressing to sepsis, and may be an indication for reoperation.
- Endocrine and exocrine function must be assessed prior to discharge. Exocrine function may be assessed on a symptomatic basis, looking for symptoms of malabsorptive diarrhea. Serial blood glucose measurements should be performed postoperatively, particularly in patients with preexisting hyperglycemia. If necessary, diabetic education and an appropriate regimen should be in place prior to discharge.
- Delayed gastric emptying is commonly seen after pancreatic resections and may be managed medically with promotility agents and slow diet advancement. Reoperation and gastroenterostomy for drainage are rarely required.

OUTCOMES

- Numerous retrospective studies have shown comparable results to standard resection techniques, namely pancreaticoduodenectomy and distal pancreatectomy. In fact, reduced endocrine insufficiency has been shown in one large retrospective review.[1]
- Postoperative pancreatic fistula rates are variable and have ranged from 8% to 63%, depending on the study.[1,11] Although pancreas-preserving resections provide an attractive alternative for benign lesions, a randomized, prospective trial is necessary to further delineate the role of central pancreatectomy.

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Chapter 44

Ampullectomy and Transduodenal Sphincteroplasty

Bharath D. Nath   Tara S. Kent

DEFINITION

- Ampullectomy and transduodenal sphincteroplasty are defined as operative approaches to the resection of lesions of the ampulla of Vater and the palliative or therapeutic reconstruction of the sphincter of Oddi, respectively, performed via a duodenotomy to facilitate exposure of the ampulla within the duodenal lumen. Operation on the sphincter of Oddi consists of reconstruction of the lumen orifices of the pancreatic and/or biliary tree, which may include the following:
  - Incision of the sphincter alone, without reconstruction (sphincterotomy)
  - Incision of the sphincter and reapproximation of the duct to the duodenal mucosa (sphincteroplasty)
  - Incision of the sphincter, division of the septum between the pancreatic and common bile ducts, and their reapproximation with suture (septoplasty)
- These operations may be employed for the treatment of benign, functional, and premalignant disorders of the ampulla and sphincter complex. Though both ampullectomy and transduodenal sphincteroplasty may be incorporated as separate components of the same procedure, they effectively serve as the extirpative and the reconstructive phase, respectively, of an operation on the ampulla of Vater.
- The standard of care for malignant tumors of the ampulla or periampullary duodenum (as well as the head of the pancreas and distal bile duct) is a pancreaticoduodenectomy.
- Ampullectomy is a more limited operation with comparably less morbidity that thus has theoretical benefit for patients with benign or premalignant lesions of the ampulla of Vater.

DIFFERENTIAL DIAGNOSIS

- Transduodenal sphincteroplasty/ampullectomy (TSA) may be considered one of several treatment options for the patient with a mass or functional lesion at the ampulla of Vater. However, the caveat is that TSA is only indicated for a small minority of patients with ampullary lesions and careful consideration of the differential diagnosis is crucial, as it will often lead to other management strategies.
- The indications for transduodenal sphincteroplasty include the following:
  - Impacted common bile stones that are not amenable to extraction by endoscopic means or a "top-down" common bile duct (CBD) exploration
  - Therapy for sphincter of Oddi dysfunction leading to ongoing injury to the liver and/or pancreas that is refractory to endoscopic management
  - Management of benign ampullary adenomas
  - Pancreas divisum

PATIENT HISTORY AND PHYSICAL FINDINGS

- Patients may come to clinical attention due to obstructive symptoms of the pancreatic or common bile ducts and may initially present with symptoms of biliary or pancreatic obstruction, such as dark urine, jaundice, steatorrhea, abdominal pain, pruritus, cholangitis, or pancreatitis. Occasionally, melena or iron deficiency anemia may lead to the diagnosis.
- The majority of ampullary adenomas are sporadic; however, a significant second group of patients are those with familial adenomatous polyposis (FAP) syndrome.[1]
- Up to 90% of patients with FAP will develop duodenal adenomas, and ampullary adenocarcinoma is the leading cause of death in FAP patients who have undergone prophylactic colectomy.[1,2]
- Whether sporadic or associated with a polyposis syndrome, adenomas at the ampulla are considered precancerous lesions warranting resection.
- Various series have documented 25% to greater than 50% of adenomas contain occult malignant foci.[1–3]
- Adenomas have a 30% transformation rate to carcinoma.[4]
- In several published series, sampling error results in a falsely negative preoperative biopsy in 25% to 30% of cases harboring malignant disease.[2,5]
- As patients with benign ampullary lesions are now often initially managed with endoscopic resection, candidates for surgical ampullectomy comprise a very small group of patients who are neither candidates for endoscopic resection nor for pancreaticoduodenectomy.[6] Additionally, patients in whom endoscopic resection has been incomplete or unsuccessful for technically limitations (such as prior Roux-en-Y gastric bypass) may fall into this group.
- In one series of 157 patients with ampullary lesions, the presence of jaundice, steatorrhea, dark urine, or pruritus was associated with malignancy, whereas when the presenting symptom was gastrointestinal (GI) bleed, the diagnosis was more commonly benign.[7] Notably, patients with obstructive symptoms are highly unlikely to be candidates for ampullectomy because of the association with malignancy.
- Sphincter of Oddi dysfunction (SOD) is a well-characterized syndrome that in turn may be due to mechanical causes (e.g., fibrosis) or functional (e.g., dysmotility in the biliary tree, persistent spasm of the sphincter due to neurohormonal dysfunction).
- SOD often presents with recurrent biliary-type pain after a cholecystectomy. Other causes of biliary pain, such as retained CBD stone, pancreatitis, and cholangitis, are typically ruled out by extensive workup before the diagnosis of SOD is made.
- Additionally, SOD may occur in the setting of a prior Roux-en-Y gastric bypass performed for morbid obesity.[8]

- Patients who have undergone a prior gastric bypass operation or Roux-en-Y gastrojejunostomy for any other indication may have anatomy that renders endoscopic management of ampullary lesions, retained CBD stone, or SOD unfavorable, necessitating a transduodenal approach.
- Patients with pancreas divisum are thought to have pancreatitis secondary to minor papillary insufficiency. This group of patients should initially be managed conservatively, and replacement of pancreatic enzymes alone may decrease symptoms. Endoscopic therapy with minor papillotomy or surgical minor papillary sphincteroplasty is the next option.[9]
- A final category of patients who may require surgical intervention on the ampulla include those who have sustained a posterior duodenal perforation as a complication of endoscopic retrograde pancreatography. Most often, these injuries should be managed nonoperatively; however, when the injury is immediately recognized, emergent transduodenal sphincteroplasty may be considered in carefully selected patients.

FIG 2 ● **A.** EUS image of an adenoma at the ampulla of Vater. The CBD and pancreatic duct (PD) are both visible and there is an irregular density that is an adenoma visible toward the center of the field *(red arrow)*.

IMAGING AND OTHER DIAGNOSTIC STUDIES

- Noninvasive imaging modalities may include magnetic resonance cholangiopancreatography (MRCP) and computed tomography (CT) with pancreatobiliary contrast protocols (**FIG 1**).
- Invasive modalities include endoscopic retrograde pancreatography (ERCP) or endoscopic ultrasound (EUS) and are part of the initial workup for lesions of the ampulla.
- Imaging modalities can provide information on extent of local disease including depth of invasion, if applicable. CT scans are the usual initial diagnostic imaging studies performed, due to ready availability and ease of interpretation.
- CT scan has use for the detection of nodal disease or distant metastases, whereas EUS has a great deal of use in the detection of depth of invasion of ampullary adenoma and hence has a role in the workup of disease amenable to local resection (**FIG 2**). This point is not without controversy, as others have argued that CT scan is not superior to EUS in terms of nodal staging.
- When stricture at the ampulla is suspected, ERCP can be used to clarify the extension of the stricture into the pancreatic parenchyma or the distal CBD; this information is critical for operative planning.

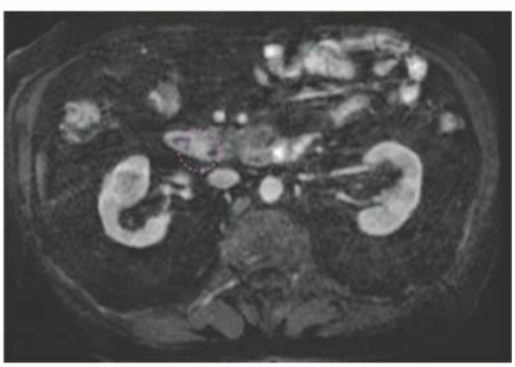

FIG 1 ● MRCP image demonstrating a 1.3-cm adenoma at the ampulla of Vater. The ampullary adenoma is outlined in a *dashed purple line* in this image.

- For strictures that extend beyond the ampulla itself, the operation of choice would be a pancreaticoduodenectomy or CBD reconstruction, that is, hepaticojejunostomy depending on the etiology.
- ERCP, hepatobiliary iminodiacetic acid (HIDA) scan, and MRCP with secretin stimulation or sphincter manometry may be used to make the diagnosis of SOD.
- Patients with delayed excretion of contrast after ERCP (>45 minutes), CBD dilatation greater than 1.2 cm, and elevated alkaline phosphatase or serum glutamic oxaloacetic transaminase (SGOT) (greater than two times the upper limit of normal) have excellent response to endoscopic sphincterotomy alone without other diagnostic maneuvers.
- Patients who meet some but not all of these criteria benefit from further diagnostic testing with manometry, and those patients in whom manometry is abnormal may benefit from sphincterotomy.
- Patient with biliary pain but without any of the aforementioned abnormalities may undergo manometry but have generally lower rates of success following sphincterotomy even in the presence of abnormal manometry.
- Although this has not been validated prospectively, one small study suggested that HIDA scan with morphine as an adjunct has the advantage of a noninvasive test that, when positive, correlates well with a positive surgical outcome.[10]
- MRCP with secretin stimulation is another modality that has been used to demonstrate SOD dysfunction in patients with prior Roux-en-Y gastric bypass for morbid obesity.[8]
- Sphincter manometry is performed via a miniaturized pressure catheter that is placed in the sphincter of Oddi using a side-viewing endoscope. Four categories of manometric abnormalities are defined and include the following:
  - Papillary stenosis, which is defined as persistently elevated resting pressures within the sphincter of Oddi that are unresponsive to pharmacologic means of sphincter relaxation
  - Dyskinesia, in which the response to pharmacologic relaxation is preserved within the context of elevated resting pressures

- Tachyoddia, in which there is an increased frequency of spontaneous contractions of the sphincter and physiologically abnormal (paradoxical) response to cholecystokinin.[11]
- Paradoxical sphincter response, in which an increase in sphincter tone is observed in response to cholecystokinin administration
- Endoscopy with secretin stimulation test may also be used in the stratification of patients with pancreas divisum who are likely to benefit from surgical sphincteroplasty. Briefly, EUS may be used to visualize the minor pancreatic duct. After administration of secretin, increase in ductal dilatation gives evidence to an obstructive papillary stenosis. The absence of this dilatation should prompt consideration of further trials of nonsurgical therapy.

SURGICAL MANAGEMENT

Preoperative Planning

- Biliary tract decompression, that is, by percutaneous transhepatic biliary drain placement or ERCP, may be required if the patient has presenting symptoms of biliary obstruction.
- Preoperative placement of an epidural catheter for pain control is a useful adjunct for a planned open operation and limits postoperative dependence on narcotic pain medication.
- General strategies to optimize patients for major surgery should be employed as indicated. These may include optimization of nutritional status as well as smoking and alcohol cessation.

Positioning

- The patient is positioned supine on the operating table. Sequential compression device boots are placed. Unless there is a contraindication to heparin administration, 5,000 units of unfractionated heparin are given in the preoperative holding area as deep venous thrombosis (DVT) prophylaxis.
- Preoperative antibiotics are administered within 1 hour of incision. Appropriate antibiotics should cover for skin flora as well as for gram-negative enterics and anaerobes.
- Our practice is to extend the left arm and tuck the right arm and place the Bookwalter (or similar) retractor on the patient's right side. A right subcostal (Kocher) incision with extension a short distance across the midline is used (**FIG 3**).

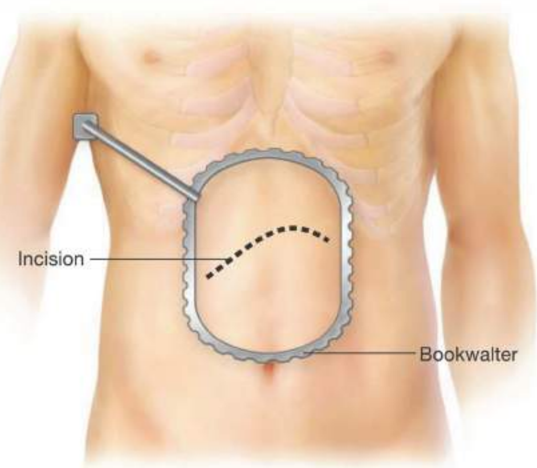

FIG 3 ● The patient is positioned in the supine position. The right arm is tucked and a Bookwalter retractor is typically placed on the right side. A right-sided subcostal incision with extension across the midline is used.

INCISION AND EXPOSURE

- A right subcostal (Kocher) incision is made with extension across the midline to facilitate exposure. The incision should be made approximately two fingerbreadths inferior to the costal margin. Adequate exposure is facilitated by the placement of a fixed retractor such as the Bookwalter or Thompson. If the gallbladder is present, a cholecystectomy is typically performed. We suggest leaving a long cystic duct stump to facilitate placement of transcystic duct stump biliary catheter to guide identification of the ampullary orifice. This maneuver can optimize the location of the subsequent duodenotomy. The liver is retracted superiorly and the hepatic flexure is completely mobilized such that it can be safely retracted inferiorly out of the operative field.

KOCHER MANEUVER

- The second portion of the duodenum is grasped and retracted medially so as to enable division of the peritoneum at its lateral border. An avascular plane is developed, with extension toward the midline to completely mobilize the duodenum through the third portion (**FIG 4**). The location of the ampulla is typically at the distal aspect of the second portion of the duodenum; hence, wide mobilization of the duodenum with a Kocher maneuver that extends inferiorly and medially toward the midline with full mobilization of the hepatic flexure to expose the third portion of the duodenum is essential to provide adequate exposure and a tension-free closure. This mobilization also allows the duodenum to be retracted up into the field where it may be maintained with stay sutures for subsequent steps of the operation. The placement of laparotomy pads posterior to the duodenum to further elevate it into the incision is recommended.

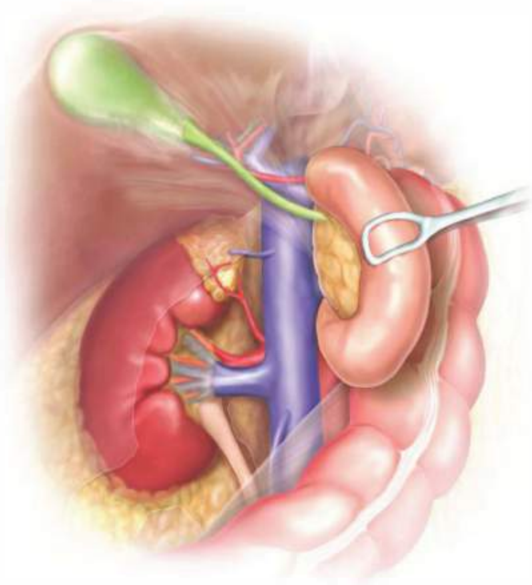

FIG 4 ● A Kocher maneuver is performed by incision of the lateral attachments of the duodenum and extension to the third portion of the duodenum, exposing the junction of the middle colic and the superior mesenteric vessels.

DUODENOTOMY AND EXPOSURE OF THE AMPULLA

- Bimanually palpate the second portion of the duodenum to identify the lesion. If it cannot be palpated, place a biliary catheter via the cystic duct stump, inflate the balloon, and withdraw it until you meet resistance—the balloon will be palpable at the ampulla. An antimesenteric duodenotomy is then made to expose the luminal orifice of the ampulla (**FIG 5**). The duodenotomy may be made either in a longitudinal or a so-called lazy S curvilinear incision. We typically favor a longitudinal incision, which allows for extension of the incision if a wider field of exposure is needed. Alternatively, if a wide exposure is required to remove a large adenoma, a curvilinear incision offers the broadest operative field. The duodenum will stretch, so use care not to make an unnecessarily large incision. A 5-cm longitudinal incision will usually facilitate adequate exposure. Stay sutures are placed around the edges of the duodenotomy to maintain the operative field, thus exposing the lumen of the duodenum.

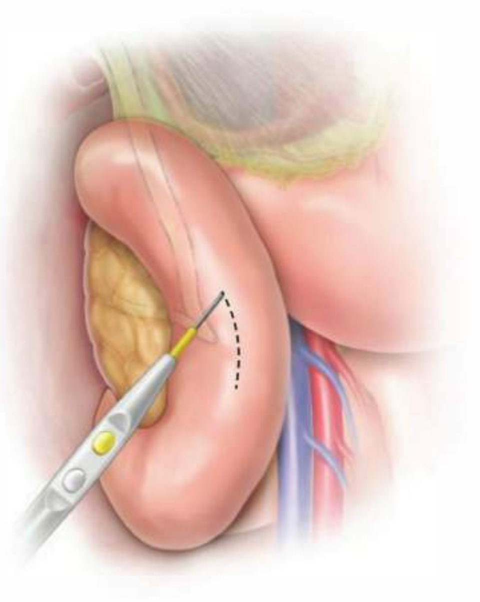

FIG 5 ● A duodenotomy is performed. The placement of the incision may be longitudinal or in a lazy S configuration. Palpation of the ampulla through the duodenal wall or palpation of a biliary catheter threaded through the cystic duct stump across the ampulla facilitates placement of the incision. The *dashed line* represents the approximated location of the ampullar structures. Palpation of the structures (and any preoperatively placed biliary stents) should guide the placement of the incision.

IDENTIFICATION OF THE MAJOR AND MINOR PAPILLA

- The major and minor (if present) papillae are identified. Adenomas are readily apparent. Alternatively, the biliary catheter will identify the major papilla.
- The minor papilla is typically located 2 cm cephalad to the major orifice. Its identification may be facilitated, if needed, by intraoperative secretin injection (75 U/kg) to stimulate pancreatic secretions.

PREPARATION FOR THE EXTIRPATIVE PHASE

- At this point, it is advantageous to prepare the field for excision of the ampulla (**FIG 6**). The maneuvers used will be dependent on the goals of the operation specific to the individual patient. If a mass is to be excised, placement of a traction suture (2-0 silk) into the mass allows it to be elevated, retracted, and excised.[3]
- From within the lumen of the duodenum, full-thickness, circumferential stay sutures are placed to demarcate 1.0-cm borders around the planned resection area (i.e., 1.0 cm from the ampulla or obvious borders of the mass itself), which will also facilitate delivery of the ampulla into an optimal position for resection. These sutures also stabilize the redundant duodenal mucosa.

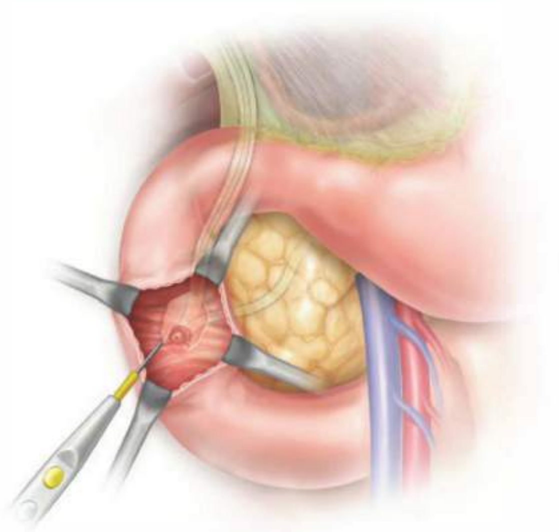

FIG 6 ● Circumferential cautery around the ampulla results in the exposure of the biliary and pancreatic ductal orifices. If difficulty is encountered identifying the pancreatic orifice, intraoperative secretin administration may be used, with a resultant clear effluent observed in the operative field from the pancreatic orifice. The localization of the biliary duct is enabled by the placement of a directed biliary catheter via the cystic duct stump.

PERFORMANCE OF THE EXTIRPATIVE PHASE

- Retracting the mass inferiorly, *needle tip* electrocautery is used to divide the posterior duodenal mucosa until the bile duct is reached. At that point, sutures are placed to approximate the (full-thickness) CBD and the medial duodenum (5-0 absorbable monofilament). The dissection then continues circumferentially in a cranial to caudal fashion.
- The biliary catheter, when present, is withdrawn. Needle-tipped electrocautery is used to incise the medial (deep) wall of the CBD. This transaction point can be up to 3 cm proximal to the duodenal orifice and still accommodate a ductoplasty.
- As the dissection progresses circumferentially, 4-0 or 5-0 absorbable monofilament sutures are placed full-thickness through the CBD and then the duodenal wall and tied. Hence, the reconstruction occurs as the dissection is performed. This approach provides optimal identification of the edge of the incised bile duct and prevents catastrophic retraction of the CBD out of the field of view.
- Alternatively, delaying reconstruction until both pancreatic ducts and CBDs have been excised serves two purposes. First, intraoperative frozen section of the completely excised specimen may be performed and additional ductal margins (up to 1 cm) taken as needed. Second, the reconstruction with orientation of the pancreatic and CBDs may be optimized.
- For this approach, sutures should be placed in the bile and pancreatic ducts as the dissection proceeds and the needles left in place. Opposing bites of duodenum will be taken later to approximate these structures after the resection is complete.
- The pancreatic ductal orifice is encountered at about the 2 o'clock position. Similar to the CBD, stay sutures (5-0 polydioxanone [PDS] or similar) are placed full thickness through the pancreatic duct and ultimately are secured to the duodenum.
- The dissection is carried circumferentially with sutures placed through the duodenal wall until the entire ampullary complex has been excised.

TECHNIQUES

INTRAOPERATIVE FROZEN SECTION

- If the operation is performed for an adenomatous lesion, intraoperative frozen section should be used. Malignancy found on intraoperative frozen section should warrant consideration of conversion to pancreaticoduodenectomy.
- Between 25% and 45% of patients with pathologic T1 periampullary lesions will have positive lymph node metastases. Thus, pancreaticoduodenectomy is the preferred management strategy for malignancy. Intraoperative analysis of the resected adenoma is essential.[4,10,12]

RECONSTRUCTIVE PHASE

- Reconstruction proceeds with creation of a septum by apposition of the CBD and pancreatic ducts. Full-thickness interrupted sutures using 5-0 monofilament, absorbable sutures are placed through each duct such that they can be tied on the lumen side (**FIG 7**).
- The pancreatic ducts and CBDs are then approximated to the duodenal wall by taking the previously placed sutures through the ducts and placing full-thickness suture bites through the duodenum, exiting in the duodenal mucosa. This is carried out in a circumferential fashion until a duodenal defect remains at the inferior portion of the reconstruction, which is then closed by reapproximation (**FIG 8**).
- Our practice is to close the duodenotomy in a transverse fashion when this can be accomplished in a tension-free manner (typically dependent on the size of the duodenotomy). Alternatively, we use a longitudinal closure using seromuscular 3-0 silk sutures. Oversewing is avoided in order to prevent stricture and to maintain maximal duodenal patency. In some cases, when a longitudinal closure provides a better primary closure but narrows the lumen, we also perform a gastrojejunostomy.
- A closed suction drain may be left in close proximity to the duodenotomy at the surgeon's discretion, and the abdomen is closed in a standard fashion.

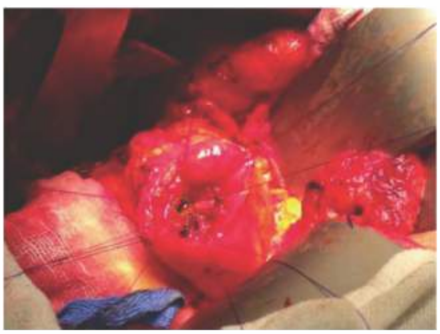

FIG 7 ● A completed reconstruction of the ampullary structures. The CBD is identified by the *dashed green line*, whereas the pancreatic duct is identified by the *dashed blue line*.

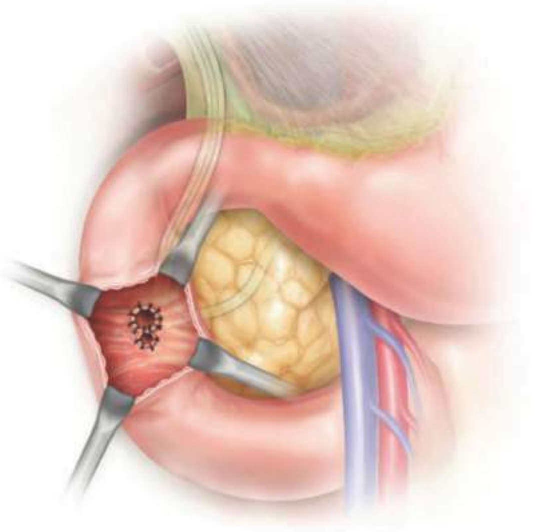

FIG 8 ● Reapproximation of the ductal structures. The reapproximated ducts are always smaller than the excised ampulla; hence, the additional defect may be closed with simple duodenal stitches.

PEARLS AND PITFALLS

Sphincter manometry	■ Avoid use of anticholinergics or opioids such as morphine, which alter sphincter of Oddi pressures.
Postoperative pneumobilia	■ Expected; indicative of patency of the repair
Delayed reconstruction of pancreatic and CBD	■ Facilitates optimization of the orientation of the ducts to the duodenum and enables additional margins to be taken if needed
Bariatric surgery patients with pancreatobiliary-type pain	■ SOD and ampullary stenosis should be in the differential and may be amenable to surgical intervention. ■ More recently, data has emerged questioning the value of endoscopic management of SOD. The extension of this finding to surgical management is unknown.

Preoperative ERCP and EUS	■ Both are crucial modalities to demonstrate the feasibility of ampullectomy.
Duodenotomy	■ The duodenotomy will stretch. Although it must be of sufficient size so as to afford appropriate exposure, start small and extend as needed.
Closure of the duodenotomy	■ If transverse closure is not possible to accomplish in a tension-free manner, a longitudinal closure may be used, with a gastrojejunostomy if concern exists that the duodenal lumen is thus narrowed.
Identification of the ampulla	■ A biliary Fogarty catheter may be passed via the cystic duct in order to facilitate identification of the ampulla.

POSTOPERATIVE CARE

- Routine postoperative care includes pain control, strict recording of urine output via a Foley catheter, gastric decompression via a nasogastric tube, and monitoring output of a closed suction drain.
- Patient-controlled analgesia or an epidural is typically used. Patients are transitioned to oral pain medication once tolerable of clear liquids.
- Our practice per the clinical pathway is to draw routine full set of labs on the first postoperative day and then the fourth postoperative day but otherwise only when clinical suspicion raises concern. In sphincteroplasty patients, it is prudent to include total bilirubin and serum amylase and lipase and to delay advancement of diet if pancreatic enzymes remain elevated postoperatively.
- Sequential compression stockings and unfractionated heparin (5,000 units three times a day) are used routinely. Additionally, pantoprazole (40 mg intravenously daily) is continued in the postoperative period.
- The nasogastric tube is typically discontinued on the third postoperative day.
- The epidural and Foley catheter are typically discontinued on the third postoperative day. In the absence of an epidural, the Foley catheter is removed once postoperative urine output is satisfactory, typically on postoperative day 1 or 2.
- The drain output is continuously monitored. The drain is left in place until the patient can tolerate a regular diet. The drain is then removed unless the character or volume of output is of concern for a leak at the duodenal closure site.

OUTCOMES

- When performed for SOD, patient satisfaction and symptom relief has been noted to vary with SOD subclass. In one series, patients with type I SOD reported good outcomes in nearly 100% of patients. However, results were not as favorable in type III and type II dysfunction with 58% and 61% favorable outcomes, respectively. In multivariate analysis, patients with good outcomes tended to be older (47 years old vs. 33 years old), whereas patients with poor outcomes tended to suffer from chronic pancreatitis.[9]
- Surgical sphincteroplasty is associated with a 30% complication rate. Complications after ampullectomy occur at half the frequency of complications of pancreaticoduodenectomy and with a lesser degree of severity.[10]
- When performed for minor papillary stenosis, success rates vary with patient characteristics. Success is lowest in patients with pancreatic-type pain without clinical evidence of pancreatitis, intermediate in patients with chronic pancreatitis, and highest (75% to 90%) when undertaken after a single episode of acute pancreatitis.
- When performed for SOD, a retrospective review indicated that the success rate of transduodenal sphincteroplasty was low in patients with concomitant chronic pancreatitis but relatively high in patients who had undergone prior bariatric surgery.[9]
- In patients who had undergone prior Roux-en-Y gastric bypass and subsequently underwent operation for SOD, one relatively small case series demonstrated that the majority of patients had pain improvement after surgery.[8]
- When performed for malignancy, retrospective analysis indicates significant disadvantages to transduodenal resection versus pancreaticoduodenectomy including increased incidence of local recurrence and decreased survival. However, the only prospective series comparing the two techniques is relatively small and demonstrates that in selected patients outcomes may be equivalent.[13]

COMPLICATIONS

- In one series of patients comparing surgical ampullectomy to endoscopic ampullectomy, a 42% morbidity rate was observed among the surgical ampullectomy group versus the 18% in the endoscopic ampullectomy group. Complications after endoscopic ampullectomy included hemorrhage, pancreatitis, and intractable nausea, in decreasing order of frequency. After surgical ampullectomy, the most frequent complications included dehydration, symptomatic pancreatitis, wound infection, and intraabdominal abscess.
- Major complications are rare but include leakage at the duodenotomy leading to pancreaticobiliary fistula or intraabdominal abscess and sepsis. Cholangitis is also reported with a frequency of 6% in one series.[14]

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Chapter 45

Enucleation of Pancreatic Neuroendocrine Tumor

Megan B. Anderson   Christopher D. Raeburn   Barish H. Edil

DEFINITION

- Pancreatic neuroendocrine tumors (PNETs) are a diverse group of neoplasms that can arise from mature endocrine cells of the pancreas (α, β, δ, and γ cells) and multipotent cells, which have the ability to differentiate into endocrine and exocrine cells. PNETs were previously known as islet cell tumors.
- PNETs can be subdivided into functional and nonfunctional based on their production of specific pancreatic endocrine hormones. Functional PNETs can produce insulin, gastrin, glucagon, vasoactive intestinal polypeptide (VIP), and somatostatin.

DIFFERENTIAL DIAGNOSIS

- Functional PNETs amenable for enucleation are the following:
  - Insulinoma
  - Selected gastrinoma
  - Selected somatostatinoma
- Selected nonfunctional PNETs amenable for enucleation are typically less than 2 cm but this is an area of controversy.

PATIENT HISTORY AND PHYSICAL FINDINGS

- A thorough history and physical must be obtained to assess for signs of functional tumors, symptoms of mass effect, or evidence of metastatic disease. Physical exam should focus on abdominal masses, organomegaly, signs of biliary obstruction or liver dysfunction, and lymphadenopathy.
- Although most PNETs are sporadic, 10% can be associated with predisposing syndromes such as multiple endocrine neoplasia type 1 (MEN-1), von Hippel-Lindau (VHL) disease, neurofibromatosis type 1 (NF1), and tuberous sclerosis complex (TSC).
- Nonfunctional PNETs are typically slow growing and occur in the head of the pancreas. These lesions usually present similarly to pancreatic adenocarcinoma due to the mass effect of the tumor: jaundice, abdominal pain, and weight loss.
- Functional PNETs
  - Insulinoma: Whipple's triad—symptoms of hypoglycemia, generally when fasting, at night, or during exercise; hypoglycemia documented at the time of symptoms; and symptom relief with glucose administration.
    - Supervised 72-hour fast with a plasma glucose of less than 45 mg/dL
    - Increased C peptide more than 100 pmol/L
    - Negative sulfonylurea screen in urine
    - Negative insulin antibodies
  - Gastrinoma: Zollinger-Ellison syndrome—refractory peptic ulcer disease and secretory diarrhea
    - Serum gastrin of more than 500 pg/mL
    - Gastric pH less than 3
    - Positive secretin or calcium stimulation test

IMAGING AND OTHER DIAGNOSTIC STUDIES

- Imaging: Computerized tomography (CT), magnetic resonance imaging (MRI), endoscopic ultrasonograph with fine needle aspiration (EUS/FNA), somatostatin receptor scintigraphy (SRS), percutaneous transhepatic portal venous sampling (PTPVS), and arterial stimulation with venous sampling (ASVS) all may play a role in localization of a PNET and preoperative planning. **FIG 1** shows a CT scan of an insulinoma at the level of the head of the pancreas. These lesions are typically best visualized on arterial phase CT.
- CT scanning is unfortunately only 67% sensitive in localizing PNET and these other adjunctive measures may be required.
- As a part of EUS evaluation, tattoo small lesions or lesions that are deep within the parenchyma of the pancreas to make localization easier at the time of operation.
- Based on the data collected from laboratory tests and imaging studies, only select PNETs are amenable to enucleation. Low-grade tumors such as insulinomas are most amenable to enucleation.

SURGICAL MANAGEMENT

Preoperative Planning

- Because most (>90%) insulinomas are benign, enucleation is usually preferred. A formal pancreatic resection should be considered if there is evidence of invasion, lymphadenopathy, or if the tumor is in close proximity to the pancreatic

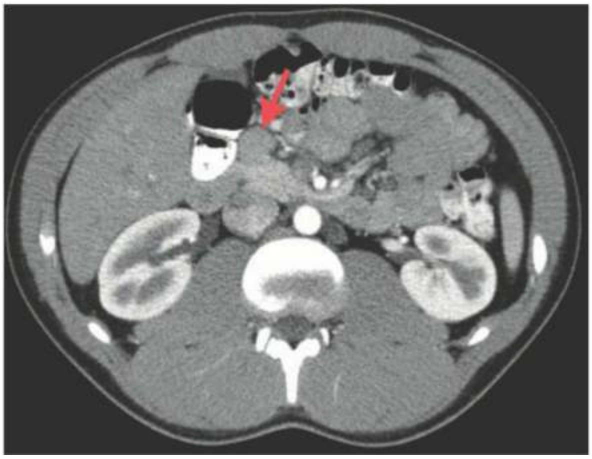

FIG 1 • CT scan of abdomen showing an insulinoma in the head of the pancreas. It is well circumscribed, consistent with a benign PNET. It is presented as it is unusual; it does not enhance on the arterial phase of imaging. *Arrow* points to an exophytic insulinoma at the head of the pancreas.

duct or major vessels. It is possible to perform an enucleation through traditional open technique or laparoscopically.

- For lesions where the pancreatic duct may be at risk for injury, some have advocated preoperative placement of a pancreatic duct stent. There is not clinical data that supports or condemns this approach.
- Contraindications would include recent pancreatitis, uncontrolled coagulopathy, comorbidities that would limit life expectancy, and signs of malignancy, which include enlarged lymph nodes or distant metastases.

Positioning

- The patient should be placed supine on the operating room table. The entire abdomen should be sterilely prepped and draped.

PLACEMENT OF INCISION

- Open: An upper midline incision should be made to enter the abdomen.
- Laparoscopic: An infraumbilical 10-mm port should be placed to gain access to the abdomen. From there, another two 10-mm ports will be placed in the left upper quadrant and right lower quadrant, and two 5-mm ports will be placed in the right upper quadrant and left lower quadrant as shown in FIG 2.

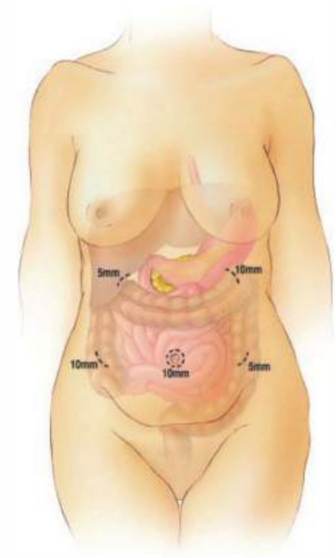

FIG 2 ● Illustration of port site placement for laparoscopic enucleation of PNET. It is best to bring the drain(s) out through the left upper quadrant and/or right upper quadrant port sites. Illustration by Frank Corl.

ABDOMINAL EXPLORATION

- A thorough examination of the abdomen should be performed prior to proceeding with enucleation to exclude advanced locoregional disease or metastatic disease. PNETs most commonly metastasize to the liver; thus, thorough examination of the liver is critical and intraoperative ultrasound (IOUS) is the most sensitive imaging modality for detecting metastases.

PANCREATIC DISSECTION

- If the lesion lies in the head of the pancreas, this area is mobilized by first dissecting the omentum from the hepatic flexure. A Kocher maneuver allows you to further mobilize the head of the pancreas. Division of the right gastroepiploic vessels on the anterior surface of the pancreatic head will allow for full exposure. While mobilizing medially, the superior mesenteric vein (SMV) will be encountered and care must be taken to avoid a vascular injury.
- The gastroepiploic vein may need to be divided to provide adequate exposure to the pancreatic neck.
- If the tumor is located in the neck, the plane below the neck and anterior to the portal vein/SMV might need to be developed.
- If the lesion is in the tail of the pancreas, mobilizing the splenic bed may expose this area. This requires division of the gastrosplenic ligament (containing gastroepiploic vessels) and also the short gastric vessels.
- Obtain access to the lesser sac by dividing the gastrocolic ligament from left to right. Retract the stomach more superiorly, along with the omentum to adequately visualize the pancreas.
- At this point, inspection of the pancreas is done. If the tumor is easily identified, further dissection may be

avoided unless patient has an inherited syndrome or if there are clinical concerns of multicentric disease.

- Dissecting out the superior and inferior borders of the pancreas using blunt and sharp technique may further help delineate the location of the lesion and allows access to the posterior pancreas if necessary for tumor identification.
- Once the pancreas is visible, palpate the mass using your finger or a laparoscopic instrument. In open cases, a wide Kocher maneuver and splenic mobilization facilitates bimanual palpation of the pancreatic head and body/neck, respectively. If the tumor is small, IOUS is also useful in localizing the mass as well as to better evaluate the proximity to the pancreatic duct and vascular structures.
- Once the mass is located, care must be taken to avoid any major surrounding vascular structures.
- Once the pancreas has been sufficiently mobilized and excellent exposure has been obtained, one should be able to visualize the mass using the aforementioned techniques. Please see **FIG 3** to appreciate how exposure of the pancreas provides visualization of the mass.

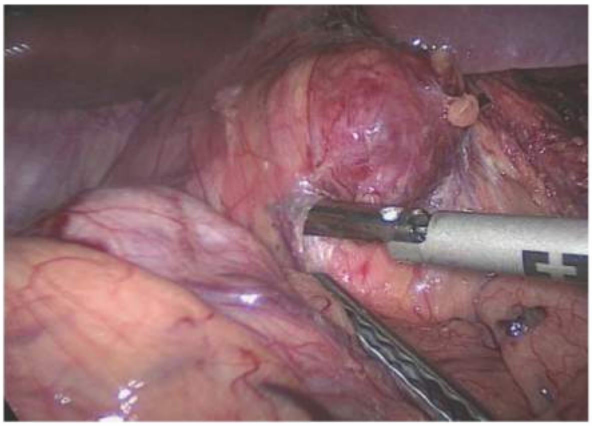

FIG 3 ● Intraoperative photograph of an insulinoma. This photo shows the well-encapsulated mass that extends outside the parenchyma of the pancreas being dissected using an ultrasonic energy device. This anatomic relationship of a PNET to the parenchyma of the pancreas, coupled with the pseudocapsule, make this lesion ideal for enucleation.

DISSECTING THE MASS

- PNETs, especially insulinomas, are typically well circumscribed and well encapsulated, and a dissection plane should be evident. **FIG 4** demonstrates a well-encapsulated insulinoma and a dissection plane, which can be followed with electrocautery.
- Once the appropriate tissue plane has been identified, it may be further dissected out using different type of energy devices. Constant gentle elevation and traction allows for visualization of the plane of dissection and feeding vessels.
- The authors advocate the use of surgical clips on any bridging structure greater than 1 mm.
- A figure-of-eight suture placed in the mass can serve as a valuable retraction point and facilitate development of the tissue plane along the pseudocapsule of a PNET.
- Once the mass is removed, care should be taken to ensure excellent hemostasis. In addition, IOUS can be used to demonstrate the integrity of the pancreatic duct.
- In the case of gastrinoma, some advocate for routine duodenotomy as there is a higher risk of multiple tumors, which can be small and otherwise difficult to detect.

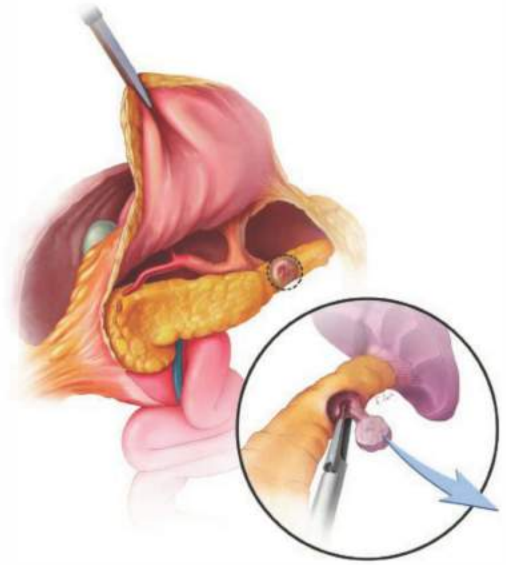

FIG 4 ● Schematic demonstration of adequate exposure of the pancreas. This figure emphasizes the importance of retracting the stomach on providing adequate exposure. The *inset* demonstrates how the lesion should be easily dissectible from the pancreatic parenchyma.

CLOSURE AND DRAIN PLACEMENT

- When closing the 10-mm ports, the fascia is ideally closed to prevent incisional hernia in the future.
- A drain should be placed along the area that has been enucleated; this will aid in monitoring for and controlling any postoperative leaks. The drains are most easily brought out through the left upper quadrant or right upper quadrant incisions, as demonstrated in **FIG 5**.

FIG 5 ● A photograph of the closed abdomen; the drains are most easily brought out through the right upper quadrant or left upper quadrant port sites.

PEARLS AND PITFALLS

EUS with tattooing of the lesion	■ A tattoo that localizes very small PNETs is invaluable to guide the operation. As most are now approached laparoscopically, this facilitates identification of the neoplasm without the ability of palpation.
Deep difficult PNETs	■ If enucleation is difficult for body/tail tumors or violation of the pancreatic duct is suspected, perform either laparoscopic or open distal pancreatectomy, with preservation of the spleen when possible.
Technique	■ Grasping a PNET will often lead to laceration. The neoplasm should not be grasped; rather, use an instrument to push the lesion to provide exposure. ■ A suture through the lesion serves as an excellent retraction tool when exposure is challenging.
IOUS	■ A very useful tool in determining duct relationship with tumor to plan enucleation versus resection early in the operation.
Drain	■ The vast majority of pancreatic surgeons place a drain following enucleation. The fistula rate is very high.

POSTOPERATIVE CARE

- Postoperatively, the patient may have their diet advanced as tolerated. If an insulinoma is removed, plasma glucose should be monitored every 15 minutes until stabilized. The drains should be monitored for the quantity and quality of the output. Once patient is taking adequate oral intake, the drains should be sent for amylase levels to rule out a leak before the drains are removed.

OUTCOMES

- If the PNET is an insulinoma, enucleation should be curative. If a nonfunctional PNET is elected for enucleation, the patient should be placed in a surveillance program and for PNETs that are large or potentially malignant, the operation should be a formal resection with lymphadenectomy.

COMPLICATIONS

- Early complications include the following:
  - Pancreatic leak
  - Acute pancreatitis
  - Wound or intraabdominal infection
  - Bleeding
- Late complications
  - Chronic pancreatic leak resulting in a cutaneous fistula, ascites, or pseudocyst
  - Recurrent PNET

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Chapter 46 Operative Treatment of Gastrinoma

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DEFINITION

- Zollinger-Ellison syndrome is a rare etiology of ulcer disease that is caused by gastrin secretion of neuroendocrine tumors (gastrinomas) typically found in the duodenum and pancreas. These tumors may be sporadic or associated with multiple endocrine neoplasia type 1 (MEN-1). Although the gastrin-mediated gastric acid hypersecretion can be controlled with modern antacid and proton pump inhibitor medications, the potentially malignant nature of the gastrinoma is the main determinant of patient survival. Therefore, surgical management remains critical in the care of patients with gastrinomas.

DIFFERENTIAL DIAGNOSIS

- Table 1 summarizes the potential etiologies of hypergastrinemia.

PATIENT HISTORY AND PHYSICAL FINDINGS

- Patients with gastrinomas typically have nonspecific symptoms, and this has historically led to delayed diagnosis from 3 to 9 years after initial onset of symptoms. Although presentation may occur anytime from childhood to old age, patients typically present with a male predominance (3:2) in the fifth decade of life with sporadic gastrinomas and in the fourth decade of life with MEN-1–related gastrinomas.[1]
- The most common symptoms are abdominal pain, diarrhea, and gastroesophageal reflux disease (GERD) (Table 2). Typically, patients have a small, solitary ulcer (<1 cm in diameter) in the first portion of the duodenum, although they may also have a history of recurrent ulcers in atypical locations such as the jejunum (11%) and distal duodenum (14%).[2,3]
- The most common complications are due to ulcer perforation, although up to 20% of patients do not have an ulcer on presentation.
- Gastrinomas arise sporadically in a majority of cases (75% to 80%), whereas the remainder are due to MEN-1. It is important to differentiate the etiology as this dictates the clinical and surgical management of these patients. In addition to gastrinomas, patients with MEN-1 also develop parathyroid adenomas, pituitary adenomas, and other neuroendocrine tumors.[4]

Table 1: Differential Diagnosis of Hypergastrinemia

Elevated Gastric Acid Secretion	Normal/Decreased Gastric Acid Secretion
Helicobacter pylori infection	Pernicious anemia
Retained gastric antrum	Atrophic gastritis
Gastrinoma	Proton pump inhibitor or H_2 blocker use
Antral G-cell hyperplasia	Postvagotomy
Renal failure	
Short bowel syndrome	

IMAGING AND OTHER DIAGNOSTIC STUDIES

- If a gastrinoma is suspected, then a serum fasting gastrin level should be obtained. Prior to this test, the patient should be instructed to hold antacid medication (proton pump inhibitors held for 7 days; histamine receptor blockers held for at least 30 hours).
- An elevated gastrin level greater than 10 times the upper limit of normal (>1,000 pg/mL) should be followed by a gastric pH probe in order to rule out achlorhydria. A gastric pH of 4.0 or greater confirms the diagnosis of gastrinoma if other etiologies (e.g., retained antrum after Billroth II resection) have been ruled out.
- A gastrin level that is elevated but less than 10 times the upper limit of normal should be followed by a secretin stimulation test. Although normal G cell gastrin secretion is inhibited by secretin, gastrin release by gastrinoma cells is actually increased. Secretin is infused intravenously over 1 minute after baseline gastrin measurements are obtained; gastrin is then measured at 2, 5, 10, 15, and 20 minutes after infusion. A positive test, typically defined by a rise in serum gastrin of 200 pg/mL or greater, confirms diagnosis of gastrinoma.

Table 2: Signs and Symptoms of Gastrinoma

Abdominal pain (75%)
Diarrhea (73%)
Peptic ulcers (>90%)
Reflux esophagitis (44%)
Nausea (33%)
Emesis (25%)
Weight loss (17%)
Complications of hyperacidity
  Bleeding (25%)
  Perforation
  Obstruction
  Stricture (pylorus, duodenum, esophagus) (<10%)
Physical findings
  Hypertrophic gastric rugal folds (94%)
  Multiple ulcers
  Unusual ulcer locations
    Distal duodenum (14%)
    Jejunum (11%)
  Pancreatic mass

From Mozell E, Stenzel P, Woltering EA, et al. Functional endocrine tumors of the pancreas: clinical presentation, diagnosis, and treatment. Curr Probl Surg. *1990;27:301–386; Roy PK, Venzon DJ, Shojamanesh H, et al. Zollinger-Ellison syndrome. Clinical presentation in 261 patients.* Medicine. *2000;79:379–411; Meko JB, Norton JA. Management of patients with Zollinger-Ellison syndrome.* Annu Rev Med. *1995;46:395–411.*

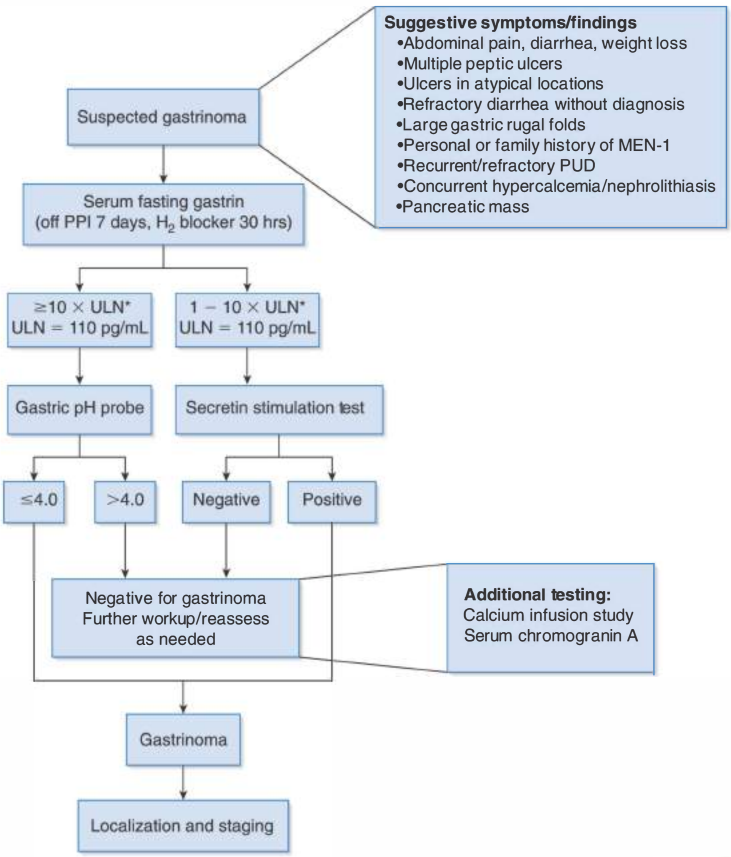


FIG 1 ● Diagnosis of suspected gastrinoma. ULN, upper limit of normal. PPI, proton pump inhibitor; MEN-1, multiple endocrine neoplasia; PUD, peptic ulcer disease.

- If these tests do not confirm the diagnosis but a high clinical suspicion remains, then additional tests may be used. The calcium infusion study consists of a continuous intravenous infusion of 5 mg/kg 10% calcium gluconate over a 3-hour period. Serum gastrin and calcium are measured prior at baseline and at 30-minute intervals for 3 hours after the test begins.[5] A positive result is typically defined as an elevation in serum gastrin by 395 pg/mL or greater, but multiple criteria exist.[6] Serum chromogranin A levels have also been found to be elevated in patients with gastrinomas, and this test may be used to confirm diagnosis in carefully selected cases[7] (**FIG 1**).
- After obtaining a biochemical diagnosis of gastrinoma, attention is turned to preoperative localization and staging. Up to 90% of gastrinomas can be located in the area bounded by the junctions of the cystic and common bile ducts, second and third portions of the duodenum, and neck and body of the pancreas—the so-called gastrinoma triangle (**FIG 2**).
- Initial localization studies include contrast-enhanced triple-phase protocol computed tomography (CT) or magnetic resonance imaging (MRI), and endoscopic ultrasonography (EUS). The decision to use CT versus MRI should be determined by the clinician based on institutional expertise and availability. Although the accuracy of these modalities continues to improve, the sensitivity for detection of tumors less

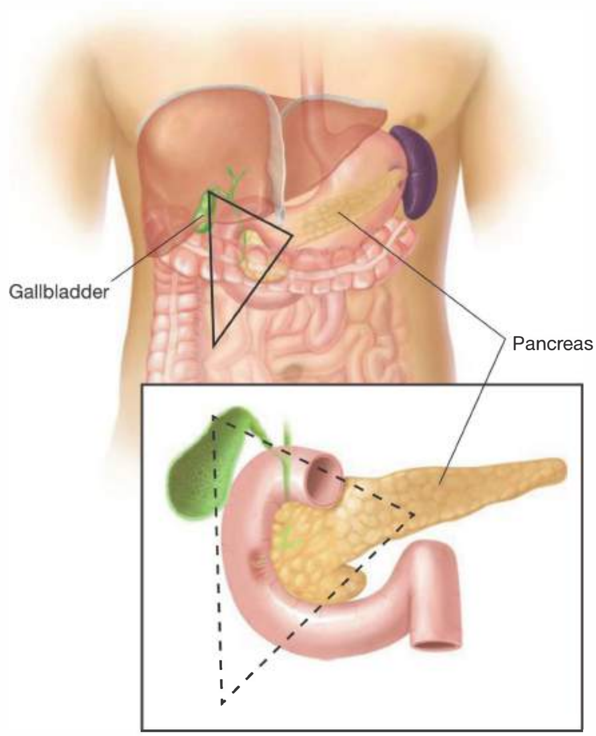


FIG 2 ● The gastrinoma triangle. Up to 90% of gastrinomas are located in this region.

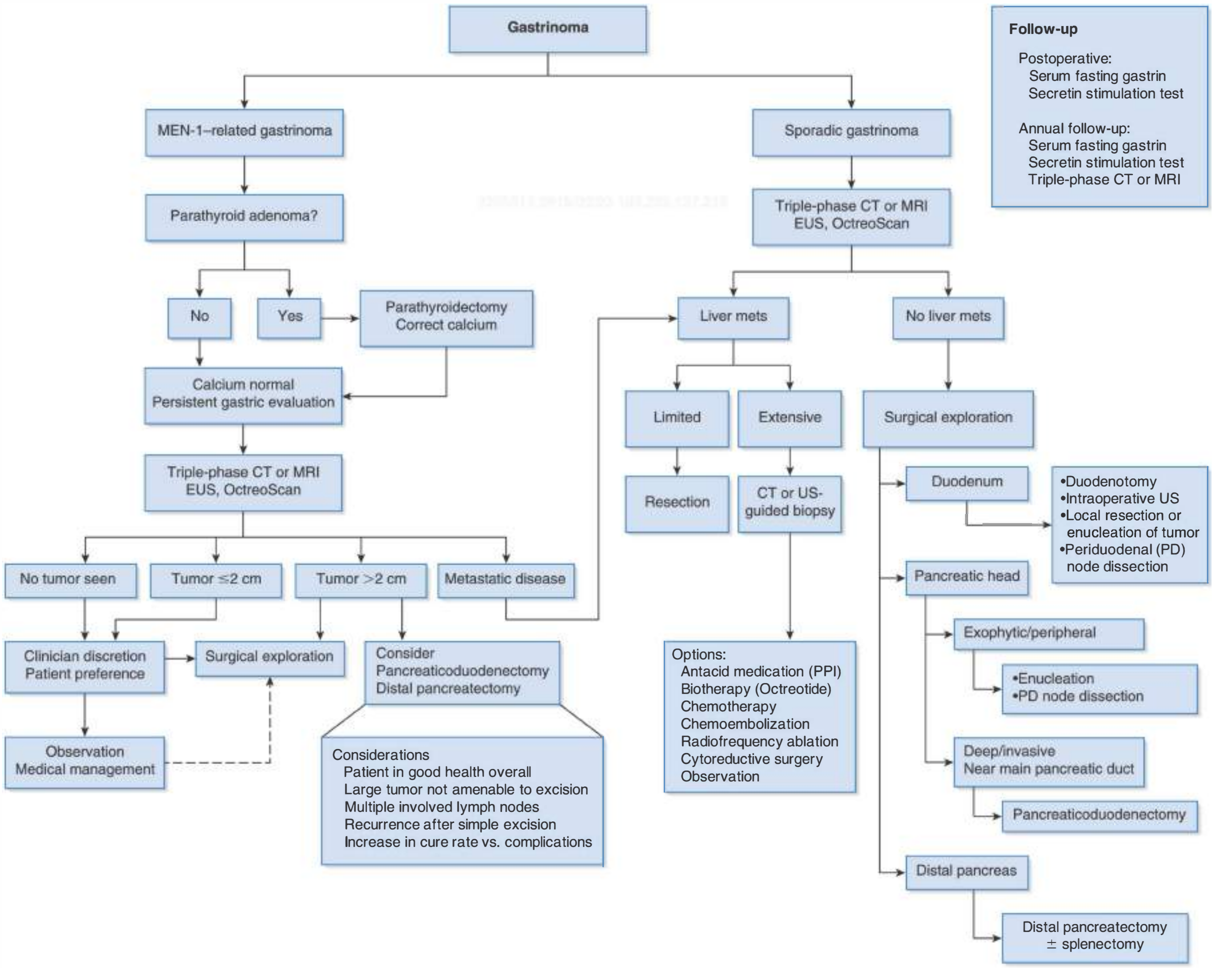


FIG 3 ● Localization and treatment of gastrinoma.

than 2 cm in diameter is decreased, although lesions as small as 4 mm have been detected.[8] EUS can detect smaller lesions (up to 2 to 3 mm, depending on operator experience) and also has the advantage of being able to obtain a cytologic specimen.

- Somatostatin receptor scintigraphy (SRS), also known as OctreoScan, takes advantage of the high level of somatostatin receptor expression in gastrinomas by using radiolabeled 111-indium pentetreotide to detect both primary tumors and hepatic metastases. Although the accuracy of other imaging modalities is improving, SRS continues to have a place in tumor localization and staging as it remains highly sensitive for detection of metastatic disease.[9]
- Patients determined to have MEN-1–related gastrinoma should be evaluated for hyperparathyroidism. If a primary hyperparathyroidism is present, it should be addressed prior to further surgical treatment as hypercalcemia may increase anesthetic risk and also elevates gastrin and acid production.
- If the etiology is sporadic and no metastases are detected, then surgical exploration is indicated even if a tumor is not localized by preoperative imaging as these tumors can often be found with careful intraoperative exploration.
- The risk of liver metastases is increased when tumors are larger than 2 cm.[10]
- Patients who present with metastatic disease should undergo resection, if possible, as chemotherapy has limited efficacy in the treatment of gastrinomas. Other modalities, such as radiofrequency ablation, hepatic artery embolization, liver transplantation, and radiolabeled somatostatin therapy, may be considered when anatomic resection is not possible (**FIG 3**).

SURGICAL MANAGEMENT

Positioning

- Patients should be placed in the supine position for exploratory laparotomy to identify gastrinomas.

TECHNIQUES

PLACEMENT OF INCISION

- Either a bilateral subcostal incision or an upper midline incision may be used to approach the duodenum and pancreas for exploration (FIG 4).

Exploration and Kocher Maneuver

- After incision and entry into the peritoneal cavity and initial exploration, the hepatic flexure and ascending colon are mobilized (FIG 5A), the peritoneal reflection

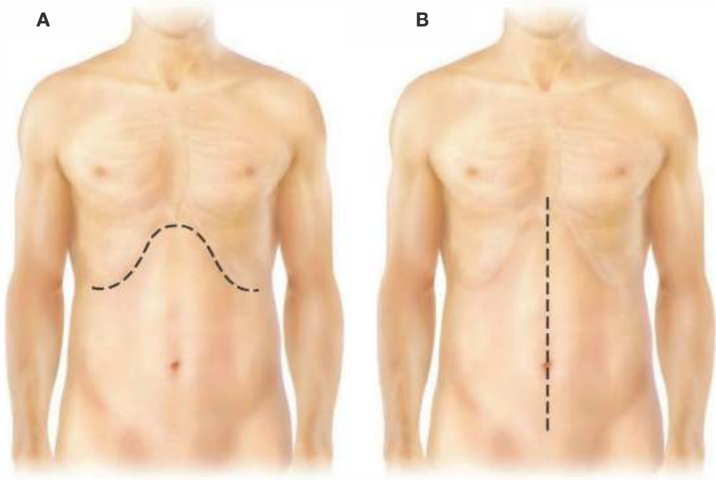


FIG 4 ● Potential incisions for exploration. Bilateral subcostal incisions **(A)** or upper midline incision **(B)** may be used.

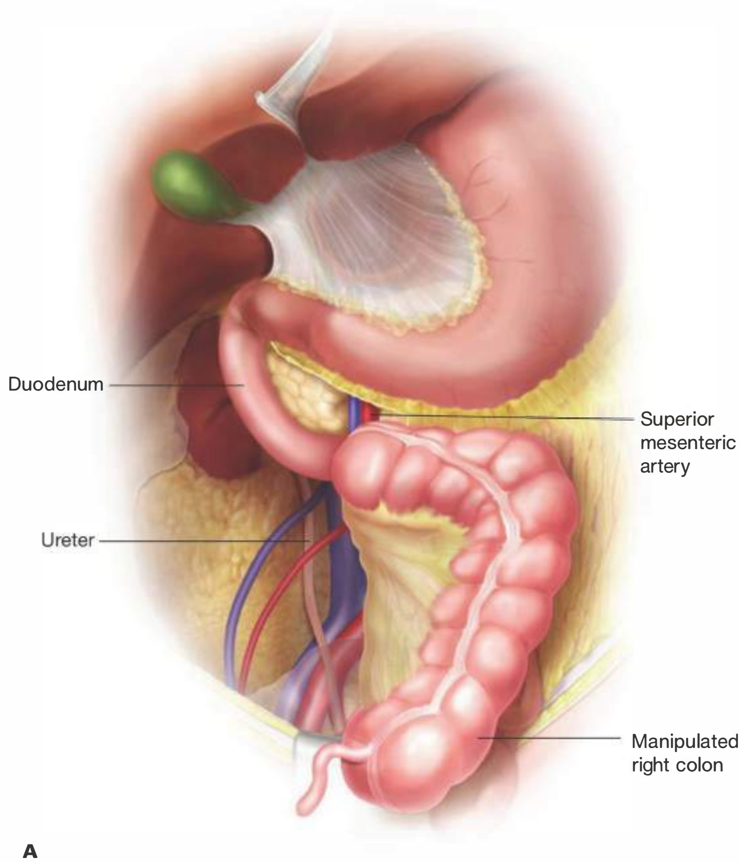


FIG 5 ● Kocher maneuver. An extended Kocher maneuver allows lifting of the pancreatic head out of the retroperitoneum for palpation **(C)** after mobilization of the right colon **(A)** and incision of the peritoneal reflection along the duodenum **(B)**. Separation from the transverse mesocolon allows for complete mobilization of the pancreas and palpation of the pancreatic body and tail **(D)**. *(continued)*

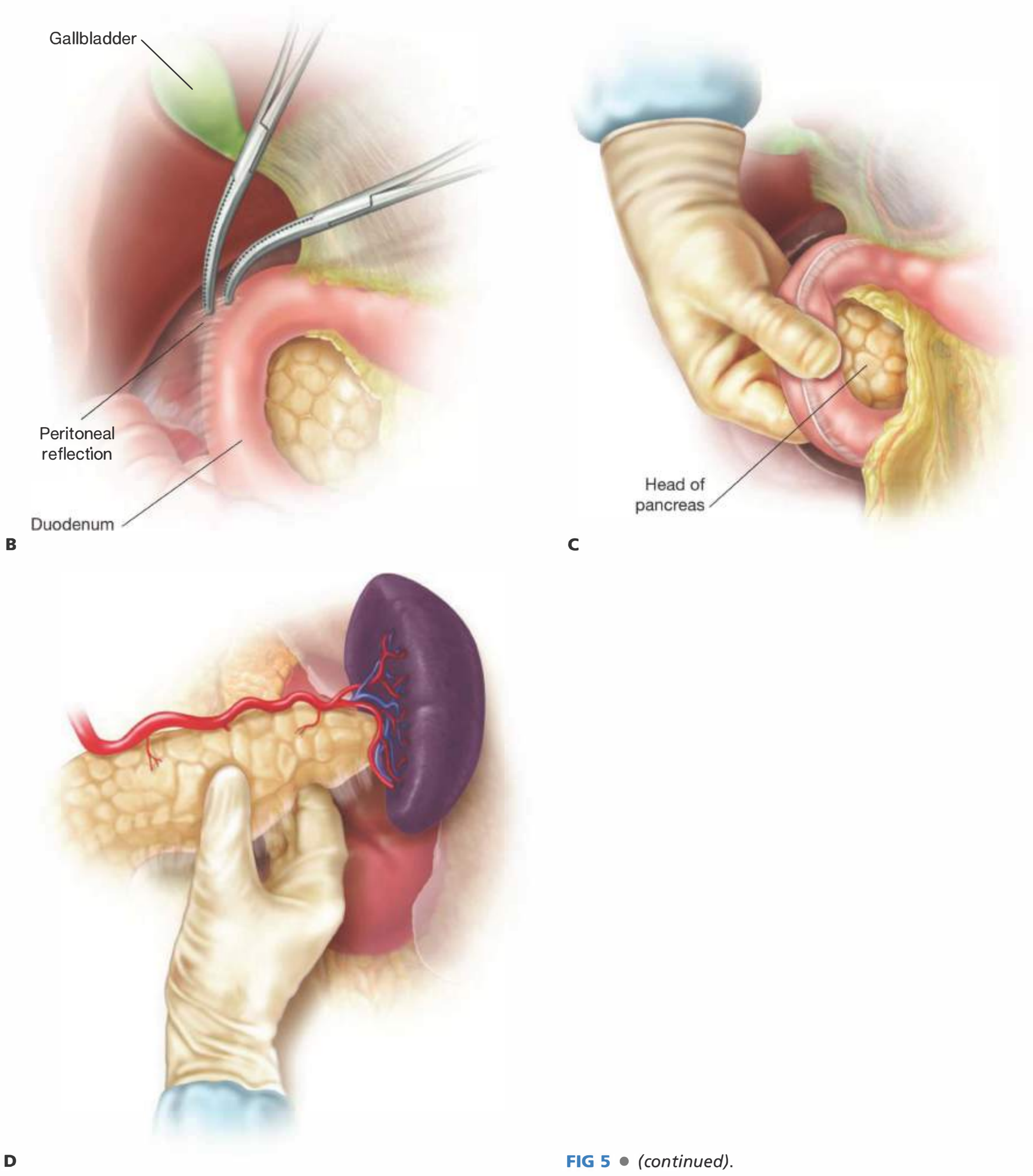


FIG 5 ● *(continued)*.

of the duodenum is incised along the second and third portion of the duodenum, and an extended Kocher maneuver is performed in order to expose and mobilize the duodenum and head of the pancreas (**FIG 5B**).

- After exposure is obtained, the surgeon may palpate the duodenum and pancreatic head. (**FIG 5C**).
- It is important to also palpate the pancreatic body and tail. To accomplish this, the lesser sac is opened and the avascular inferior pancreatic border incised; this can be aided by mobilizing the splenic flexure if necessary. Once exposed, the pancreatic body and tail may be carefully palpated to detect any additional tumors (**FIG 5D**).

Intraoperative Ultrasound

- After mobilization of the duodenum and pancreas and detection of visible and palpable tumors, an ultrasound probe is used to visualize small tumors in the duodenum

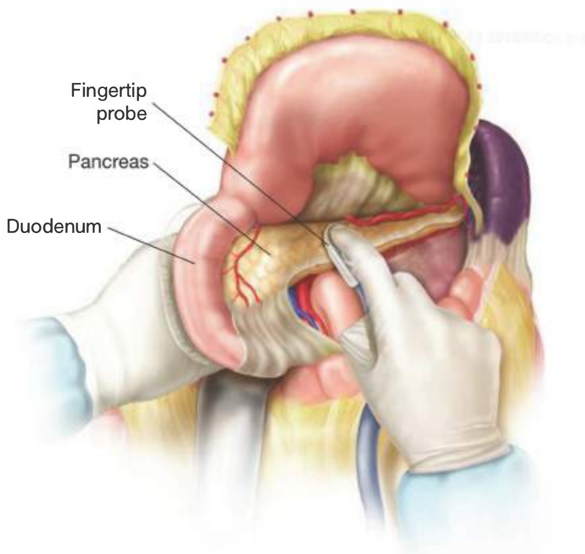


FIG 6 ● Ultrasound examination of the duodenum and pancreas.

and pancreas. The relationship of any tumor to the pancreatic duct should be noted if an enucleation will be performed (**FIG 6**).

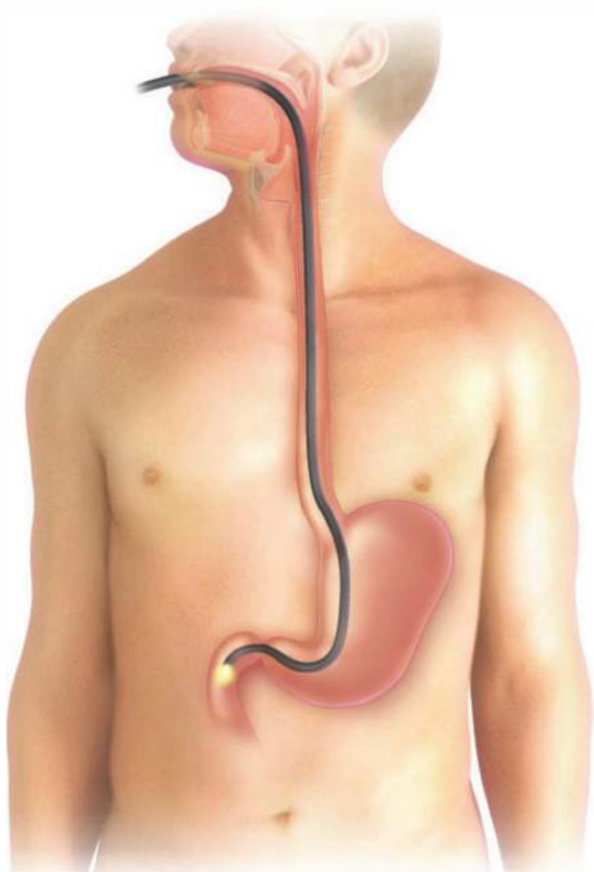
- The type of probe used should be dictated by surgeon experience and preference. We prefer a fingertip transducer in our institution.
- During ultrasound examination, the surgeon's left hand is generally placed posterior to the duodenum and pancreas, while the right hand handles the probe.
- At this time, the liver is also examined for any possible metastatic lesions, and suspicious lesions should be biopsied.

Intraoperative Endoscopy

- Next, a gastroscope is used to perform intraoperative endoscopy. The gastroscope is advanced orally into the stomach and then duodenum where transillumination is used to identify any remaining gastrinomas. These lesions, located in the submucosa of the duodenum, will appear as shadows upon transillumination (**FIG 7**).

Duodenotomy

- A 2- to 3-cm longitudinal duodenotomy is created on the antimesenteric aspect of the second portion of the



A

FIG 7 ● Intraoperative endoscopy. The endoscope is advanced into the duodenum **(A)** where submucosal tumors may be visualized directly **(B)** or through transillumination **(C)**. *(continued)*

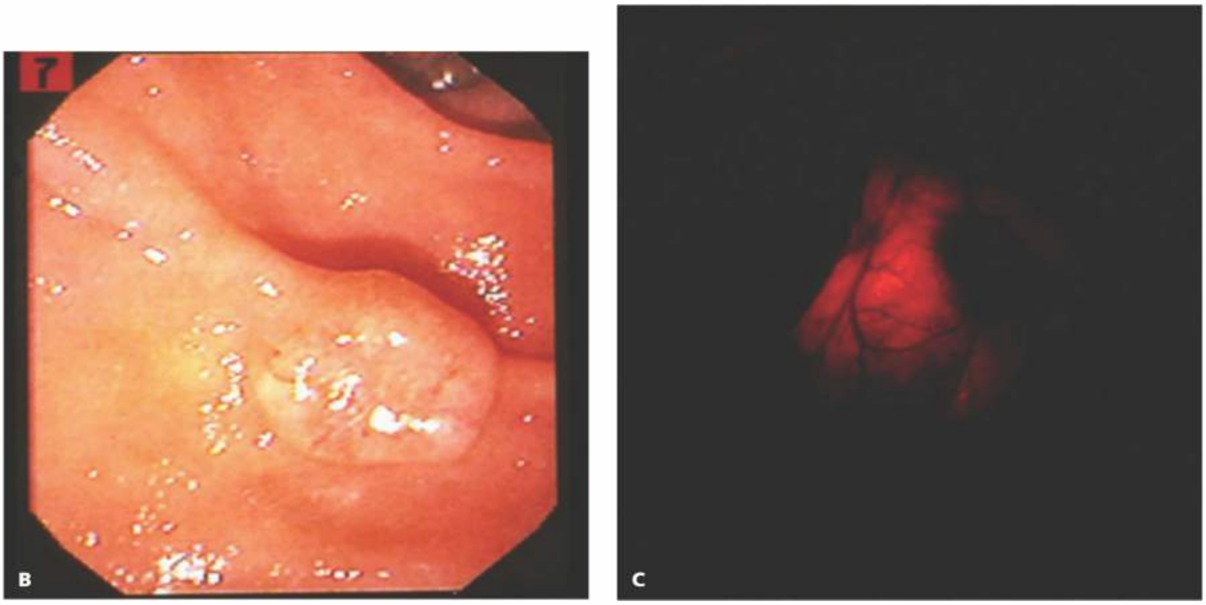


FIG 7 ● *(continued)*.

duodenum. If duodenal lesions were identified during exploration prior to this, then the duodenotomy may be relocated to enable excision of the lesion.

- Once the duodenotomy is made, the duodenal wall is palpated carefully with the index finger and thumb (**FIG 8**).
- The third and fourth portions of the duodenum may be difficult to examine, and so the mucosa can be everted into the duodenotomy using the index finger. This enables direct visualization of all portions of the duodenum (**FIG 9**).
- A full-thickness excision is performed for any duodenal lesion found, and a margin of at least 2 mm should be obtained.
- Lesions found on the medial wall of the duodenum should not be excised until the pancreatic duct and

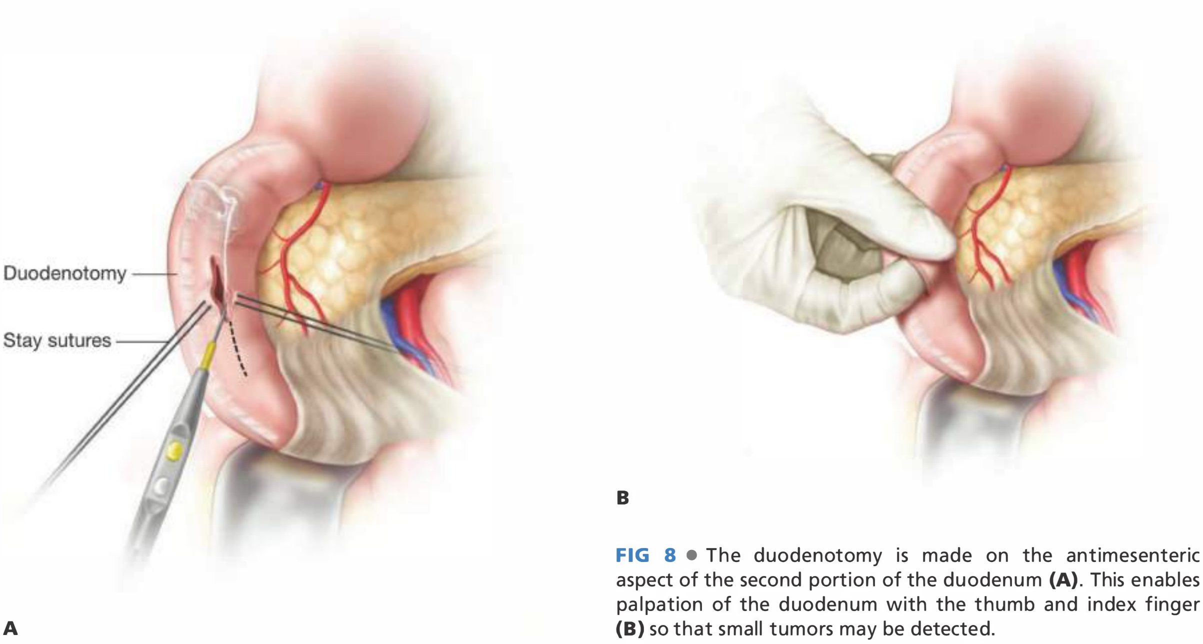


FIG 8 ● The duodenotomy is made on the antimesenteric aspect of the second portion of the duodenum **(A)**. This enables palpation of the duodenum with the thumb and index finger **(B)** so that small tumors may be detected.

ampulla of Vater are identified. This may be aided with use of a small catheter passed through the ampulla.

Excision of Pancreatic Tumors

- Tumors found in the pancreas are managed based on size and location. Tumors found in the head of the pancreas may be enucleated if they are exophytic, but if they are invasive or near the main pancreatic duct, a pancreatico-duodenectomy may be required.
- Tumors found in the distal pancreas require distal pancreatectomy. Splenectomy is not mandated; need for splenectomy is based on the tumor location and suspicion of lymph node metastases. (See Part 3, Chapters 33 to 41 for details of pancreaticoduodenectomy and Part 3, Chapters 40 to 42 for details of distal pancreatectomy.)

Periduodenal Lymph Node Dissection

- A lymph node dissection encompassing the periduodenal and peripancreatic nodes is important as they may contain microscopic metastases or actually represent primary tumors.
- Lymphatic tissues are identified and excised from around the pancreatic head, celiac axis, common hepatic artery, superior mesenteric artery, common bile duct, and portal vein. Lymphadenectomy should begin in the hepatoduodenal ligament and proceed from porta hepatis to celiac axis, followed by excision of all lymph nodes from the anterior and posterior aspects of the pancreatic head (**FIG 10**).
- If a primary tumor is identified, then that region should be paid specific attention as positive lymph nodes are most likely to be found close to the primary tumor.[11]

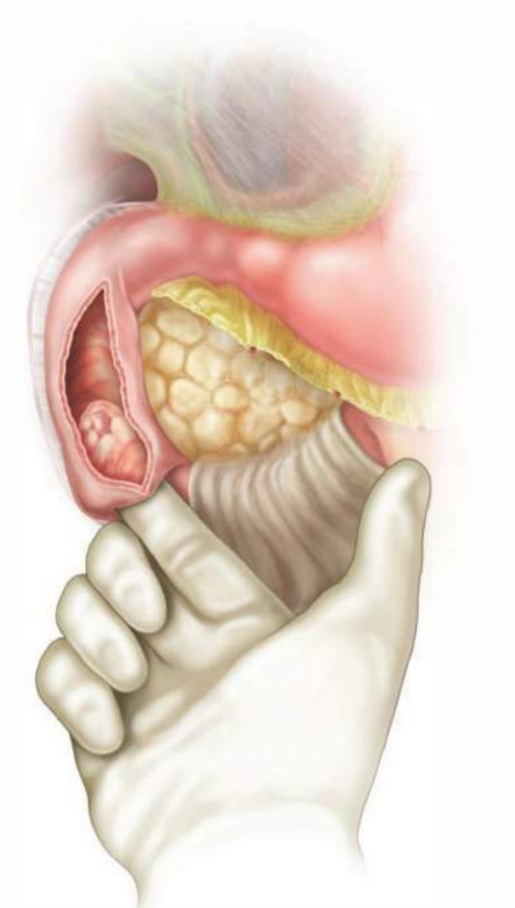


FIG 9 ● Eversion of the mucosa of the third and fourth portions of the duodenum into the duodenotomy.

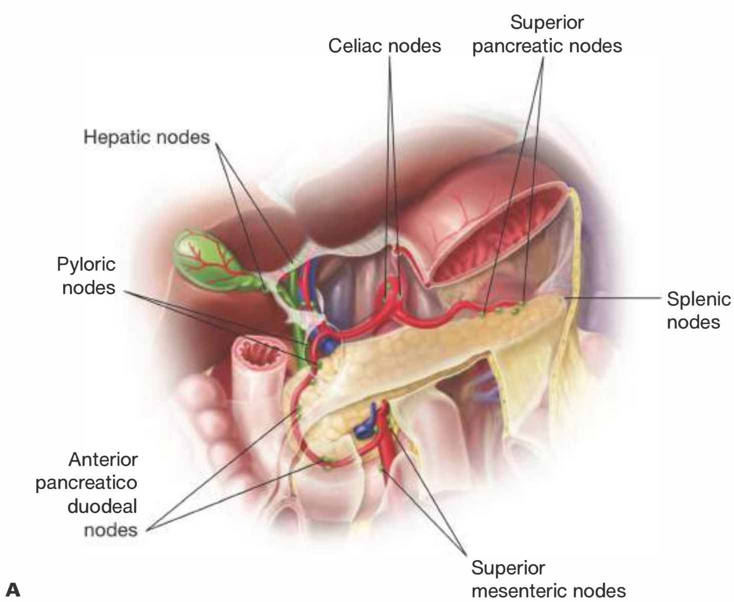


FIG 10 ● Lymphadenectomy for gastrinoma should encompass nodes in the hepatoduodenal ligament, celiac axis and anterior **(A)** as well as posterior **(B)** pancreatic head. *(continued)*

B

FIG 10 ● *(continued)*

Closure of Duodenotomy

- After completion of exploration and excision of gastrinomas, the duodenotomy is closed transversely if possible in order to prevent narrowing of the lumen.
- This is not always possible when a long duodenotomy was required. If this is the case, then a careful longitudinal closure may be used (**FIG 11**).
- The duodenum is closed in two layers. Either interrupted or a running closure may be performed based on surgeon's preference.
- We place a Jackson-Pratt (JP) drain adjacent to the closed duodenotomy in order to monitor output in the postoperative setting. If pancreatic tumors have been enucleated, then an additional drain may be placed overlying the resected lesion.

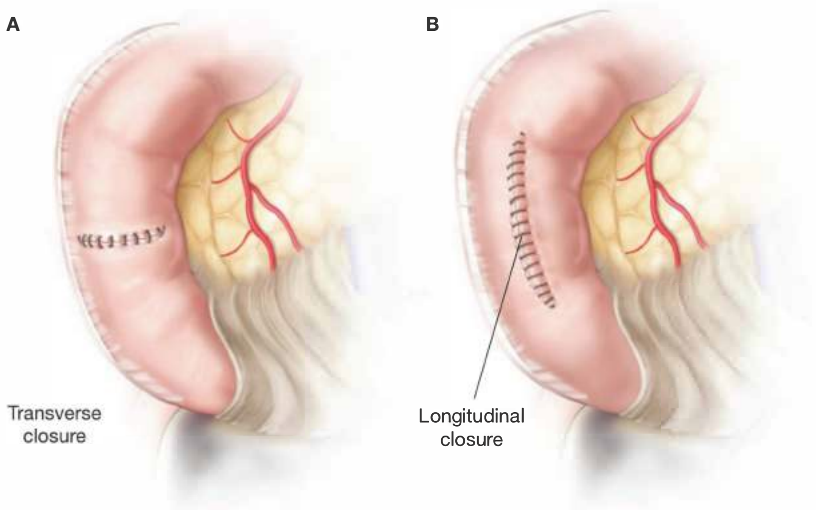


FIG 11 ● A transverse closure of the duodenotomy **(A)** is preferable, but the incision length may make a careful longitudinal closure **(B)** necessary.

PEARLS AND PITFALLS

Operative indications	■ Biochemical diagnosis of sporadic gastrinoma ■ Gastrinoma >2 cm in MEN-1 patients ■ No evidence of unresectable or extensive metastatic disease ■ Reasonable surgical candidate
Surgical exploration	■ Intraoperative ultrasound and endoscopy with transillumination greatly aid detection of tumors. ■ Duodenotomy should be performed in all patients as duodenal tumors are the most frequently missed. ■ Tumors require full-thickness excision with a 2-mm margin. ■ Avoid enucleation of pancreatic tumors if invasive or near main duct; resection is indicated.
Lymphadenectomy	■ Exploration and excision of lymph nodes is crucial.
Closure	■ Close duodenotomy transversely, if possible.

POSTOPERATIVE CARE

- After exploration, the patient should be placed on a surgical floor and be kept NPO until return of bowel function. Drain output should be monitored closely for character and volume until PO intake is resumed. If there is clinical concern of a leak, then a Gastrografin swallow study should be obtained for confirmation. We remove the JP drain when output is less than 50 mL per day and serosanguineous once patient is eating normally.
- Three and 6 months after discharge, patients should return to clinic for history and physical, CT or MRI, and serum fasting gastrin and secretin stimulation tests. Subsequent follow-up should occur every 6 months until 3 years postoperation and should include these same studies. OctreoScan is not recommended for routine surveillance by current National Comprehensive Cancer Network (NCCN) guidelines.[12]

OUTCOMES

- Mortality from this disease is due to metastasis, and it is thought that at least 60% of gastrinomas are malignant. Patients who present with liver metastases have a 10-year overall survival of 30%, whereas patients without liver metastases have a 15-year overall survival of 83%.[13]
- Sporadic disease is potentially curable by surgical exploration. A large series comparing surgical versus medical treatment demonstrated a 41% cure rate at 12 years as well as significantly fewer liver metastases (5% vs. 29%). Disease-related survival at 15 years was 98% with surgical intervention versus 74% with medical treatment.[14]
- Patients with MEN-1 are not typically curable, as only 1% to 6% are disease-free at 5 years.[15] Long-term survival is still possible despite the lack of biochemical cure, and 5-year survival rates of 98% have been reported.[16]

COMPLICATIONS

- Recurrence
- Residual tumor left after exploration
- Duodenal leak
- Pancreatic leak
- Infection (intraabdominal abscess)
- Duodenal stricture

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Chapter 47

Lateral Pancreaticojejunostomy with (Frey) or without (Puestow) Resection of the Pancreatic Head

Kevin E. Behrns Jose G. Trevino

DEFINITION

- Chronic pancreatitis is an inflammatory disease that encompasses a spectrum of morphologic, histologic, and clinical features, which range from subclinical inflammatory changes evident only in histologic specimens to marked morphologic gland destruction accompanied by acinar cell dropout, prominent deposition of fibrous extracellular matrix, and pancreatic duct strictures.

DIFFERENTIAL DIAGNOSIS

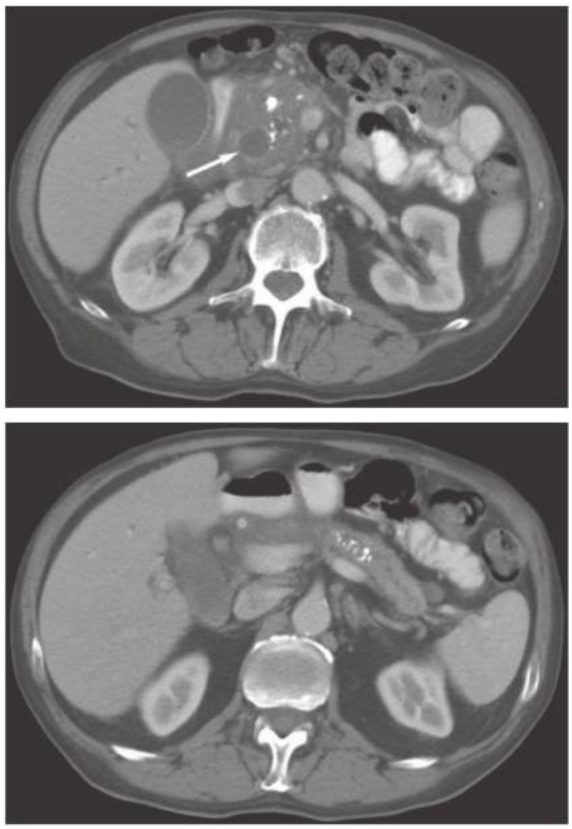
- Acute pancreatitis
- Autoimmune pancreatitis
- Pancreatic adenocarcinoma
- Intraductal papillary mucinous neoplasm (IPMN)

PATIENT HISTORY AND PHYSICAL FINDINGS

- Advanced stages of chronic pancreatitis manifest clinically by disabling pain and pancreatic exocrine and endocrine insufficiency.[1,2] The most prominent etiology of chronic pancreatitis is excess consumption of alcohol.
- Other forms of chronic pancreatitis including autoimmune pancreatitis, paraduodenal pancreatitis, and familial pancreatitis are attributed to genetic mutations.[2–5]
- Differentiating alcoholic chronic pancreatitis from autoimmune pancreatitis, especially focal autoimmune pancreatitis,[6] and adenocarcinoma of the pancreas may require extensive evaluation and prove challenging.[7]
- Important risk factors that exacerbate the development of chronic pancreatitis include alcohol use and smoking cigarettes.[8,9]
- A detailed history of alcohol consumption should be obtained; heavy alcohol use (>5 drinks per day) is present in the majority of patients with chronic pancreatitis.[8,9]
- The pain associated with chronic pancreatitis may be either episodic or persistent.[2] Episodic abdominal pain has a duration of 1 to 2 weeks and is interrupted by pain-free periods of a few months. Persistent pain occurs daily but on occasion may spontaneously resolve for a period of a month or more.[10]
- The weight loss seen in chronic pancreatitis typically occurs over months to years, but it may be more rapid if morphologic changes such as pseudocyst formation induce gastroduodenal obstruction.
- Other complications of chronic pancreatitis include jaundice from biliary obstruction and upper gastrointestinal bleeding from gastric varices secondary to splenic vein obstruction.

IMAGING AND OTHER DIAGNOSTIC STUDIES

- Computed tomography (CT) is the imaging procedure of choice. Intravenous contrast-enhanced, multiplanar, thin-slice CT provides excellent imaging of pancreatic parenchymal and ductal anatomy.[11] CT characteristics of chronic pancreatitis include an enlarged pancreatic head with multiple calcifications and a dilated pancreatic duct distally (**FIG 1**).
- Detection of early-stage disease may be enhanced by magnetic resonance (MR) with cholangiopancreatography (MRCP) with or without secretin administration. Morphologic changes



A

B

FIG 1 ● **A.** CT of the abdomen demonstrating an enlarged head of the pancreas with multiple calcifications indicative of alcoholic chronic pancreatitis. A small pseudocyst is also noted in the head *(arrow)*. **B.** The distal pancreas contains calcifications and a dilated pancreatic duct.

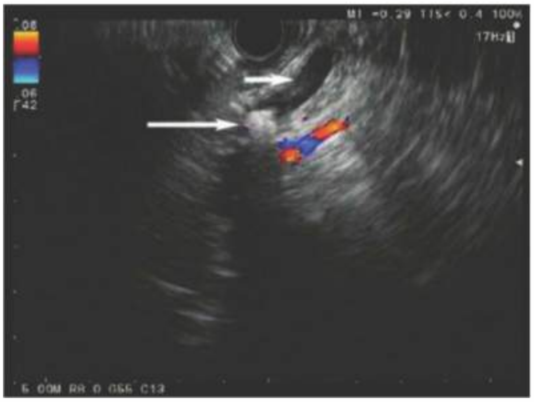


FIG 2 ● Endoscopic ultrasound demonstrating a dilated pancreatic duct *(short arrow)* with a calculus *(long arrow)* in a patient with chronic pancreatitis.

in the pancreatic duct and hydrodynamic-significant strictures may be evident on these images.[12]

- Endoscopic ultrasound (EUS) with or without functional testing by administration of secretin may aid in the diagnosis of early fibrosis in chronic pancreatitis (**FIG 2**). EUS has a sensitivity of 84% and a specificity of 100%, correlating with histology for chronic pancreatitis.[13] Furthermore, EUS is advantageous when mass lesions are present in chronic pancreatitis because EUS-guided biopsy is the most reliable method of confirming malignancy.
- Imaging of the pancreatic duct prior to surgical intervention is essential because all strictures and intraductal calculi must be addressed by the operative approach. Ductal anatomy can be delineated by MRCP or endoscopic retrograde cholangiopancreatography (ERCP). ERCP is often performed in the context of pancreatic duct stenting as endotherapy often precedes operative management.

SURGICAL MANAGEMENT

- Operative management of chronic pancreatitis by lateral pancreaticojejunostomy with or without pancreatic head resection is indicated in patients with disabling abdominal pain, weight loss, and evidence of pancreatic duct obstruction.[14] Morphologic characteristics are associated with outcomes. An excellent response to pancreatic head resection with pancreaticojejunostomy is most likely in the setting of an enlarged head of the pancreas and a distally dilated pancreatic duct.[15]

Table 1: Preoperative Checklist for Patients Undergoing a Frey Procedure

Parameter	Assessment
Alcohol abstinence	Enrollment in substance abuse program with aftercare
Failed medical or endoscopic management	Detailed review of previous medical history
Laboratory evaluation	Blood chemistries, hematologic assessment, liver function tests including coagulation profile, pancreatic function test (fecal fat)
Assessment of pancreatic parenchyma for fluid collections or mass lesions	CT or MRI
Assessment of pancreatic duct	MRCP or ERCP
Assessment of biliary obstruction	Liver chemistries, cholangiogram

CT, computed tomography; MRI, magnetic resonance imaging; MRCP, magnetic resonance with cholangiopancreatography; ERCP, endoscopic retrograde cholangiopancreatography.

Preoperative Planning

- These patients are often afflicted with a chronic disease and have lacked regular medical care, thus a thorough evaluation of the patient prior to pancreatic head resection and duct drainage is essential.
- Patients should be alcohol-free for at least 6 months and enrolled in an alcohol cessation program with aftercare. Ideally, cigarette smoking would also be stopped prior to an operation, although this is difficult for most patients.
- Specific attention should be paid to the nutritional status of patients with chronic pancreatitis because they often meet criteria for severe protein and caloric malnutrition. Fat-soluble vitamin deficiency should also be considered. If malnutrition is evident, a nasojejunal feeding tube should be placed with the delivery of enteral feeds with pancreatic enzyme supplementation prior to operative intervention. Additional protein supplementation may also be necessary. Generally, 2 to 4 weeks of enteral nutrition prior to an operation will place the patient in an anabolic state.
- Table 1 highlights the preoperative checklist of patients who are candidates for a Frey procedure with longitudinal drainage of the pancreatic duct.

Positioning

- The patient is placed on the operating room table in a supine position. Because the risk for blood loss is moderately high, at least two large-bore intravenous cannulas should be established or a central line should be placed. Arterial monitoring is recommended for patients with comorbidities.

TECHNIQUES

EXPOSURE OF THE PANCREAS

- A midline celiotomy is created to allow adequate exposure of the upper abdomen. After a thorough exploration of the abdomen, the pancreas is exposed by elevating the omentum off the transverse colon and pancreatic head back to the origin on the stomach. The hepatic flexure is mobilized as necessary and the duodenum is widely Kocherized. Frequently, the posterior wall of the stomach is adherent to the pancreas and must be dissected free. At the inferior border of the pancreatic neck, the right gastroepiploic vein is circumferentially dissected and divided at the insertion into the superior mesenteric vein (SMV). The distal stomach and proximal duodenum are mobilized from the head of the pancreas to allow adequate exposure for resection of the pancreatic head. The SMV should not be dissected free from the posterior surface of the pancreas for fear of venous injury. These maneuvers should provide wide exposure of the pancreas from the duodenum to the tail of the pancreas (**FIG 3**).

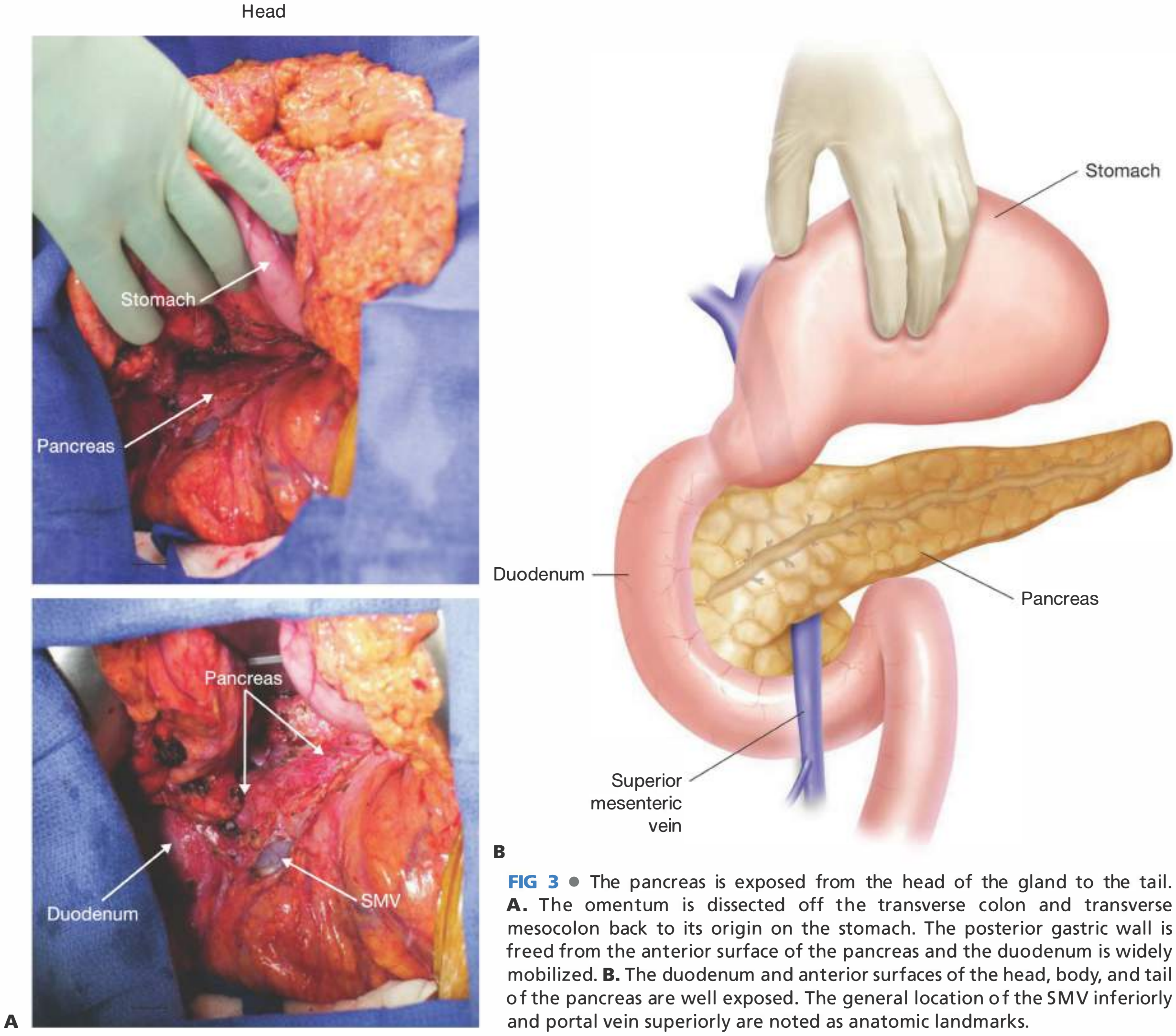
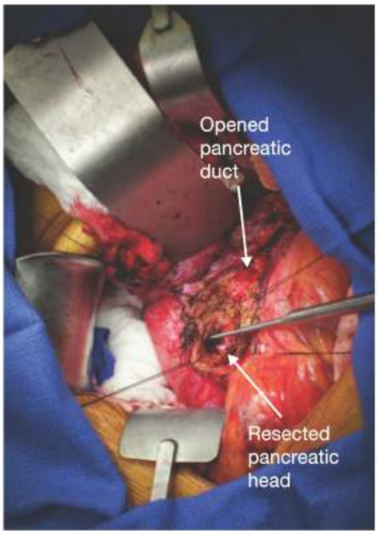


FIG 3 ● The pancreas is exposed from the head of the gland to the tail. **A.** The omentum is dissected off the transverse colon and transverse mesocolon back to its origin on the stomach. The posterior gastric wall is freed from the anterior surface of the pancreas and the duodenum is widely mobilized. **B.** The duodenum and anterior surfaces of the head, body, and tail of the pancreas are well exposed. The general location of the SMV inferiorly and portal vein superiorly are noted as anatomic landmarks.

PANCREATIC HEAD RESECTION

- The gastroduodenal artery is identified at the superior border of the pancreas and ligated with a figure-of-eight 4-0 Prolene suture. The resection of the pancreatic head should be mapped with care to avoid injury to the SMV. The pancreatic head is generously resected, leaving only a thin rim (3 to 5 mm) of tissue along the duodenal wall and posteriorly (**FIG 4**). Usually, the pancreatic duct is evident with excavation of the head, and the duct may be followed distally. Resection of the pancreatic head should not be deeper than the posterior surface of the pancreatic duct. If this plane is not readily apparent, the duct should be identified in the body of the gland (described in the following text) and its course followed proximally to the head of the gland. Bleeding during the pancreatic head resection may be brisk and requires meticulous ligation with 5-0 Prolene sutures. The use of electrocautery to control arterial bleeding should be avoided because this often leads to temporary sealing of the vessel.

A



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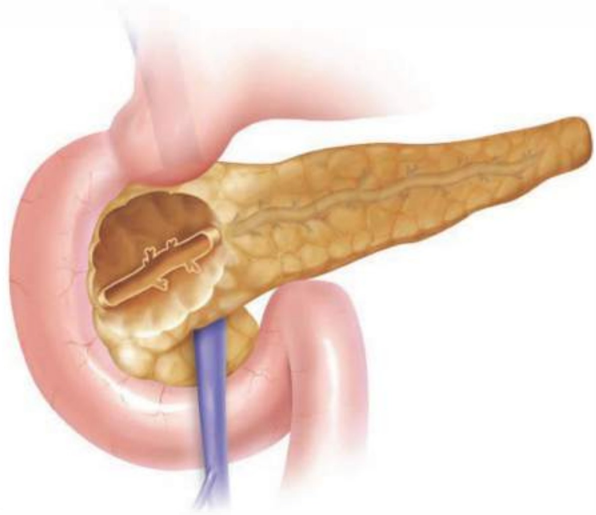
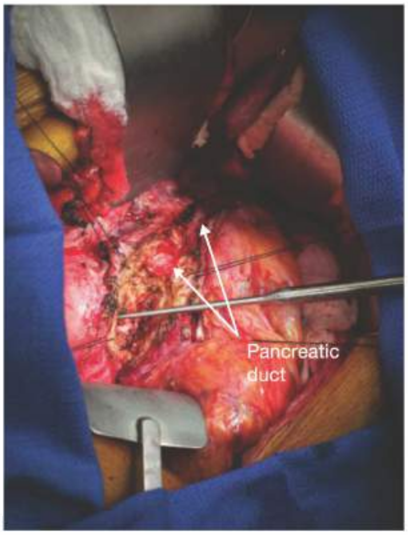


FIG 4 ● The enlarged head of the pancreas is resected, taking care to identify safety landmarks including the SMV, portal vein, and the posterior surface of the pancreatic duct. **A.** The head of the pancreas is resected by outlining the resection bed to the right of the SMV and portal vein. The head is resected deeper in increments such that the pancreatic duct is identified. The resection should not go deeper than the posterior surface of the pancreatic duct. Bleeding should be controlled by suture ligation. All stone material should be removed. The probe identifies the pancreatic duct entering the duodenum. **B.** The drawing demonstrated excavation of the head of the pancreas with important landmarks.

LONGITUDINAL PANCREATIC DUCTOTOMY

- If the pancreatic duct is identified during the pancreatic head resection, it can be followed distally by inserting a probe into the duct and cutting down on the probe with cautery. However, extensive fibrosis with ductal strictures may prevent identification of the duct in the head of the gland or preclude proximal tracing of the duct. If the duct cannot be identified or traced, it can often be accessed well to the left of the SMV. Care should be taken not to identify the duct over the SMV–splenic vein confluence. Once the duct is identified distally, it should be opened from the tail of the pancreas to the junction of the pancreatic head and duodenum (**FIG 5**). All pancreatic stones should be removed unless extraction of the stone would cause substantial parenchymal damage.

A



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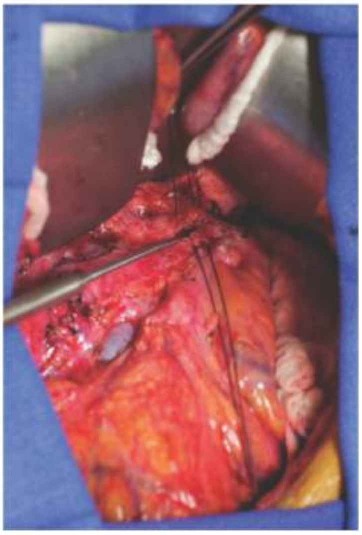
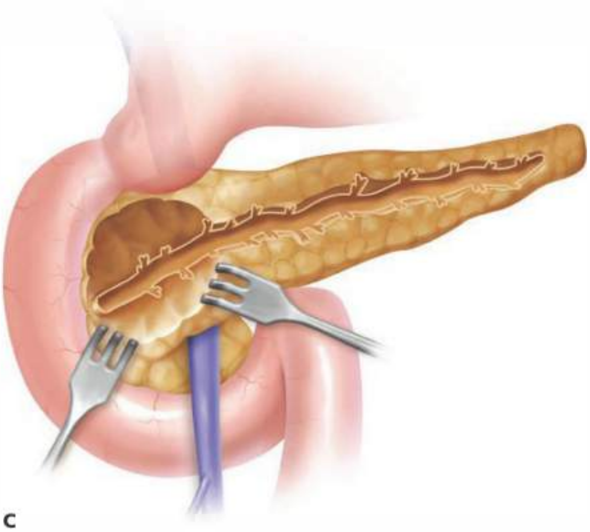


FIG 5 ● The pancreatic duct is opened from the head of the pancreas to the tail. **A.** Once the pancreatic head is resected, the pancreatic duct can be followed distally and opened over a probe until the duct is opened out to the tail of the gland. **B.** If the pancreatic duct cannot be identified in the head of the gland, a dilated duct can be opened to the left of the SMV in the tail of the gland and followed distally to the pancreatic head resection. *(continued)*



C

FIG 5 ● *(continued)* **C.** The drawing demonstrates the pancreatic duct opened from the duodenum to the head of the gland.

INTRAPANCREATIC BILIARY SPHINCTEROPLASTY

- Patients with biliary stricture are candidates for an intrapancreatic biliary sphincteroplasty, which is accomplished by identifying the bile duct along the duodenal wall in the depths of the excavated pancreatic head. This portion of the procedure is markedly aided by preoperative biliary stent placement. The intrapancreatic bile duct can be palpated by transduodenal compression on the biliary stent. The bile duct is opened over the stent with the longitudinal bile ductotomy extending up to the entrance of the bile duct into the pancreas. The stent is removed and not replaced. Once opened, the bile duct should accept at least a 6- to 8-mm probe. The bile duct is then circumferentially sewn with interrupted 6-0 polydioxanone (PDS) sutures to the surrounding pancreatic parenchyma such that the bile duct is widely opened (**FIG 6**).

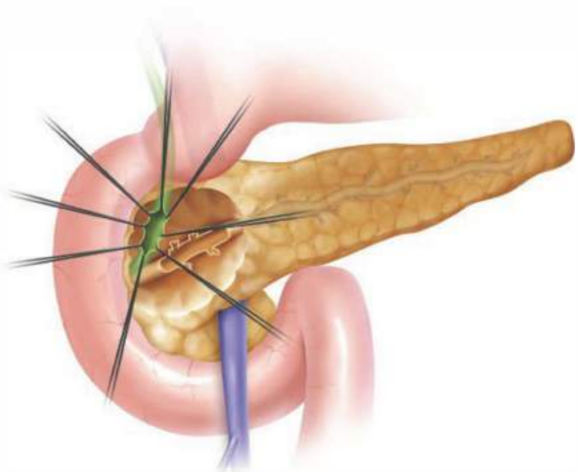
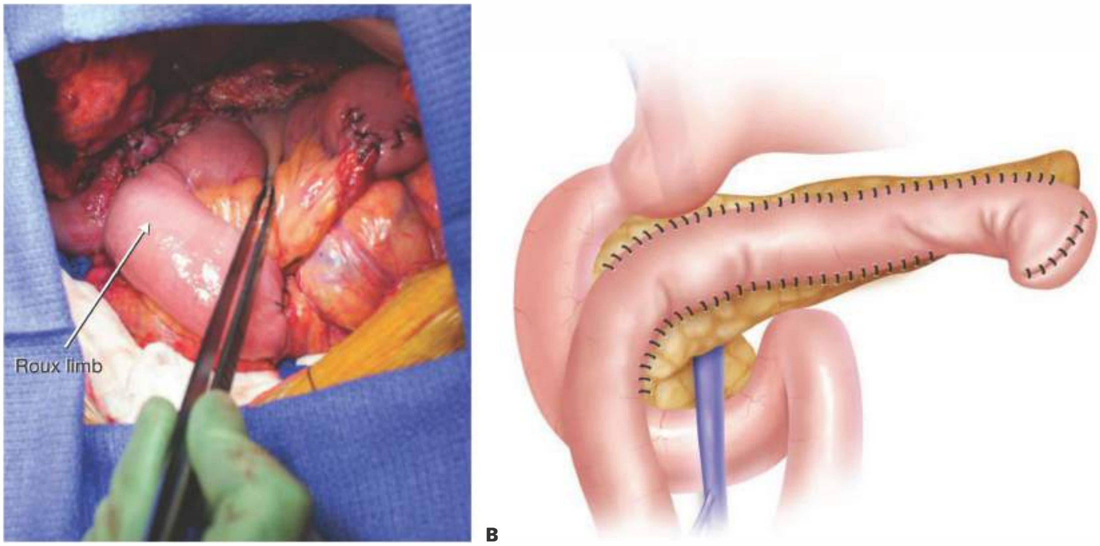


FIG 6 ● An intrapancreatic biliary sphincteroplasty may be performed in patients with a bile duct stricture. A longitudinal bile ductotomy is performed. The bile duct should be opened superiorly to its entrance in the pancreas. The bile is secured circumferentially to the pancreas with interrupted 6-0 PDS sutures. The bile duct should accept a probe of 6 to 8 mm in diameter.

TECHNIQUES

ROUX-EN-Y PANCREATICOJEJUNOSTOMY

- A Roux-en-Y limb of jejunum is prepared by dividing the jejunum 15 to 30 cm distal to the ligament of Treitz. The mesentery is transected back toward its origin by dividing bridging vessels. The Roux-en-Y limb is delivered to the pancreas in a retrocolic position to the right of the middle colic vasculature. The divided end of the jejunum is oriented to the tail of the pancreas, and a two-layer side-to-side pancreaticojejunostomy is created with running 4-0 Prolene sutures (FIG 7). The epithelium of the pancreatic duct need not be incorporated with the inner layer of suturing. The jejunum should be opened in increments to avoid the creation of an overly long jejunotomy. A jejunojejunostomy is created 40 to 50 cm distal to the pancreaticojejunostomy to reestablish intestinal continuity.



A B

FIG 7 ● **A.** A Roux-en-Y limb is delivered to the pancreas in retrocolic fashion to the right of the middle colic vein. The limb is sewn to the pancreas in two layers with running 4-0 Prolene. **B.** The drawing demonstrates the completed side-to-side pancreatojejunostomy.

PLACEMENT OF A FEEDING JEJUNOSTOMY

- A feeding jejunostomy is appropriate in malnourished patients. A red rubber catheter or alternative device is placed approximately 30 cm distal to the jejunojejunostomy. The tube may be placed by imbricating the tube to create a tunnel, and the tube should be tacked to the abdominal wall in four-quadrant fashion. Two closed suction drains are placed at the superior and inferior aspects of the pancreaticojejunostomy, and the abdomen is closed.

PEARLS AND PITFALLS

Patient selection	■ Alcohol abstinence, chronic pain management ■ Optimum outcomes are observed in patients with an enlarged head of the pancreas and dilated pancreatic duct.
Pancreatic head resection	■ Ligate the gastroduodenal artery first. ■ Perform a generous resection leaving only thin (3–5 mm) rim of pancreatic tissue. ■ Dissection of the superior mesenteric vein should be avoided. ■ Suture ligation, not cauterization, of bleeding vessels
Pancreatic ductotomy	■ Ductotomy should extend from duodenum to the far tail of pancreas.
Intrapancreatic biliary sphincteroplasty	■ Assess biliary obstruction; place a biliary stent preoperatively if intrapancreatic biliary sphincteroplasty is anticipated.
Pancreaticojejunostomy	■ Open the jejunum incrementally to avoid an overly large jejunotomy.

POSTOPERATIVE CARE

- Because of the risk of postoperative bleeding, the patient should be admitted to a monitored setting. The initial 24 to 48 hours require close observation for hemorrhage. If hemorrhage occurs, a CT arteriogram should be obtained to look for blood in the gastrointestinal lumen versus intraabdominal hemorrhage. Bleeding into the gastrointestinal tract will require an operative approach, whereas intraabdominal bleeding may be treated by angioembolization.
- Oftentimes the exposure of the pancreas requires dissection of chronically inflamed adhesions and, therefore, the fluid requirements postoperatively may be high; close monitoring of the urine output is required.
- Early initiation of postoperative enteral nutrition is necessary because most of these patients are malnourished with low protein stores.

OUTCOMES

- A randomized trial comparing endoscopic therapy with stents to surgical drainage confirmed superior results for surgical treatment.[16] Patients treated with pancreatic drainage procedures had better pain control, and 47% of patients initially managed by endoscopic therapy ultimately required surgery.
- Operative treatment of chronic pancreatitis may include resection with standard or pylorus-preserving pancreatoduodenectomy or a drainage procedure such as the Frey procedure. The merits of each of these operations have been debated, but a randomized, prospective trial demonstrated that the Frey operation was associated with better short-term outcomes, although the procedures were equivalent in terms of pain control and pancreatic function in long-term analysis.[17]
- Table 2 summarizes the results of patients undergoing the Frey procedure.

COMPLICATIONS

- Postoperative hemorrhage
- Pancreatic fistula is distinctly uncommon.
- Delayed gastric emptying

Table 2: Outcomes following Local Pancreatic Head Resection with Longitudinal Pancreaticojejunostomy

Parameter	Frequency (%)
Reintervention required	8
Exocrine insufficiency	86
Endocrine insufficiency	61
Return to work	42
Continued alcohol consumption	21

Adapted from Strate T, Bachmann K, Busch P, et al. Resection vs drainage in treatment of chronic pancreatitis: long-term results of a randomized trial. Gastroenterology. *2008;134:1406–1411.*

Table 3: Complications following Local Pancreatic Head Resection with Longitudinal Pancreaticojejunostomy[a]

Complication	Frequency (%)
Major complications	23
Biliary stricture	11
Pancreatic fistula	7

[a]*Unpublished data from the authors' experience.*

- Table 3 includes the anticipated frequency of other complications, which may occur following pancreatic head resection and lateral pancreaticojejunostomy.

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Chapter 48

Enteric Drainage of Pancreatic Pseudocysts: Pancreatic Cyst Gastrostomy and Cyst Jejunostomy

Kenneth K. W. Lee

DEFINITIONS

- Collections of fluid or solid material may arise from episodes of acute pancreatitis. Although frequently referred to collectively as pancreatic pseudocysts, the 2012 revision of the Atlanta classification of acute pancreatitis distinguishes among several types of local collections that arise in acute pancreatitis based on their pathogenesis and imaging characteristics.[1] An understanding of these different collections is important as their management differs.
  - **Acute peripancreatic fluid collections** (APFCs) (**FIG 1A,B**) arise early in the course of interstitial edematous acute pancreatitis. APFCs lack a wall, are confined by fascial planes, and rarely require intervention as the risk of complications such as infection is very low and they usually resolve spontaneously (**FIG 2A,B**).
  - APFCs that fail to resolve may become **pancreatic pseudocysts** with well-defined walls. **Pancreatic pseudocysts** (**FIG 3A**) are encapsulated, well-defined peripancreatic or intrapancreatic fluid collections that arise from focal disruption of the pancreatic ductal system in the setting of acute or chronic pancreatitis or trauma. In contrast to cystic neoplasms of the pancreas, pseudocysts lack true epithelial walls and instead have walls composed of fibrous tissue containing histiocytes, giant cells, granulation tissue, and rarely eosinophils. The fluid within a pseudocyst is characteristically amylase rich as it arises from disruption of the pancreatic ductal system. The 2012 revision of the Atlanta classification of acute pancreatitis also emphasizes that pseudocysts are not associated with detectable amounts of pancreatic or peripancreatic necrosis and do not contain a solid component. Magnetic resonance imaging (**FIG 3B**) or ultrasound may be useful for identification of solid material not distinguishable on computed tomography.

A

B

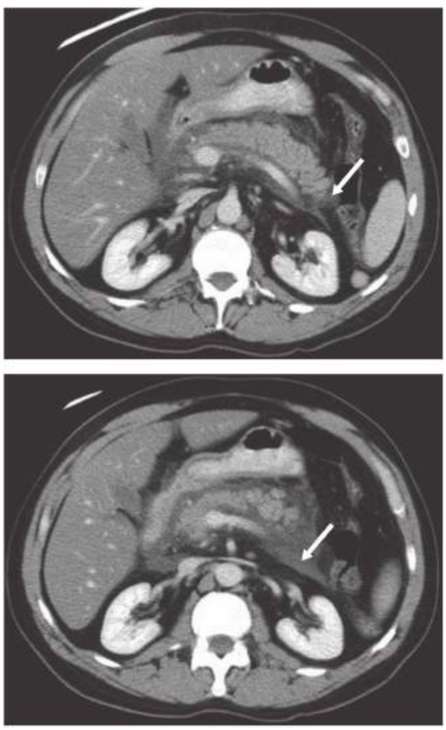


FIG 1 ● Acute peripancreatic fluid collection. **A.** The pancreas appears edematous with small amounts of fluid surrounding it. **B.** Peripancreatic fluid tracks laterally anterior to the kidney but remains confined by fascial planes.

A

B

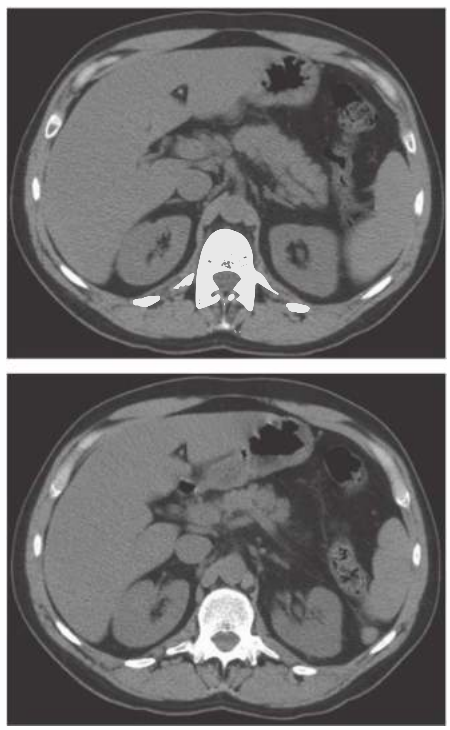
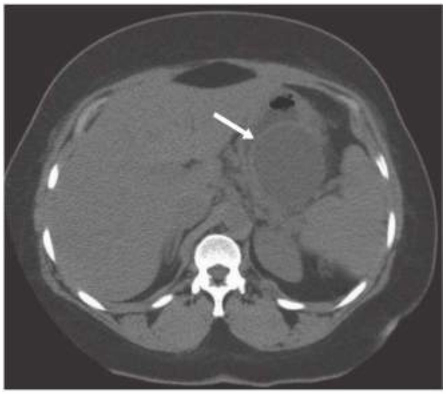


FIG 2 ● **A,B.** Acute peripancreatic fluid collection. The acute fluid collections are resolved 3 weeks later.



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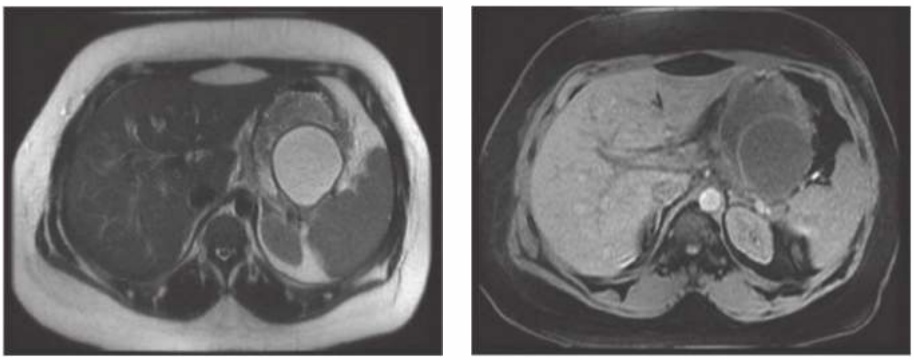
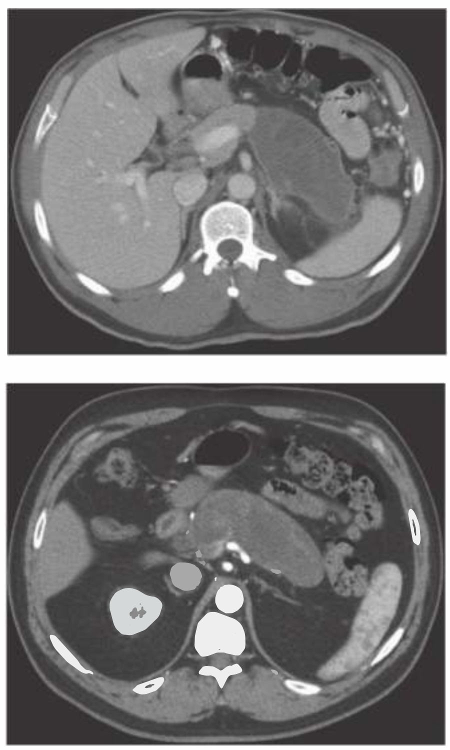


B

FIG 3 ● Pancreatic pseudocyst. **A.** A homogeneous fluid collection is surrounded by a discrete wall that is apparent despite the absence of intravenous contrast. **B.** Magnetic resonance imaging confirms the absence of solid material (necrotic debris) within the pseudocyst.

- In contrast to APFCs and pancreatic pseudocysts, acute necrotizing pancreatitis is defined by the presence of pancreatic and/or peripancreatic tissue necrosis. In the early stages of acute necrotizing pancreatitis, the necrotic tissue is described as an **acute necrotic collection** (ANC) (**FIG 4**). Such collections may additionally contain fluid leaking from the pancreatic duct or resulting from liquefaction of necrotic tissue. The natural history of ANCs is variable. Such collections may persist or absorb, remain solid or liquefy, remain sterile or become infected.
- Fibrous walls form around necrotic collections that are not reabsorbed or do not require early surgical debridement. As with acute necrotic collections, areas of **walled-off necrosis** (WON) (**FIG 5**) may contain fluid in addition to solid material.

FIG 4 ● Acute necrotic collection. Areas of pancreatic and peripancreatic necrosis surround portions of viable (enhancing) pancreas.



A

B

FIG 5 ● **A,B.** Walled-off necrosis.

- Although the pathogenesis and contents of WON differ from pancreatic pseudocysts, their management is similar to pseudocysts, particularly if communication with the pancreatic ductal system is suspected.

DIFFERENTIAL DIAGNOSIS

- **Pancreatic pseudocyst**
- **Walled-off necrosis**
- **Pancreatic cystic neoplasms** possess a true epithelial lining and thereby differ from pseudocysts that are lined by fibrous tissue (see earlier discussion). Cystic neoplasms primarily fall into two categories. **Microcystic cystadenomas** contain serous fluid and carry minimal if any risk of malignant transformation. Treatment by means of surgical resection is reserved for those that are symptomatic. **Macrocystic cystadenomas** contain mucinous material, are characterized by the presence of ovarian stroma, and have the potential for malignant transformation. Surgical resection is therefore usually recommended for such lesions.
- **Neoplasms with cystic morphology. Adenocarcinomas** of the pancreas may have cystic components. Areas of tumor necrosis, for example, may liquefy and appear cystic on imaging studies. Pancreatic ductal adenocarcinomas may also cause proximal ductal obstruction that may resemble cysts in the pancreas. **Pancreatic endocrine tumors** may also occasionally be predominantly cystic.
- **Intraductal papillary mucinous neoplasms** may arise in the main pancreatic duct or in side branch ducts and on imaging appear as solitary or multiple pancreatic cysts.
- Other benign cystic abnormalities include **lymphoepithelial cysts** and **inclusion cysts**. If diagnosed, treatment is reserved for those that are symptomatic. **Mucinous cysts** that do not contain ovarian stroma and do not appear to have potential for malignant transformation may also occur in the pancreas. Differentiation of such benign mucinous cysts from mucinous cystadenomas may be difficult.

EVALUATION

History and Physical Examination

- A thorough medical history must be taken to confirm **a history of acute pancreatitis**, or less commonly, pancreatic trauma. In the absence of such a history, the diagnosis of a pancreatic pseudocyst should be questioned, and the diagnosis of a neoplasm should be considered. As several weeks are required for a pseudocyst to form, the diagnosis of a pseudocyst should also be questioned if the clinical history of acute pancreatitis or pancreatic trauma is very recent and a cystic abnormality with an already well-formed wall is seen.
- The history should also attempt to identify the etiology of the patient's pancreatitis, as treatment of the etiology (e.g., cholecystectomy, lipid- and triglyceride-lowering medications, abstinence from alcohol consumption) should be considered.
- Symptoms potentially attributable to a pseudocyst should be elicited. Most frequently, these will include abdominal or back pain, abdominal pressure or fullness, early satiety, nausea, vomiting, or obstructive symptoms. If a complication of the pseudocyst such as infection, bleeding, or rupture has occurred, symptoms relating to the complication such as fever, light-headedness, or diffuse abdominal pain may also be present.
- The general medical history and overall health of the patient are important in determining the manner of treatment appropriate for the patient. Past surgical history should be reviewed with particular emphasis on prior operations on the stomach or small intestine and incisions that may impact on laparoscopic or open access to the abdomen.
- An abdominal mass or fullness should be sought on physical exam, and if found, its location should be noted in planning subsequent surgical procedures. Abdominal surgical scars should also be noted.

IMAGING AND OTHER DIAGNOSTIC STUDIES

- The presence and location of cystic changes of the pancreas are best determined by means of contrast-enhanced **computer tomography** (CT) or **magnetic resonance imaging** (MRI). The imaging characteristics on these studies may help to differentiate among the various types of cystic pancreatic abnormalities listed earlier. Cross-sectional imaging also demonstrates the relationship of the cyst to the stomach and other structures as well as the thickness of the cyst wall and thereby aids in treatment planning.
- Pancreatic ductal abnormalities that may influence treatment decisions can be identified by means of **magnetic resonance cholangiopancreatography** (MRCP) or **endoscopic retrograde pancreatography** (ERP). MRCP is preferred as it is noninvasive, usually does not require patient sedation, and avoids the risks of procedure-induced pancreatitis or infection of fluid collections in communication with the pancreatic duct.
- If the clinical history and imaging findings are not sufficient to determine the specific type of cystic abnormality and in particular to exclude the diagnosis of a neoplastic cyst with potential for malignant transformation, further imaging by means of **endoscopic ultrasound** (EUS) can be performed. Under EUS guidance, fine needle aspiration of the cyst contents and cyst wall can be performed to obtain samples for biochemical and pathologic analysis. EUS can also identify solid material within the cyst and assess the thickness of the cyst wall.
- ERP is not routinely performed for evaluation of pseudocysts, but in selected cases may be performed to evaluate ductal anatomy when MRCP cannot be performed or is inconclusive. Because of the potential for introducing infection into a sterile pseudocyst, ERP should be limited to patients selected for treatment (see the following text) and should be performed shortly before treatment.
- Although the pathogenesis and pathology of pancreatic pseudocysts and WON differ, their management is similar and therefore differentiating between pseudocysts and WON is not always required. In the discussion that follows, the term pseudocyst is used to describe both pseudocysts and WON as defined in the 2012 revision of the Atlanta classification of acute pancreatitis.

SURGICAL MANAGEMENT

Indications for Treatment

- Treatment should be considered for symptomatic pseudocysts or enlarging pseudocysts.
- Emergency treatment of complications such as infection, rupture, or bleeding into the pseudocyst may be required.

- Small, asymptomatic, nonenlarging pseudocysts do not require treatment as the risk of developing acute complications is low. However, as the risk of complications arising in large asymptomatic, nonenlarging pseudocysts is uncertain and may be larger, treatment of such large pseudocysts can be considered.
- Treatment should be considered if the diagnosis of a neoplasm with malignant potential cannot be excluded.

Treatment Options

- Surgical resection can be performed for removal of a pseudocyst.
- External drainage may be achieved by percutaneous or surgical means.
- Internal drainage of a pseudocyst creates a communication between the pseudocyst and the gastrointestinal tract.
  - Drainage into the stomach is achieved by creating a communication between the posterior wall of the stomach and a pseudocyst known as a **cyst gastrostomy**. This may be achieved by endoscopic means, surgical means, or a hybrid combination of these methods. The anastomosis can be fashioned within the stomach via an anterior gastrotomy, outside the stomach via the lesser sac, or within the stomach via endolaparoscopic means.
  - Drainage into the small intestine is achieved by surgical creation of an anastomosis between a defunctionalized segment of the small intestine (Roux limb) and a pseudocyst known as **a cyst jejunostomy**.
  - Pseudocysts arising in the head of the pancreas are infrequently drained by creation of an anastomosis between the descending duodenum and the pseudocyst known as a **cyst duodenostomy**.

Choice of Procedure

- Surgical resection should be considered when the diagnosis of a cystic-appearing neoplasm such as a mucinous cystadenoma cannot be excluded or selectively by means of a distal (left) pancreatectomy for a pseudocyst or WON involving the tail of the pancreas. Distal (left) pancreatectomy is discussed elsewhere in this text. Because of the greater morbidity and mortality of a pancreaticoduodenectomy (Whipple procedure), resection should not be considered for pseudocysts in the head of the pancreas.
- As pseudocysts arise as a result of disruption of the pancreatic ductal system and WON is also commonly associated with pancreatic duct disruption, external (percutaneous) drainage of pseudocysts or WON may give rise to a pancreatic fistula. Therefore, when treatment is necessary, internal drainage into the gastrointestinal tract is preferred. However, external drainage may be preferred if treatment of the pseudocyst is required before a wall suitable for construction of an anastomosis has formed. Temporary relief of symptoms may be achieved by large volume fine needle aspiration. Infection of an evolving pseudocyst is treated by placement of a drainage catheter. External drainage may also be considered if internal drainage does not appear safe for treatment of acute complications such as pseudocyst rupture or infection that arise in mature pseudocysts.
- Surgical drainage is most commonly performed into either the stomach or the small intestine. Cystojejunostomies have a lower incidence of pseudocyst recurrence and perioperative bleeding compared to cystogastrostomies but require creation of a Roux limb and an intestinal anastomosis (see below). Additionally, pseudocyst recurrence after creation of a cyst gastrostomy may be amenable to endoscopic treatment. Therefore, if the stomach suitably abuts the pseudocyst, a cyst gastrostomy is usually created. Otherwise, a Roux-en-Y cyst jejunostomy is created.
- Endoscopic cyst gastrostomy (discussed in detail elsewhere in this text) is especially well suited for treatment of true pseudocysts containing only fluid and no necrotic tissue.
- Open and minimally invasive (laparoscopic or robot-assisted) techniques of creating cystogastrostomies and Roux-en-Y cystojejunostomies are fundamentally identical.

Preoperative Preparation

- Patients should be prepared in routine fashion for major abdominal surgery.
- Comorbidities such as hypertension and cardiopulmonary disease should be optimized.
- Patients should be evaluated and treated for pancreatic endocrine and exocrine insufficiency.
- Coagulation disorders if present should be corrected.
- Routine antibiotic and thromboembolic prophylaxis should be administered.
- In malnourished patients, surgery should be delayed and preoperative nutritional support should be given when possible. Enteral nutrition is preferred but may not be possible due to the mass effects of the pseudocyst.

Positioning

- For either open or minimally invasive procedures, the patient is placed in a supine position. Arms may either be tucked or extended outward.
- Table-mounted retractors are used as needed for open procedures.

DESCRIPTION OF PROCEDURES

- Gastric drainage procedures
  - Transgastric cyst gastrostomy
  - Extragastric cyst gastrostomy
  - Intragastric cyst gastrostomy
- Jejunal drainage procedure
  - Roux-en-Y cyst jejunostomy

TECHNIQUES

TRANSGASTRIC CYST GASTROSTOMY

- A midline incision provides excellent exposure for **open transgastric cyst gastrostomies**. Palpation of the abdomen after induction of anesthesia and review of the patient's preoperative imaging studies will guide placement of the incision.
- A wound protector is placed, thorough exploration of the abdomen is performed, and the fullness posterior to the stomach caused by the pseudocyst is palpated and localized. If necessary, the pseudocyst can be further localized using ultrasound (**FIG 6**).
- Port placement for **minimally invasive transgastric cyst gastrostomy** will vary according to the size and position of the pseudocyst. In general, however, one midabdominal 5-mm port, two right upper abdominal 5-mm ports, and two left upper abdominal 5-mm ports will suffice. These ports are upsized as necessary for insertion of staplers and ultrasound probes.
- Stay sutures are placed over the epicenter of this fullness (**FIG 7**), and a longitudinal anterior gastrotomy is made using electrocautery (**FIG 8**). This incision should be centered between the lesser and greater curvatures of the stomach to facilitate subsequent closure of the anterior gastrotomy. The anterior gastric wall is usually mobile and, consequently, the anterior gastrotomy can usually be made short. The longitudinal orientation of the gastrotomy allows it to be lengthened proximally or distally, if needed.
- Through the posterior wall of the stomach, the pseudocyst is palpated. The location of the pseudocyst can be confirmed by means of intraoperative ultrasound (**FIG 9**) or passage of a needle through the posterior wall of the stomach into the pseudocyst and aspiration of fluid from the pseudocyst (**FIG 10**). Both measures also provide an estimate of the distance between the stomach and the pseudocyst cavity. Fluid obtained by aspiration can be sent for biochemical, microbiologic, cytologic, and pathologic studies as indicated.
- The pseudocyst is entered through the posterior wall of the stomach using electrocautery at the site determined

FIG 6 ● Ultrasound can be used to localize the pseudocyst and assist in positioning of the anterior gastrostomy (laparoscopic cyst gastrostomy).

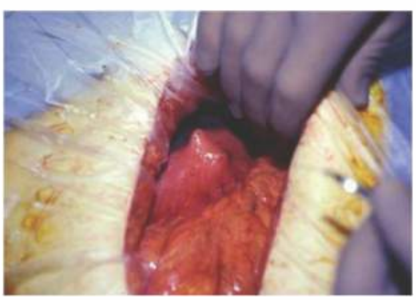


FIG 7 ● Stay sutures placed into the anterior wall of the stomach may facilitate creation of the anterior gastrostomy (open cyst gastrostomy).

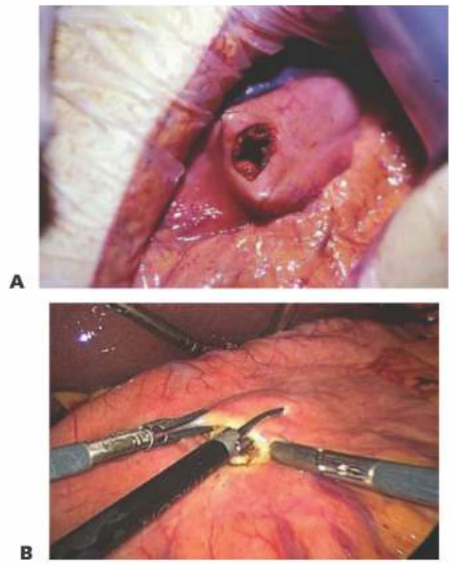


FIG 8 ● A longitudinal anterior gastrotomy is made. **A.** Open cyst gastrostomy. **B.** Laparoscopic cyst gastrostomy.

FIG 9 ● Ultrasound examination through the posterior wall of the stomach assists in localization of pseudocyst and positioning of the cyst gastrostomy incision (laparoscopic cyst gastrostomy).

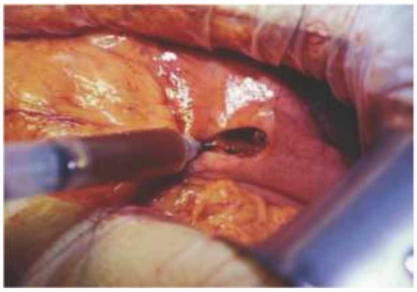


FIG 10 ● Transgastric aspiration of the pseudocyst confirms the location of the pseudocyst and distance from the gastric wall and assists in positioning of the cyst gastrostomy incision (open cyst gastrostomy).

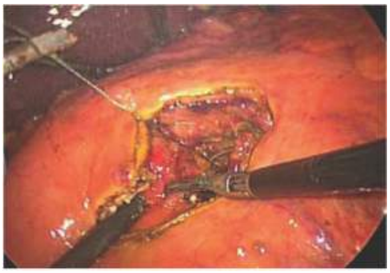
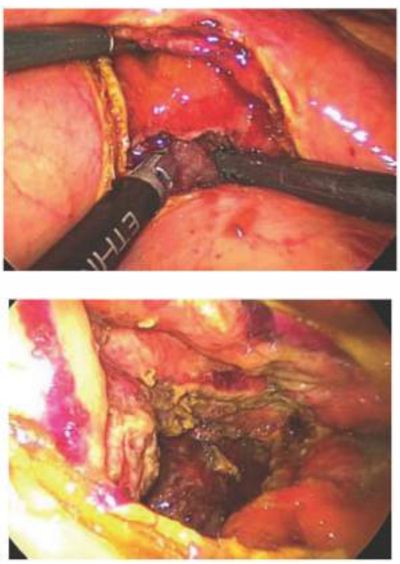


FIG 12 ● A portion of the cyst wall is excised and sent for frozen section examination to confirm the presence of a fibrous wall consistent with a pseudocyst and absence of an epithelial lining suggestive of a cystic neoplasm (laparoscopic cyst gastrostomy).

by ultrasound or aspiration and the contents of the pseudocyst are evacuated (**FIG 11**). Any necrotic debris within the cavity is removed. A portion of the pseudocyst wall is excised and sent for frozen section evaluation to confirm the presence of a fibrous wall and to exclude the presence of an epithelial lining (**FIG 12**).

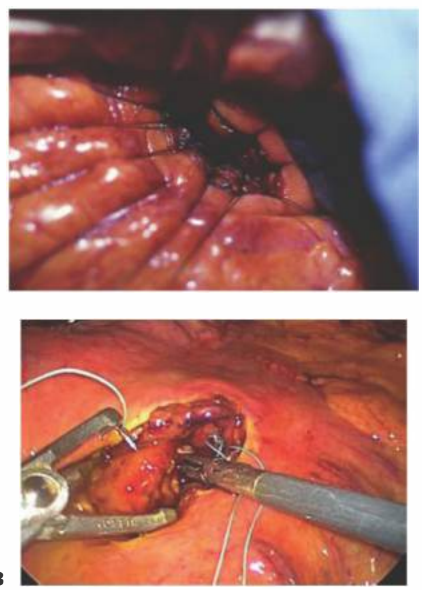
- The opening into the pseudocyst is enlarged using electrocautery or another type of energized device. A finger or ultrasound probe placed into the pseudocyst helps to define the extent to which the posterior wall of the stomach is adherent to the anterior wall of the pseudocyst. A cyst gastrostomy of 5 cm or more is desirable when possible. The pseudocyst cavity is explored and any loculations within it are opened.
- Absorbable 2-0 sutures are placed circumferentially that approximate the posterior gastric wall to the pseudocyst wall (**FIG 13**). These sutures reinforce the adherence of the pseudocyst to the stomach and promote hemostasis along the cyst gastrostomy.
- After the initial entry into the pseudocyst, the cyst gastrostomy can also be enlarged using a linear surgical stapler. However, it remains mandatory to excise a portion of the pseudocyst wall for histologic evaluation.
- After ensuring that hemostasis is satisfactory, a nasogastric tube is positioned in the stomach and the anterior gastrotomy is closed using sutures or staplers. Depending on the length and position of the gastrotomy and the size of the stomach, the closure is oriented longitudinally or transversely.
- A final exploration of the abdomen is performed, and the midline incision is closed. Drains are not routinely placed.



A

B

FIG 11 ● The pseudocyst is entered **(A)** and its contents including any necrotic material are removed **(B)**.



A

B

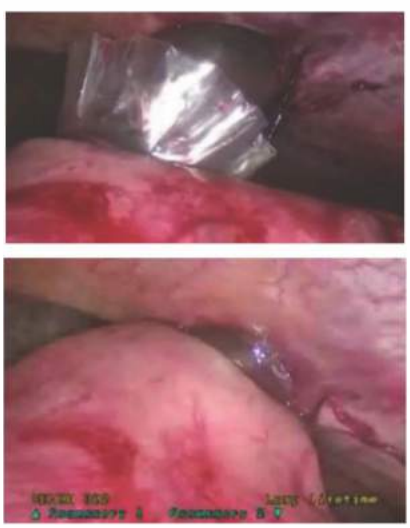
FIG 13 ● **A,B.** Sutures are placed circumferentially along cyst gastrostomy to reinforce the adherence of the stomach to the pseudocyst wall and to ensure satisfactory hemostasis along the cyst gastrostomy. **A.** Open cyst gastrostomy. **B.** Laparoscopic cyst gastrostomy.

EXTRAGASTRIC CYST GASTROSTOMY

- Lesser sac pseudocysts in proximity to the posterior wall of the stomach can be anastomosed in side-to-side fashion to the stomach without entering the stomach through an anterior gastrostomy.
- The lesser sac is widely entered through the gastrocolic omentum.
- The posterior wall of the stomach and the anterior wall of the pseudocyst are identified where they lie in close proximity but are not adherent to one another.
- Small openings are made in the posterior wall of the stomach and the anterior wall of the pseudocyst where they lie in close proximity to one another, and a linear stapler is inserted into these openings and fired. Additional applications of the stapler are used as necessary to create an adequate anastomosis. The common opening is then closed using staplers or sutures.
- Alternatively, parallel incisions are made in the posterior wall of the stomach and the anterior wall of the pseudocyst and a hand-sewn anastomosis is fashioned.
- This technique of anastomosis between the stomach and pseudocyst can be performed as either an open or minimally invasive procedure.
- With this technique, the anastomosis between the stomach and the pseudocyst is not limited by the extent of their adherence to one another. Complications arising from the anterior gastrotomy are also eliminated.
- However, a leak at the cyst gastrostomy will result in extraluminal extravasation of gastrointestinal contents and a gastric fistula. Placement of a drain adjacent to the cyst gastrostomy should be considered.

ENDOLAPAROSCOPIC INTRAGASTRIC CYST GASTROSTOMY

- Laparoscopic access into the peritoneal cavity is achieved in the usual manner. Three right-sided 5-mm ports are initially placed. The mobility of the anterior wall of the body of the stomach is assessed to determine if it will reach to the abdominal wall. To do so, the pneumoperitoneum may need to be decreased. Once confirmed, traction sutures are placed into the stomach at this location, and passed out through the abdominal wall at the previously determined site.
- The jejunum is followed from the duodenojejunal junction to a site where the jejunum is mobile. A noncrushing bowel clamp is applied across the jejunum to prevent distention of the intestine during subsequent insufflation of the stomach.
- A 12-mm port is inserted at the previously determined site. A small gastrotomy is made at the center of the traction sutures, and the 12-mm port is advanced through this opening into the stomach. The traction sutures are used to hold the stomach upward against the abdominal wall. This is facilitated by also using a cuffed 12-mm port (**FIG 14**).
- The stomach is insufflated through the intragastric port, and laparoscopic examination of the inside of the stomach is performed. The bulge in the posterior wall of the stomach caused by the retrogastric pseudocyst is visible (**FIG 15**).
- An endoscope is the passed via the mouth into the stomach, providing intragastric visualization and allowing for laparoscopic instrumentation to be passed into the stomach through the single intragastric port (**FIG 16**).
- After localization of the pseudocyst by means of aspiration or ultrasound evaluation, an incision is made through the posterior wall of the stomach into the pseudocyst using electrocautery or other types of energy devices (**FIG 17**).
- A small portion of the pseudocyst wall is excised for frozen section evaluation, and the cyst gastrostomy is



A

B

FIG 14 ● **A,B.** Assisted by traction sutures, a cuffed 12-mm port is inserted into the stomach **(A)**, and the stomach is pulled upward against the abdominal wall.

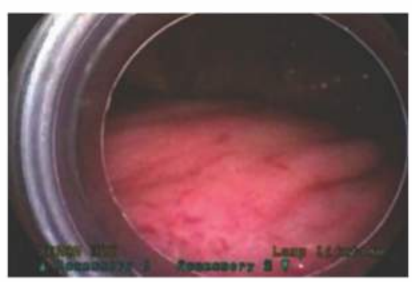


FIG 15 ● After passage of a laparoscope into the stomach through the intragastric port, a bulge in the posterior wall of the stomach caused by the retrogastric pseudocyst is visible.

FIG 16 ● An endoscope passed through the mouth into the stomach provides intragastric visualization and permits passage of laparoscopic instruments through the single intragastric port.

enlarged using either stapling or energy devices. Particular attention is given to ensuring satisfactory hemostasis. Through the cyst gastrostomy drainage and debridement of the cyst cavity are completed (**FIG 18**). Small amounts of residual debris will subsequently pass through the cyst gastrostomy. A nasogastric tube is positioned in the stomach, the port is removed from the stomach, and the gastrotomy is closed using either sutures or staplers. The bowel clamp is removed from the intestine and the remaining laparoscopic ports are removed. A drain is not routinely placed.

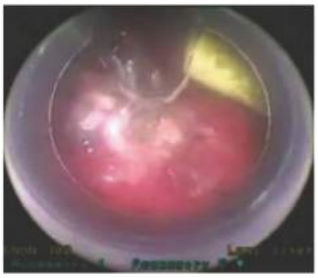


FIG 17 ● Under endoscopic visualization and after localization of the retrogastric pseudocyst, a small incision is made in the posterior wall of the stomach and the pseudocyst is entered.

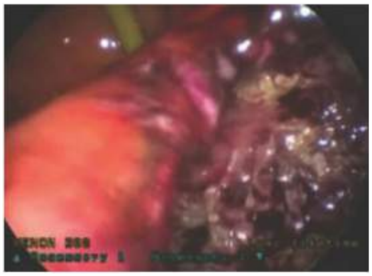


FIG 18 ● The cyst gastrostomy is enlarged using staplers or energy devices, and drainage and debridement of the pseudocyst are completed.

ROUX-EN-Y CYST JEJUNOSTOMY

- A midline incision provides excellent exposure for **open Roux-en-Y cyst jejunostomies**. Palpation of the abdomen after induction of anesthesia and review of the patient's preoperative imaging studies will guide placement of the incision. As the operation is performed predominantly below the transverse mesocolon, the incision is usually slightly more inferior than the incision used for creation of a cyst gastrostomy.
- A wound protector is placed and thorough exploration of the abdomen is performed. The pseudocyst typically presents as fullness bulging into the transverse mesocolon, and the fullness caused by the pseudocyst is palpated and localized.
- Port placement for **minimally invasive Roux-en-Y cyst jejunostomy** will vary according to the size and position of the pseudocyst. In general, however, ports are positioned lower in the abdomen than for creation of a minimally invasive cyst gastrostomy. Port placement is selected not only for creation of the cyst jejunostomy but also for creation of the Roux limb and subsequent enteroenterostomy.
- The transverse colon is elevated upward, allowing visualization of the transverse mesocolon and the bulging resulting from the pseudocyst. The location of the pseudocyst can be confirmed by aspiration. If the location of the pseudocyst is not readily apparent, intraoperative ultrasound can be used with reference to the patient's preoperative imaging studies (**FIG 19**). Ultrasound evaluation may also assist in identifying mesenteric vessels overlying the pseudocyst that should be avoided in fash-

FIG 19 ● Intraoperative ultrasound localization of pancreatic pseudocyst bulging through the transverse mesentery.

FIG 20 ● Dissection and exposure of pseudocyst bulging through the transverse mesentery.

FIG 21 ● Creation of Roux limb using a linear stapler to divide the jejunum and its mesentery.

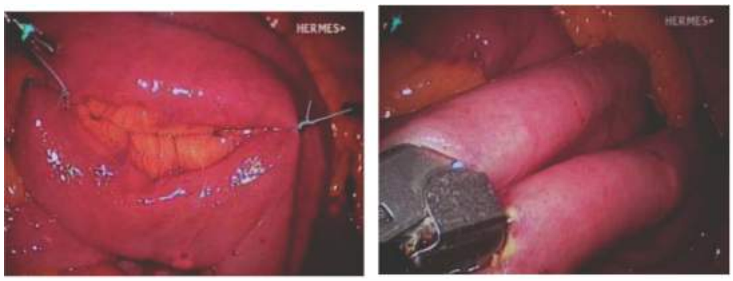


FIG 22 ● Creation of side-to-side enteroenterostomy using a linear stapler.

ioning the cyst jejunostomy. Adhesions overlying the pseudocyst are then taken down using sharp and blunt dissection (**FIG 20**).

- With the pseudocyst identified and exposed, a defunctionalized Roux limb is then prepared. The consequences of a leak subsequently occurring at the cyst jejunostomy are mitigated by use of a Roux limb rather than a functional loop of jejunum. The jejunum is followed from the duodenojejunal junction to a site where the mobility of the jejunum and the configuration of its vascular arcades are suitable. As the cyst jejunostomy is positioned below the mesocolon, mobility of the Roux limb is rarely an issue. However, occasionally, the jejunal mesentery may be very foreshortened or thickened as a result of the prior episode(s) of pancreatitis. The intestine is divided using a linear stapler, and the mesentery is divided, taking care to ensure that hemostasis is meticulous and that the blood supply to both ends of the jejunum is satisfactory (**FIG 21**).
- Gastrointestinal continuity can be reestablished before or after creating the cyst jejunostomy and can be performed using staplers, sutures, or a combination of both (**FIG 22**). The anastomosis can be performed in either a side-to-side or end-to-side fashion. A Roux limb measuring 40 to 50 cm should be created. In some instances, a longer Roux limb may be created if the patient's history or imaging results suggest the possible need for an additional cyst jejunostomy or biliary reconstruction in the future. In this case, the manner in which the enteroenterostomy is made and the positioning of the Roux limb should be carefully considered. After completing the enteroenterostomy, the resulting mesenteric defect is closed with sutures to prevent hernias.
- The Roux limb is positioned next to the pseudocyst and a side-to-side anastomosis measuring 3 to 5 cm in length is then created between the pseudocyst and the Roux limb. As with the extragastric cyst gastrostomy, this anastomosis can be performed using staplers (**FIG 23**) and/or sutures (**FIG 24**). Stapler and suture choice is determined by the thickness of the pseudocyst wall.
- A drain is placed adjacent to the anastomosis, and after confirming that hemostasis is satisfactory, the incision or ports are closed.

FIG 23 ● Creation of side-to-side Roux-en-Y cyst jejunostomy using a linear stapler. The jaws of the stapler are positioned in the Roux limb *(right)* and pseudocyst *(left)*.

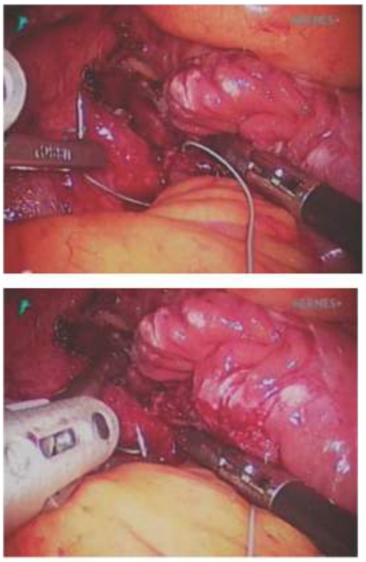


FIG 24 ● Creation of side-to-side Roux-en-Y cyst jejunostomy using sutures. Suture has been passed through the Roux limb **(top)** and is now being passed through the pseudocyst **(bottom)**.

PEARLS AND PITFALLS

Differential diagnosis	▪ Cystic neoplasm must always be considered.
Imaging and other diagnostic studies	▪ Management is driven by high-quality imaging. The anatomic relationships, presence of necrotic debris, and involvement of pancreatic duct must be well-determined to implement appropriate therapy. ▪ Be mindful of a potential disconnected pancreatic duct.

Preoperative planning	▪ Timing of intervention is key. The goal is to allow the process to adequately mature while minimizing the duration of disability.
	▪ Anatomic relationships drive management.
	  ▪ Cyst gastrostomy is technically least demanding but associated with higher recurrence rates.
	  ▪ Approach the pseudocyst from the transverse mesocolon for cyst jejunostomy.
	  ▪ Consider laparoscopic approach or endoscopic assistance.
	▪ Look for venous thrombosis and varices.

Surgical management	▪ Debride all necrotic material. ▪ Respect varices. Be liberal with ligation. ▪ Running or locking sutures to fashion the anastomosis are advised to minimize the risk of postoperative bleeding.

POSTOPERATIVE CARE

- A nasogastric tube is routinely placed in patients who undergo creation of a cyst gastrostomy and left in place until gastric emptying appears satisfactory.
- Drain output is evaluated for the presence of amylase and lipase. If present, the drain is left in place until output has ceased.
- Routine antibiotic and thromboembolic prophylaxis are administered. Other aspects of routine postoperative care are followed.
- Patients are evaluated for resolution of symptoms previously attributed to the pseudocyst. If symptoms persist, follow-up imaging (CT or MRI) is performed. Otherwise, routine follow-up imaging is obtained after 3 months to confirm resolution of the pseudocyst. Thereafter, further evaluations are dictated by the development of new symptoms.
- If symptoms persist after a cyst gastrostomy and imaging confirms the presence of a residual pseudocyst, endoscopy should be performed to evaluate the patency of the cyst gastrostomy. If narrowed, the cyst gastrostomy can be endoscopically dilated. The residual pseudocyst can be accessed, debrided, and drained endoscopically. Additionally, a nasocystic catheter can be placed for irrigation of the cavity.
- If symptoms persist after a Roux-en-Y cyst jejunostomy and imaging confirms the presence of a residual pseudocyst, the cyst jejunostomy can occasionally be evaluated and if

necessary be dilated endoscopically. However, the Roux construction often prevents this from being accomplished. Although revision of the cyst jejunostomy may need to be considered, if imaging studies demonstrate evidence of patency of the cyst jejunostomy (e.g., air in the pseudocyst), consideration should be given to allowing additional time for resolution of the pseudocyst before proceeding with surgery. Additionally, careful evaluation of the patient's symptoms should be performed to ensure that they are caused by the residual pseudocyst before embarking on further surgery.

COMPLICATIONS

- In addition to intraperitoneal bleeding, bleeding may occur from gastrotomies used to access the stomach and from any of the anastomotic sites. The cyst gastrostomy is particularly prone to bleeding because of the inherently rich blood supply of the stomach and the inflammation associated with the episode of pancreatitis and pseudocyst formation. Endoscopy is useful for not only evaluating the cyst gastrostomy but also for evaluating for bleeding within the pseudocyst cavity. However, accumulation of blood, fluid, and debris within the cavity may hinder thorough evaluation and consideration should be given to early angiography. Angiography should also be strongly considered for evaluation of bleeding from a Roux-en-Y cyst jejunostomy, as this anastomosis cannot be readily evaluated endoscopically.
- Leakage can occur at anastomotic and gastric closure sites. Leakage from an anterior gastrotomy closure or enteroenterostomy is managed as with any gastrointestinal leak. Leakage from a Roux-en-Y cyst jejunostomy can be managed nonoperatively if controlled satisfactorily by the drains placed at the time of surgery. Additional drains can be inserted percutaneously if needed. As the Roux limb is defunctionalized, surgical exploration is not required if adequate drainage is established. If leakage occurs from an extragastric cyst gastrostomy, the patient should initially be made nil per os (NPO). With adequate drainage from the surgically placed drains, leaks from either type of anastomosis will usually heal spontaneously.

REFERENCE

1. Banks PA, Bollen TL, Dervenis CL, et al. Acute Pancreatitis Working Group. Classification of acute pancreatitis—2012: revision of the Atlanta classification and definitions by international consensus. *Gut*. 2012;62:102–111.

Chapter 49

Pancreatic Debridement

Nicholas J. Zyromski

DEFINITION

- Two hundred and seventy thousand patients are admitted to U.S. hospitals yearly with the primary diagnosis of acute pancreatitis. Among these patients, 10% to 15% will develop severe acute pancreatitis with variable necrosis of the peripancreatic soft tissue and pancreatic parenchyma.
- Necrotizing pancreatitis (NP) is a serious problem with attendant mortality of approximately 20%.
- Once pancreatic and peripancreatic necrosis have been established, one of the three outcomes will present itself. **FIG 1** illustrates these potential outcomes. A small percentage of patients will resolve their necrosis with no intervention. Another portion of patients will develop infection in the necrosis; this typically demands treatment. A third group of patients will have persistent necrosis. If the necrosis causes no symptoms, no intervention is necessary. However, symptomatic necrosis remains an indication for intervention. Symptoms may include fullness/early satiety, general malaise, and back pain. These symptoms are related to mass effect of the necrosis as well as to the inflammatory response.

PATIENT HISTORY AND PHYSICAL FINDINGS

- The etiology of pancreatitis should be investigated. Patients with biliary pancreatitis should be considered for cholecystectomy with cholangiography at the time of pancreatic debridement. A significant number of patients will have idiopathic cause; current data implicates microlithiasis and/or sludge in many of these cases. Therefore, strong consideration should be given to cholecystectomy if technically possible and safe at the time of debridement.
- NP patients have widely variable physiologic condition prior to necrosectomy. On two ends of the spectrum, a patient may be acutely ill with systemic sepsis and require debridement urgently for infectious control. On the other hand, many patients may be "walking wounded"—that is to say, they are home from the hospital managing some oral alimentation and are in reasonable physical health; however, they remain moderately to profoundly symptomatic.
- All efforts should be made to optimize nutritional and physical condition prior to pancreatic debridement. The clinician should understand that objective nutritional values will never normalize with a volume of necrotic tissue in the retroperitoneum generating a persistent inflammatory response. Enteral alimentation is ideal; parenteral nutrition may be necessary to supplement caloric and protein intake.
- It must be emphasized that multiple approaches are available to treat NP patients. The disease is extremely heterogeneous and no one intervention fits all patients. Ideally, a multidisciplinary team consisting of surgeons, interventional endoscopists, and interventional radiologists are invested in evaluating these patients. One doctor must be responsible for the long-term care of these patients as the recuperation typically encompasses 6 to 12 months or longer.

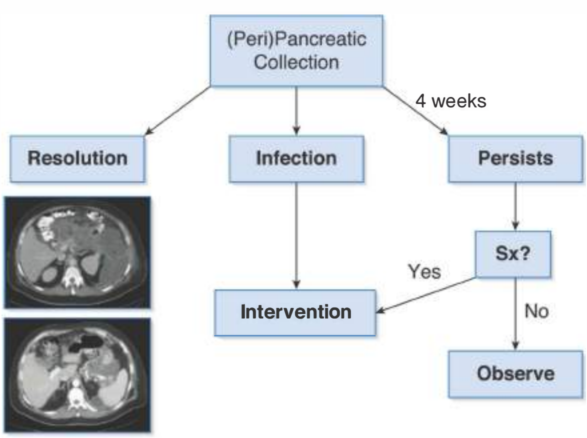


FIG 1 ● Necrosis outcomes. *Sx*, symptoms.

IMAGING AND OTHER DIAGNOSTIC STUDIES

- A current cross-sectional image—that is, computed tomography (CT) or magnetic resonance imaging (MRI) scan—of the abdomen and pelvis is critically important to use as a road map guiding debridement.
- An important diagnostic consideration involves estimating the volume of solid material (as opposed to fluid) in the peripancreatic collection. MRI is more accurate than CT in making this estimation. Ultrasound may be most accurate; however, transabdominal ultrasound is plagued by artifact from hollow viscus. Endoscopic ultrasound (EUS) is an excellent modality; however, it requires sedation and is moderately invasive. **FIG 2** illustrates MRI and ultrasound images.
- Endoscopic retrograde pancreatography (ERP) is most accurate in defining pancreatic ductal anatomy and, specifically, the presence of disrupted main pancreatic duct. If ERP is undertaken in the setting of NP, it should be done a short time before planned debridement, as ERP has a high chance of contaminating what otherwise may be sterile necrosis. Fine needle aspiration of the pancreatic and peripancreatic necrosis is relatively sensitive in diagnosing infection. This modality is not commonly necessary or used in contemporary practice.
- Transabdominal ultrasound of the gallbladder should be performed to diagnose stones or sludge and inform the need for cholecystectomy.
- Broad-spectrum empiric antibiotic treatment is not recommended currently. Antibiotic therapy should be reserved for documented infections with a discrete endpoint in treatment.
- NP patients have an extremely high (56%) incidence of venous thromboembolic events. Screening duplex ultrasonography should be considered in all NP patients.

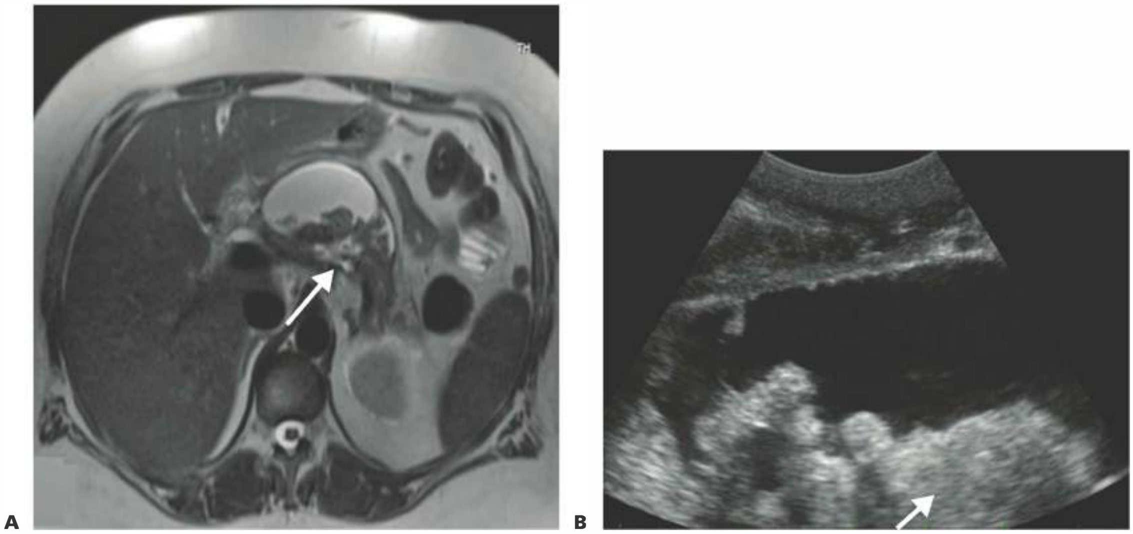


FIG 2 ● **A.** MRI showing solid and fluid components *(arrow)* of peripancreatic collections. **B.** IOUS image of the same collection. Solid necrosis is highlighted with *arrow*.

SURGICAL MANAGEMENT

- Perhaps the most important concept regarding NP is that this disease is extremely heterogeneous. The intervention/operative approach is dictated primarily by anatomic distribution of necrosis, involvement of the pancreatic parenchyma by necrosis, and specific individual clinical situation.
- Treatment approaches include percutaneous drainage, endoscopic drainage, a combination of percutaneous and endoscopic approaches, retroperitoneal debridement (videoscopic-assisted retroperitoneal debridement [VARD] or sinus tract necrosectomy), surgical transgastric approach, or traditional open operative debridement with external drainage.
- **FIG 3** illustrates typical patterns of necrosis. The image on the left with necrosis confined to the lesser sac may be approached through the posterior stomach either endoscopically or surgically. The middle image with necrosis extending down the left paracolic gutter may be best approached from the retroperitoneum (VARD). The image on the right with necrosis extending down both paracolic gutters and/or the small bowel mesentery root poses a challenging problem. This group also includes patients with pancreatic head involvement. These patients may be best approached by open operative debridement.
- Definitive intervention should not be undertaken earlier than 4 weeks from the incident episode of pancreatitis.

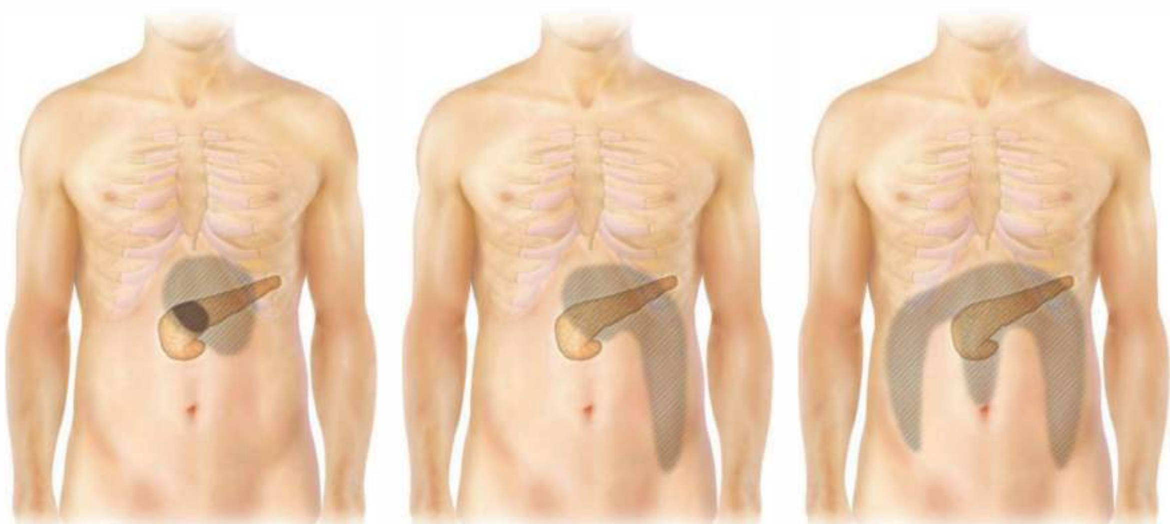


FIG 3 ● Necrosis patterns.

Goals of pancreatic debridement are shown in Table 1.

Table 1: Goals of Debridement

1	Debride as much solid necrotic tissue as possible safely.
2	Provide wide drainage of the pancreas (externally or into the alimentary tract if possible).
3	Establish enteral access.
4	Perform cholecystectomy and cholangiography if indicated.
5	Perform all the above with as little physiologic derangement as possible.

OPEN NECROSECTOMY

Exposure

- The patient may be approached through the midline or a low transverse incision, which provides superb access to the upper abdomen.
- Intraoperative ultrasound (IOUS) should be performed prior to disrupting any of the collections. IOUS provides important information about volume of solid necrosis.
- The surgeon should review recent cross-sectional image immediately before operating; this is a good "road map" directing debridement as well as to refresh memory of danger spots. Specific attention should be paid to the relationship of necrosis to the superior mesenteric and portal veins.
- A moderate amount of oozing from the diffuse inflammatory process is common. Infracolic adhesions, particularly to the undersurface of the transverse mesocolon, are quite common; these should be divided with careful blunt dissection as well as sharp dissection.
- The gastrocolic ligament should be divided. The inflammatory response commonly foreshortens the gastrocolic ligament and attention should be paid not to injure either the gastroepiploic vessels or the transverse colon wall.
- Lesser sac necrosis is always more cranial than it may seem.
- If necrosis extends down the paracolic gutters, these provide a reasonable and safe point of entry into the retroperitoneum. Debridement should progress from lateral to medial, paying special care to the known position of the superior mesenteric vein and portal vein around the pancreatic head (**FIG 4**).
- Catastrophic hemorrhage may occur from inadvertent vigorous debridement in the area of the superior mesenteric vein/portal vein (SMV/PV). The wall of the vein is weak from the inflammatory process. Proximal and distal vascular control is challenging because of the inflammatory process and in a desperate circumstance, applying a long straight vascular clamp across the porta hepatis and root of the small bowel mesentery may be a life-saving maneuver, allowing time to ligate the SMV/PV.
- It is important to release the colic flexures to provide full exposure of the upper retroperitoneum.
- Samples of the peripancreatic collection are commonly sent for Gram stain, aerobic, anaerobic, and fungal cultures.

Debridement

- The best tool for debriding pancreatic necrosis is the experienced surgeon's "educated finger." A ring forcep also is an excellent instrument.
- It is critical to only take the necrosis that is freely mobile. Vigorous debridement of immature necrosis, particularly along the area of major veins, is fraught with hazard.
- A reasonable approach is to debride one field at a time and to pack that area before moving onto the next area of debridement. For example, debride the left paracolic gutter, then pack this area with laparotomy sponges, and then move into the lesser sac or other areas in a stepwise fashion. Oozing from the retroperitoneum is very common; however, the vast majority of this bleeding will stop with a short period of tamponade.

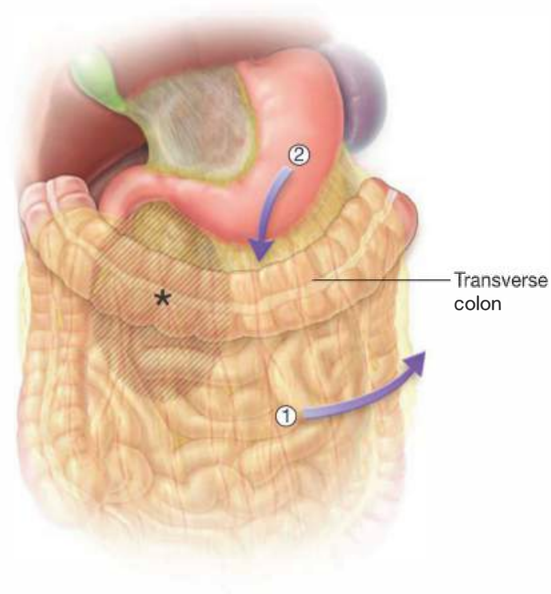


FIG 4 ● If necrosis extends down the right paracolic gutter, *(1)* this route provides safe access to the retroperitoneum. When dividing the gastrocolic ligament *(2)*, attention should be focused to preserving the gastroepiploic vessels and avoiding transverse colon injury. The *asterisk* highlights the danger zone with underlying SMV/PV.

FIG 5 ● Intraoperative photograph of right transverse mesocolon vessels skeletonized by adjacent necrosis *(arrow)*. The transverse colon is reflected cranially in the surgeon's hand.

- Vigorous irrigation of the retroperitoneum helps dislodge small volume necrosis.
- It is common to see skeletonized vessels both in the mesocolon as well as the retroperitoneum. These are quite friable; it is preferable to ligate these vessels if any question about their integrity exists. Many of these are already thrombosed (**FIG 5**).

Cholecystectomy

- Cholecystectomy may be performed at this point in the procedure if indicated and if the patient is physiologically stable. Obviously, the decision to perform cholecystectomy is a judgment call. A patient who is septic, requiring vasopressor support during debridement, is not the ideal candidate for a cholecystectomy, which is typically not a straightforward procedure and may involve substantial hemorrhage.
- Cholecystectomy is typically performed in the retrograde fashion. If the inflammatory process is too dense, cholecystectomy may be deferred, although it should not be abandoned and completely forgotten as a significant number of patients (35%) will have recurrent biliary symptoms (either cholecystitis or pancreatitis) if cholecystectomy is not performed within the next several months.
- In the setting of a densely inflamed right upper quadrant, subtotal cholecystectomy (Thorek's procedure) is acceptable (**FIG 6**).
- Cholangiography should be performed for all patients with biliary pancreatitis. Common bile duct exploration is potentially quite hazardous in this situation and experienced judgment should be sought before undertaking common duct exploration in the setting of NP. However, documenting the presence of common bile duct stones is important to direct further management.

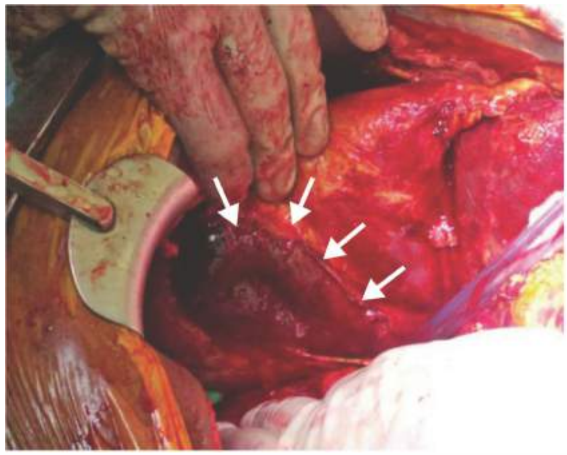


FIG 6 ● Intraoperative photograph showing densely inflamed gallbladder/right upper quadrant *(arrows)* in the setting of biliary acute NP.

Enteral Access

- Many patients with retroperitoneal necrosis have gastric ileus and/or small bowel ileus. Our preference is to place gastrojejunostomy feeding tubes liberally (**FIG 7**). This tube is easy to place and permits decompression of the stomach and feeding distal to the ligament of Treitz to provide enteral nutrition in the immediate postoperative period. The tube is then easily removed in the office once the patient has recuperated completely.
- The gastrostomy tube is placed in the anterior body in the fashion of Stamm.
- The stomach should be tacked securely to the anterior abdominal wall with heavy suture to permit replacement of the gastrojejunostomy tube should dislodgement occur.

FIG 7 ● Gastrojejunostomy feeding tube permits feeding downstream of ligament of Treitz while simultaneously decompressing the stomach.

Drains

- Debridement beds are drained widely.
- Our preference is to use closed suction large-caliber (19 mm) drains (**FIG 8**). Three-way drains, although attractive in theory, are extremely challenging to manage in the intensive care unit and on the hospital ward.
- If disconnected pancreatic duct is suspected and external drainage employed, it is critical to maintain this drain, which controls the fistula externally.

Abdominal Closure

- The fascia is most often able to be closed primarily, although the operator should pay close attention to the peak airway pressures at the time of closure.
- The need for true retention sutures is unusual; however, a combination of running and interrupted slowly reabsorbable monofilament sutures seems prudent.
- The incidence of ventral hernia after open pancreatic debridement is substantial (42%).
- The skin is typically left open to close by secondary intention.

FIG 8 ● Large-caliber closed suction drains typically provide adequate drainage of necrosis bed if thorough debridement is achieved. Drains are placed above the transverse colon; stomach is retracted cranially.

TRANSGASTRIC NECROSECTOMY

- Transgastric necrosectomy may be approached laparoscopically or through a short upper midline incision (**FIG 9**). This technique is selectively applied to patients with necrosis isolated in the lesser sac; it may be particularly effective for patients with a disconnected pancreatic tail. Clinicians should be aware that necrosis extending down the small bowel mesenteric root or paracolic gutter may not be appropriate for this technique.
- IOUS is a critical adjunct, especially if the majority of the necrosis is solid as opposed to liquid. Ultrasound should be applied through the front wall of the stomach and particularly through the back wall of the stomach to help localize posterior gastrotomy (**FIG 10**).
- The surgeon should be aware of the potential for hemorrhage from varices in the gastric wall in the setting of left-sided (sinistral) portal hypertension.
- Stay sutures in the posterior gastric wall are extremely helpful in the laparoscopic approach, delivering this

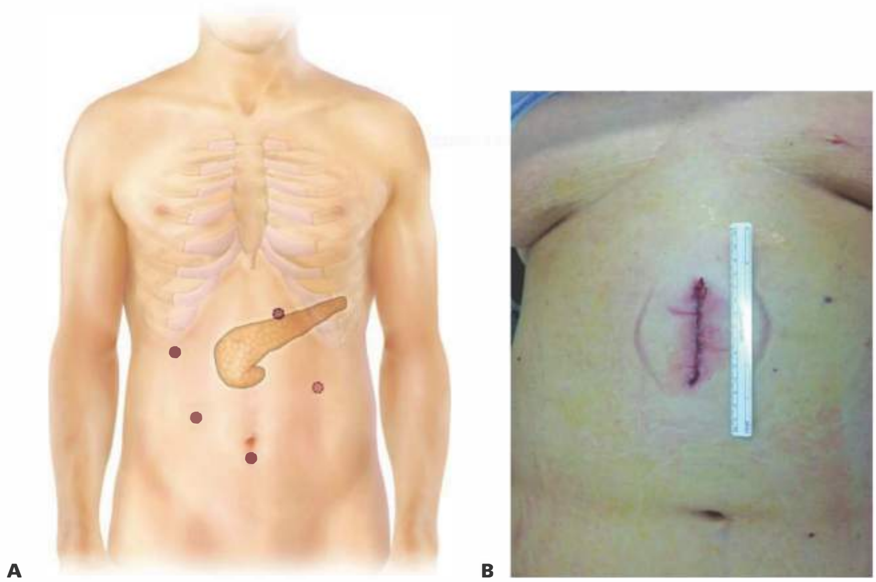


FIG 9 ● **A.** Diagram showing port placement for laparoscopic transgastric debridement. **B.** Postoperative photograph: even with heavy body habitus, open transgastric debridement may be achieved through a short (6 cm) upper midline incision.

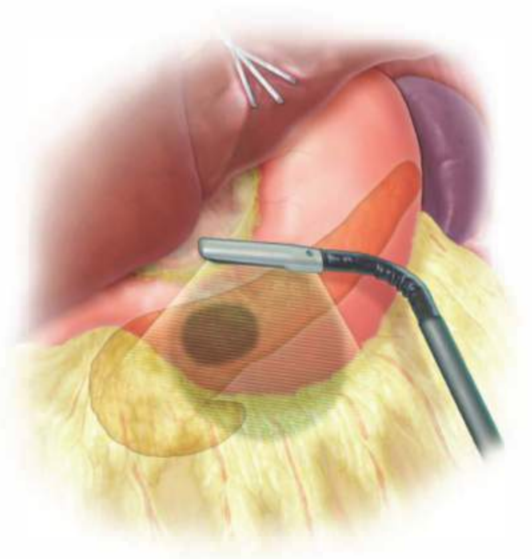


FIG 10 ● IOUS is critical, particularly in the laparoscopic approach.

opening into the operative field (**FIG 11**). Wide posterior gastrotomy is created either with cautery or a linear stapling device. The posterior gastrotomy is sutured to the cyst with permanent suture. This aids in hemostasis as well as in durably maintaining this ostomy. Gentle debridement and copious irrigation are applied. The conduct of debridement is similar to that in the open situation (**FIG 12**).

- Anterior gastrotomy is closed with suture or stapler (**FIG 13**). Often, the stomach is thick and suturing provides a more secure closure.

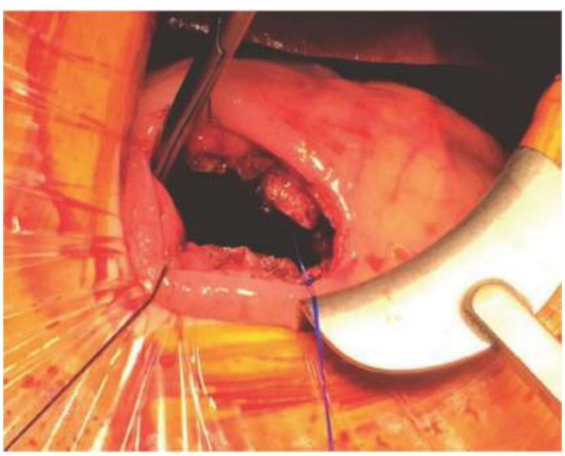


FIG 11 ● Intraoperative photograph showing anterior gastrotomy and large posterior cystogastrostomy. Note stay sutures on posterior gastric wall.

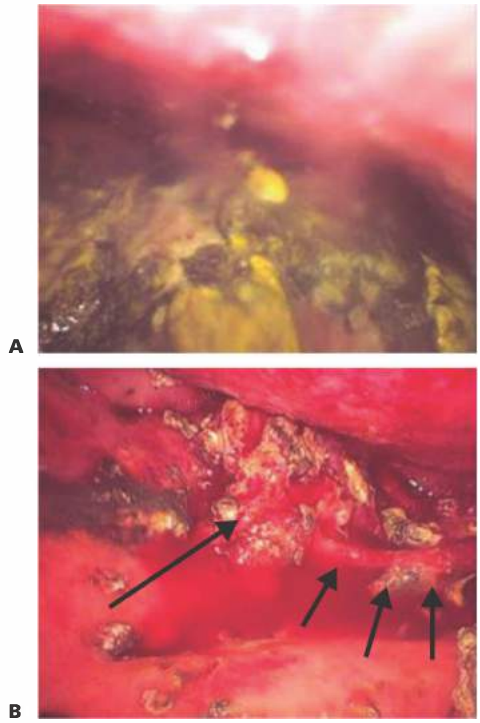


FIG 12 ● Intraoperative photographs of laparoscopic transgastric debridement. **A.** Camera is in necrosis cavity. **B.** After debridement. *Long arrow* shows disconnected pancreatitis tail; *short arrows* show splenic artery.

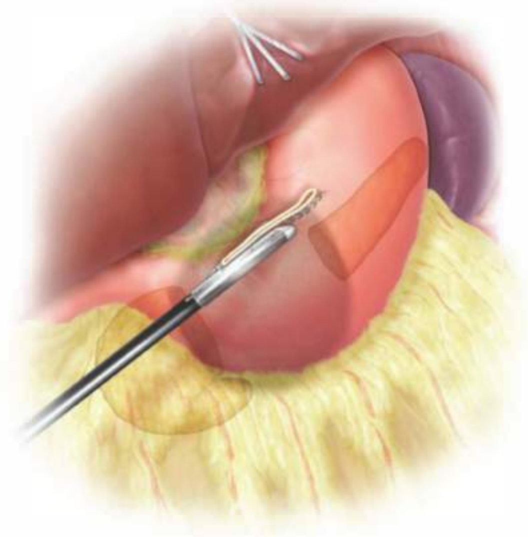


FIG 13 ● Anterior gastrotomy may be closed with suture or stapler (shown).

- If gastrostomy or gastrojejunostomy feeding tube is indicated, placing this prior to closing the anterior gastrotomy affords visualization of the tube passing through the duodenum. Care should be taken to place the gastrostomy at a distance away from the gastrotomy closure site.
- No drains are necessary with transgastric necrosectomy.
- Cholecystectomy and cholangiography may be performed if indicated.

Distal Pancreatectomy +/− Splenectomy

- In the setting of major body necrosis with a very small amount of viable pancreatic tail, the surgeon may consider distal pancreatectomy at the time of operative debridement. This should be reserved for highly select cases. It is almost always necessary to perform splenectomy in this setting due to the significant inflammatory response and frequent incidence of gastric varices.
- Preoperative embolization of the splenic artery should be considered in this clinical scenario.

PEARLS AND PITFALLS

Surgical decision making	■ NP is an extremely heterogeneous disease. Appropriate treatment must be based on the underlying necrosis anatomy as well as the patient's general condition. Ideally, treatment decisions are made in the context of multidisciplinary review. ■ Definitive intervention should not be applied before 4 weeks' time. ■ Should infection occur before 4 weeks' time, percutaneous drainage is the most appropriate intervention. ■ Keep in mind the potential for colon ischemia at any point in the course of this disease.
Operative technique	■ If forced to operate (to prove or exclude colon ischemia) prior to 4 weeks, wide drainage of immature necrosis is preferred to attempts at debriding immature necrosis. ■ In the setting of disconnected pancreatic tail, the transgastric approach may be most appropriate. Alternatively, distal pancreatectomy plus splenectomy may be considered in highly select patients. ■ Be aware of the potential for visceral arterial pseudoaneurysm. ■ When manually debriding pancreatic necrosis, only take the necrosis that comes easily. ■ In biliary pancreatitis, cholecystectomy and cholangiography should be performed if technically possible at time of debridement. Cholecystectomy may be hazardous and clinical judgment regarding extent of operation is important here.
Postoperative care	■ Do not be afraid to reoperate if the patient is not following the expected course. It is important to regain control of a poorly controlled or uncontrolled pancreatic fistula. It is also important to exclude ischemic colitis in the early postoperative period following the first debridement.

POSTOPERATIVE CARE

- Optimal nutrition support is critical for expedient recuperation. Oftentimes, this requires some combination or parenteral and enteral nutrition. While recognizing the crucial importance of enteral alimentation, the surgeon should be cognizant of small bowel and gastric ileus that are very common in the setting of NP and postdebridement. Increasing tube feeding volume too rapidly may be detrimental.
- Aggressive physical rehabilitation is also critical. Early planning for discharge to an extended-care treatment facility is prudent; direct communication with health care providers at these facilities is important to maintain the continuity of care.
- Venous thromboembolism is common occurrence in the setting of NP. Patients should be observed carefully and possibly screened with ultrasound on a regular basis. Bright red blood in the surgical drain should be considered visceral arterial pseudoaneurysm until proven otherwise. Often, a small amount of blood is from retroperitoneal venous hemorrhage; however, visceral arterial pseudoaneurysm is a potentially lethal problem that should not be missed. Cross-sectional imaging with computed tomography angiography (CTA) is rapid and widely available; CTA is an excellent first-line test with which to diagnose or exclude pseudoaneurysm.
- Appropriate duration of antibiotic treatment after satisfactory source control is important. However, no clear data exist to inform this treatment decision. Antibiotic treatment of no shorter than 7 days should be employed. We have tried to cut down antibiotic treatment and had recurrent retroperitoneal infected collections. It is noteworthy that retroperitoneal collections infected with resistant bacteria and yeast are extremely hard to clear. Consideration should be given to extended-duration antibiotic treatment in these cases.
- The patient should be observed for the presence of external pancreatic fistula. Measurement of amylase and surgically placed drains will diagnose this condition.
- Enterocutaneous fistulas may occur. These should be managed in a similar fashion to enterocutaneous fistulas developing from other conditions. Duodenal fistula is extremely challenging. Percutaneous transhepatic drainage with diversion of the biliopancreatic secretion will occasionally allow these fistulas to close with nonoperative management.

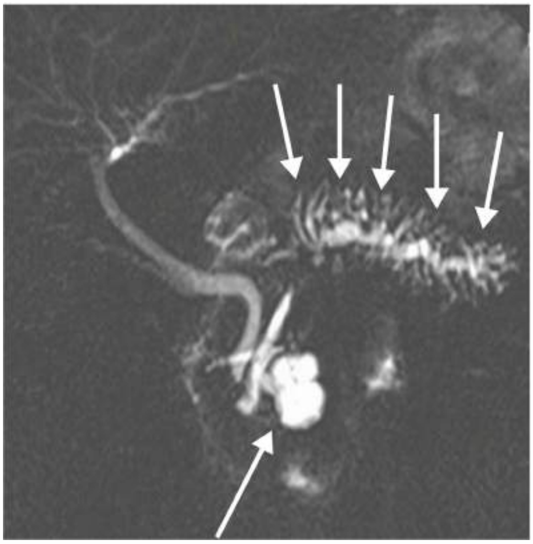


FIG 14 • MRI 2 years after transgastric debridement showing dilated main and side branch pancreatitis ducts *(short arrows)* in the disconnected tail. The etiology of this patient's pancreatitis was the side-branch IPMN *(long arrow)*.

- Patients dismissed from the hospital with controlled external pancreatic fistula and/or supplemental enteral and parenteral nutrition should have early and frequent postoperative follow-up.
- Patients who fail to progress as expected should have early cross-sectional imaging. Additional percutaneous drainage or reoperation may be necessary to regain control of an uncontrolled pancreatic fistula.
- Long-term follow-up is crucial for patients undergoing transgastric debridement, as long-term outcomes from this relatively new approach are unknown. A small number of patients will manifest recurrent pancreatitis (**FIG 14**) or recurrent retroperitoneal fluid collections (pseudocyst) after transgastric debridement.

OUTCOMES

- Mortality after pancreatic debridement in contemporary series ranges from 5% to 10% at specialized centers. Although this mortality is relatively high, this represents substantial improvement from historical mortality figures and is likely most related to improved operative selection. Patients and family members should be educated from the start of this disease process that NP is a long-term problem and that even in the best of circumstances, patients should expect a recuperation period measured in months.
- In general, reports of long-term outcomes for patients with NP and operative debridement are scarce.
- Ideally, patients will have long-term follow-up with primary physician and/or gastroenterologist attentive to exocrine and endocrine functions as well as digestive function.
- A small number of patients with NP will have intraductal papillary mucinous neoplasm (IPMN) or pancreatic adenocarcinoma as the cause. Unfortunately, prognosis in this subgroup of patients is uniformly poor.
- A small subgroup of patients with NP is too well to die but too sick to recuperate with reasonable quality of life. This is an extremely challenging group of patients to care for. However, in a highly select number of these patients, hospice care may be appropriate. These patients, for example, have protracted immobilization, protracted organ failure, and unreconstructable enteric fistulas.
- A highly select number of patients may be candidates for intestinal or multivisceral transplant. Obviously, this is decision making that must be undertaken in conjunction with the organ transplant group.

COMPLICATIONS

- Complications after pancreatic necrosectomy may be related to disease progression or operation. Table 2 highlights these complications.

Table 2: Complications of Necrotizing Pancreatitis

Short-Term	Long-Term
Pancreatic fistula (particularly with disruption of the main pancreatitis duct)	Recurrent retroperitoneal collections/infection
Colonic ischemia	Bile duct or duodenal obstruction from stricture
Venous thromboembolism	Exocrine and endocrine insufficiency
Enteric fistula	Chronic pain
Visceral arterial pseudoaneurysm	Recurrent acute pancreatitis progressing to chronic pancreatitis in the remnant pancreas
	Ventral hernia

Chapter 50

Laparoscopic Pancreatic Debridement

O. Joe Hines Kathleen Hertzer

DEFINITION

- Laparoscopic pancreatic debridement is a minimally invasive technique for pancreatic resection and is indicated in the case of infected pancreatic necrosis as a result of acute pancreatitis. Additional options for pancreatic necrosectomy include laparotomy as well as other minimally invasive methods such as percutaneous catheter drainage and endoscopic drainage. Methods of laparoscopic debridement will be the focus of this chapter.

Differential Diagnosis

- The differential diagnosis of acute pancreatitis includes biliary colic, peptic ulcer disease, cholecystitis, acute mesenteric ischemia, small bowel obstruction, visceral perforation, vascular catastrophes such as ruptured aortic aneurysm, as well as intraabdominal infection.
- In the setting of recent, severe acute pancreatitis, characteristic CT findings and patient history and physical findings are strongly supportive of infected versus sterile pancreatic necrosis, pancreatic abscess, or pancreatic pseudocyst.

PATIENT HISTORY AND PHYSICAL FINDINGS

- Acute pancreatitis has a broad range of clinical symptoms. The majority of cases can be mild and self-limiting; however, about 20% of these patients will develop severe acute pancreatitis and among these patients, approximately 30% to 70% will develop infected necrosis.[1]
- Severe acute pancreatitis is associated with high mortality and morbidity; these patients are at risk for infection, multisystem organ failure, and death.
- Secondary infection of pancreatic necrosis occurs by bacterial or fungal translocation through the GI tract or by seeding through transient bacteremia from invasive monitoring in the intensive care setting.
- Infection of pancreatic necrosis can occur as early as 10 days after the onset of acute pancreatitis. More typically, infection ensues 3 to 6 weeks after the initial onset of symptoms.
- Patient history and physical examination for pancreatitis and pancreatic necrosis include a recent history of acute pancreatitis and continued abdominal pain, chronic low-grade fever, nausea, lethargy, and inability to eat. Those patients with infected pancreatic necrosis will show signs of intraabdominal infection including tachycardia, hypotension, fever, and deteriorating organ function.
- Conservative management is recommended in the case of sterile necrosis. Surgical management can be considered in symptomatic sterile necrosis; not infrequently, occult infection proves to be present. In the setting of clearly infected pancreatic necrosis, debridement or drainage is the preferred method of treatment.
- Methods for debridement include open necrosectomy and multiple minimally invasive modalities, including laparoscopic debridement. Minimally invasive necrosectomy is technically achievable and although there is evidence that a step up minimally invasive technique (percutaneous drainage with or without following retroperitoneal necrosectomy) may reduce morbidity and mortality amongst patients with infected necrotizing pancreatitis, it is unclear if minimally invasive techniques are cost effective.[2,3]

IMAGING AND OTHER DIAGNOSTIC STUDIES

- Plain radiographs are nonspecific. Ultrasound (US) may show a diffusely enlarged, hypoechoic pancreas and can be important in identification of the etiology of pancreatitis (e.g., gallstones).
- Appropriate imaging for acute pancreatitis includes contrast-enhanced computed tomography (CT) scan when complications are clinically suspected. Complications of pancreatitis evolve with time and impending necrosis may not be appreciated on CT imaging obtained within the first 24 to 48 hours of symptoms. CT imaging in the case of mild acute pancreatitis will show pancreatic enlargement, edema, peripancreatic fat stranding as well as effacement of the normal contours of the organ.
- In the setting of pancreatic necrosis, IV contrast can help delineate areas of poor perfusion as well as the extent of necrosis and can be used to predict the severity of disease. Visualization of air bubbles within necrotic tissue is diagnostic of infection (**FIG 1**).

FIG 1 ● Infected pancreatic necrosis. CT scan showing a hypoenhancing pancreas, indicating necrosis, with gas bubbles indicating bacterial infection of the necrotic material. This is likely necrosis mixed with peripancreatic phlegmon.

Table 1: Computed Tomography Grading System of Acute Pancreatitis

Grade	Findings	Score
A	Normal pancreas	0
B	Focal or diffuse enlargement of the pancreas, irregular organ contour	1
C	Peripancreatic inflammation with intrinsic pancreatic abnormalities	2
D	Fluid collections either intrapancreatic or extrapancreatic	3
E	Two or more large collections of gas in the pancreas or retroperitoneum	4

- The grading of severity of pancreatitis can be classified into five categories (Table 1) and a CT severity index can be calculated based on the grading of unenhanced CT findings and the percentage of necrosis demonstrated on contrast-enhanced CT (Table 2). The CT severity index is the sum of the unenhanced CT score and the necrosis score where the maximum is 10 and greater than or equal to 6 indicates severe disease.[4]
- If infected pancreatic necrosis is suspected, the diagnosis is confirmed with culture results from CT-guided fine needle aspiration (FNA) or from specimens collected during necrosectomy.
- FNA and culture should be obtained in patients who show clinical features of sepsis or those with a deteriorating clinical course 1 to 2 weeks after the onset of disease.

Table 2: Necrosis Score

% Necrosis	Score
0	0
<33	2
33–50	4
≥50	6

- Commonly, the Atlanta classification is used to divide acute pancreatitis into mild and severe categories. The criteria for severe acute pancreatitis include the following: a Ranson's score of 3 or greater, an APACHE II score of 8 or greater within the first 48 hours, organ failure, or local complications (necrosis, abscess, or pseudocyst involving the pancreas). Other predictors of disease severity within the first 24 hours of hospitalization include a C-reactive protein of greater than 120 mg/dL, procalcitonin greater than 1.8 ng/mL, and a hematocrit greater than 44.[5]

SURGICAL MANAGEMENT

Preoperative Planning

- Cross-sectional imaging as described earlier is necessary to determine the extent of necrosis, for signs of infection as well as planning of approach.
- The use of prophylactic antibiotics remains controversial. Antibiotics should be restricted to clear cases of CT-proven pancreatic necrosis and tailored to culture results when available. Current recommendations include imipenem or meropenem for 2 weeks for patients with proven necrosis.[6,7] Preoperative antibiotics are recommended prior to incision.
- Access: large-bore IV or central access for fluid resuscitation, rapid blood transfusion, vasopressor infusion; Foley catheter and nasogastric tube placement. Consider central line and arterial line monitoring in the case of hemodynamic instability.
- Timing of the procedure: Better outcomes are achieved if necrosectomy is delayed for at least 21 days.[8–10] This delay allows for clinical stabilization of the patient, resolution of any signs of organ failure, and decreased inflammatory reaction.

Positioning

- Positioning for laparoscopic pancreatic necrosectomy should be supine for a transperitoneal approach and lateral for a retroperitoneal approach. If the patient is supine, prep the entire abdomen from nipple to midthigh.

TECHNIQUES

RETROGASTRIC-RETROCOLIC DEBRIDEMENT (TRANSPERITONEAL)

First Step

- A transperitoneal approach is begun by placing the initial trocar in the periumbilical position (FIG 2).
- A 30-degree angled laparoscope is used to guide the insertion of two right paramedian trocars and an additional assistant's trocar in the left lateral abdomen. Start with exploratory laparoscopy after establishing pneumoperitoneum.

Second Step

- The area of necrosis can be approached through the gastrocolic ligament or the transverse mesocolon (FIG 3).

If a percutaneous drainage catheter is in place, this can be left in position and used as a guide to identify the necrosis. Dissection is accomplished with a harmonic scalpel or bipolar electrocautery device. The left side of the pancreas may be drained by mobilization of the splenic flexure. In addition, if necrosis extends above the pancreas, the lesser sac may also be entered through the gastrohepatic ligament, taking care to safeguard the right and left gastric arteries.

Third Step

- Debridement is accomplished under direct vision with the use of a grasping instrument (FIGS 4 and 5). A 10-mm stone extractor instrument is often most efficient. Necrotic material should be sent for histology and microbiology.

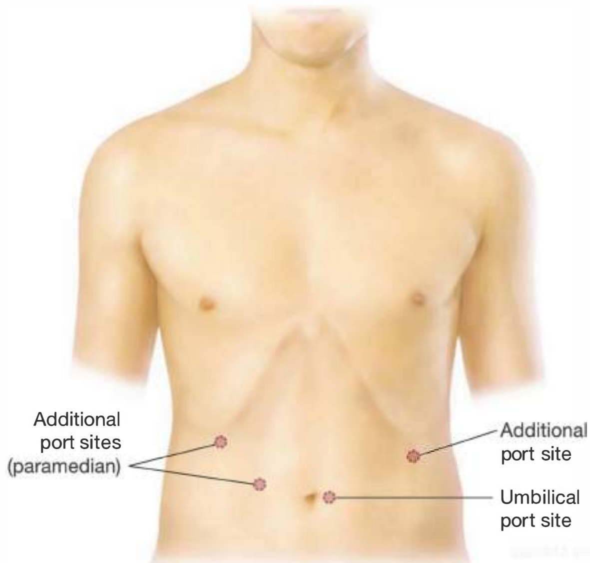


FIG 2 ● Port placement for transperitoneal debridement. Transumbilical port placement and two or more paramedian ports are placed with respect to the location of greatest pancreatic necrosis.

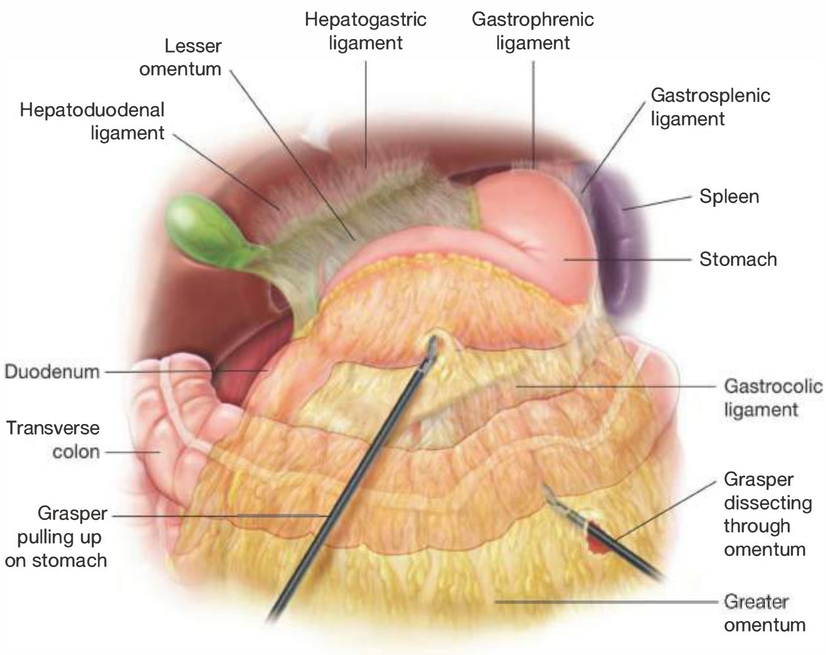


FIG 3 ● Access to the body and distal pancreas can be obtained transperitoneally through the gastrocolic ligament and the left mesocolon.

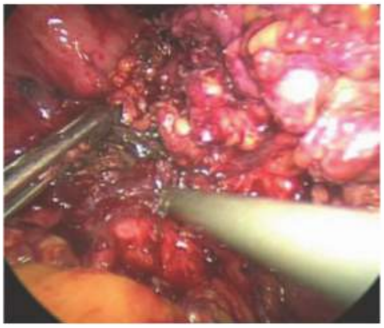


FIG 4 ● Debridement of necrotic pancreas. The pancreas has been accessed laparoscopically through the gastrocolic omentum using a harmonic scalpel. In this case, two drains had been placed preoperatively into fluid collections in the head and tail of the pancreas, respectively. Access was gained to the poorly draining tail collection by following the drain into the lesser sac. After draining purulent fluid, debridement was achieved with the use of blunt forceps.

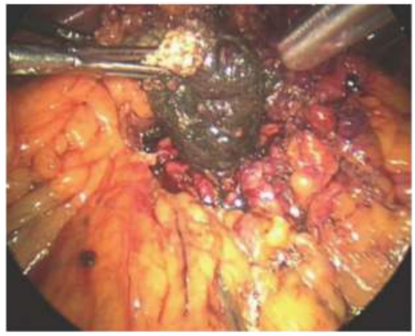


FIG 5 ● Removal of necrotic pancreas. A 6-cm piece of necrotic pancreas was removed through the anterior abdominal wall with the use of an EndoCatch bag.

- Consider intraoperative US for localization of retroperitoneal necrosis and the identification of major vascular anatomy.
- The suction-irrigator can be used to aspirate and break down pancreatic debris. An endobag is a useful tool for further removing debris.
- The cavity can be inspected by introducing the laparoscope into the debridement bed. Referring to the preoperative CT scan helps to ensure all areas of necrosis have been removed. Sump drains are placed through the trocar sites for continuous lavage of the debridement bed in the postoperative period (**FIG 6**).

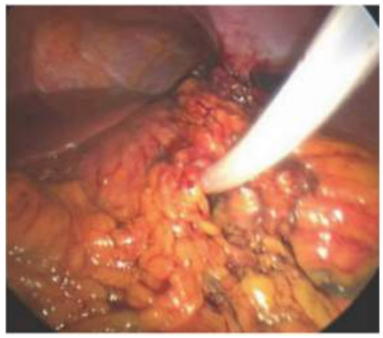


FIG 6 ● Drain placement. After adequate debridement and irrigation, an Axiom drain was placed in the cavity surrounding the body and tail and brought out through the abdominal wall through the midabdominal trocar site and secured in place.

VIDEO-ASSISTED RETROPERITONEAL DEBRIDEMENT

First Step

- Retroperitoneal debridement may be used in early necrotizing pancreatitis, especially if there is minimal fibrotic tissue, inflammation, or edema. This approach allows for examination of the posterior pancreas (**FIG 7**).
- The patient is placed in the lateral decubitus position and the retroperitoneum is entered from the right or left side, depending on the site of most inflammation and damage to the pancreas. This approach can be aided by preoperative access to the retroperitoneal space with catheter placement by interventional radiology into the dominant fluid collection.

Second Step

- A 0-degree laparoscope is inserted in the flank between the iliac crest and the 12th rib posteriorly. Alternatively, a videoscope may be inserted directly over the drain site.
- An angled, rigid, therapeutic thoracoscope facilitates debridement under visualization through a single access point.
- After insufflation, the right and left kidneys can be used as landmarks toward the head or tail of the pancreas.
- Mechanical debridement may be limited by access and visualization and may require multiple interventions; however, peritoneal contamination is limited with this approach.

Third Step

- The remainder of the procedure proceeds as previously described with samples being sent for pathology and microbiology. Drains can be placed through the port sites for continuous lavage.

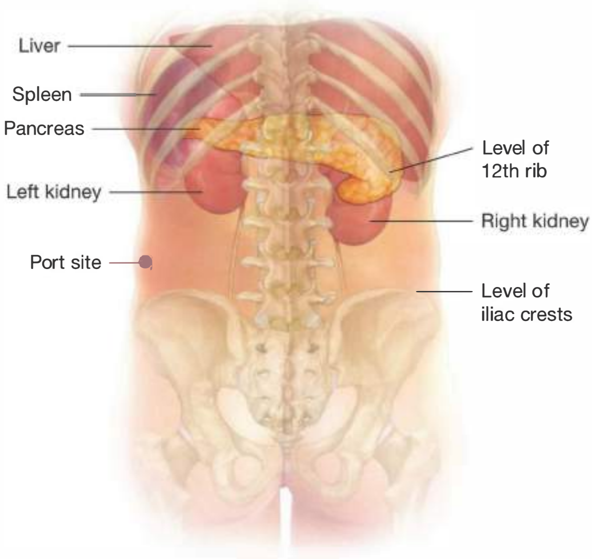


FIG 7 ● Port placement and anatomy of retroperitoneal pancreatic debridement. Patient placement is in the lateral decubitus position and the retroperitoneum can be entered through either the right or left side, depending on the site of greatest damage to the pancreas. A videoscope is placed in the flank between the iliac crest and the 12th rib or over a previously placed percutaneous drain. Other port placement depends on the location of pancreatic debris.

PEARLS AND PITFALLS

Indications	■ Indications for laparoscopic pancreatic debridement include infected pancreatic necrosis and symptomatic sterile necrosis.
Imaging	■ Contrast-enhanced CT imaging is required for determining preoperative planning.
Choice of approach	■ Retroperitoneal approach may limit the ability to adequately debride tissues but is suitable for multiple interventions. ■ Transperitoneal approach may be limited by potential peritoneal contamination and limited reintervention.
Timing	■ The optimal timing of operative intervention is 3–4 weeks following the onset of acute pancreatitis.
Drain placement	■ Preoperative drain placement can aid in initial management as well as guide intraoperative dissection and identification of necrotic material. ■ Place large drains at the time of surgery; consider continuous lavage with isotonic saline.
Indications for reimaging or relook laparoscopy	■ Reimaging and/or reoperation are indicated in cases of clinical deterioration or incomplete debridement.

POSTOPERATIVE CARE

- Immediate postoperative care will depend on the status of the patient perioperatively. However, all patients with necrotizing pancreatitis benefit from close surveillance in an intensive care unit.
- Close attention must be paid to volume status, blood glucose control, maintenance of normothermia, and adequate pain control.[11]
- Because of massive third space fluid losses and fluid shifts postoperatively, some patients will require continued intubation postoperatively in the initial 24 to 36 hours.
- Early aggressive enteral feeding can be started after the first 48 hours of resuscitation postoperatively.

OUTCOMES

- In a meta-analysis of retroperitoneal pancreatic debridement a success rate of 64% was reported with 47% morbidity and 14% mortality.[12] Recent multicenter feasibility studies of the safety and efficacy of video-assisted retroperitoneal debridement (VARD) show a reasonable safety and efficacy profile for retroperitoneal debridement, although the authors were unable to establish that VARD techniques are superior to open necrosectomy.[13]

- There are no controlled trials comparing open necrosectomy to laparoscopic methods.

COMPLICATIONS

- Acute complications include bleeding, sepsis, acute pancreatitis, pancreatic duct leak, need for repeat debridement, exocrine insufficiency, endocrine deficiency, and enteric leak.
- Long-term complications include pancreatic pseudocyst formation, chronic pancreatitis, enterocutaneous fistula, pancreatic fistula, and chronic abdominal/back pain.

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Chapter 51

Endoscopic Pancreatic Debridement and Drainage

Udayakumar Navaneethan Andres Gelrud

DEFINITION

- Endoscopic pancreatic debridement is performed in patients with pancreatic necrosis, in particular, walled-off necrosis (WON).
- Pancreatic necrosis is defined by the lack of enhancement of the pancreatic parenchyma on cross-sectional imaging after intravenous contrast administration.
- Pancreatic necrosis is classified as acute necrotic collection and WON depending on the time course (4 weeks) of the diagnosis of pancreatitis and presence or lack of encapsulated wall, by the revised Atlanta classification.[1]
- Acute necrotic collection is defined as a collection containing variable amounts of fluid and necrotic tissue involving the pancreatic parenchyma and/or the peripancreatic tissues occurring within the first 4 weeks of acute pancreatitis (**FIG 1**).[1]
- WON is a mature, encapsulated collection of pancreatic and/or peripancreatic necrosis that has developed a well-defined wall. WON usually occurs more than 4 weeks after onset of necrotizing pancreatitis (**FIG 2**).[1]

DIFFERENTIAL DIAGNOSIS

- It is important to distinguish WON from pseudocyst. Pseudocyst is a fluid collection in the pancreatic or peripancreatic tissue surrounded by a well-defined wall and contains no solid material. Diagnosis can be made usually on these morphologic criteria. Amylase activity is high if the pseudocyst fluid is aspirated. Disruption of the main pancreatic duct or its intrapancreatic branches without necrosis usually leads to pseudocyst formation.[1]
- Cystic neoplasm of the pancreas such as an intraductal papillary mucinous neoplasm or mucinous cystic neoplasm can mimic WON. A previous history of acute pancreatitis helps differentiate both conditions, and in occasion, fine needle aspiration (FNA) needs to be performed to better characterize the collection before endoscopic drainage.

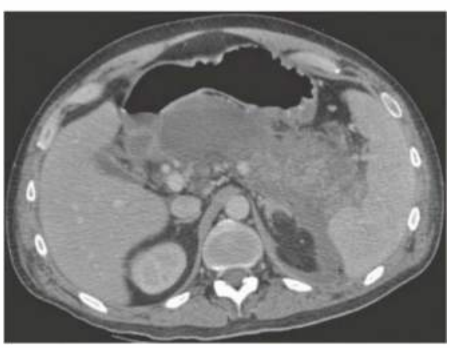


FIG 1 ● Acute necrotizing pancreatitis in a patient admitted 1 week ago now with persistent fevers and leukocytosis. CT reveals lack of contrast enhancement in most of the body and tail of the pancreas without encapsulation.

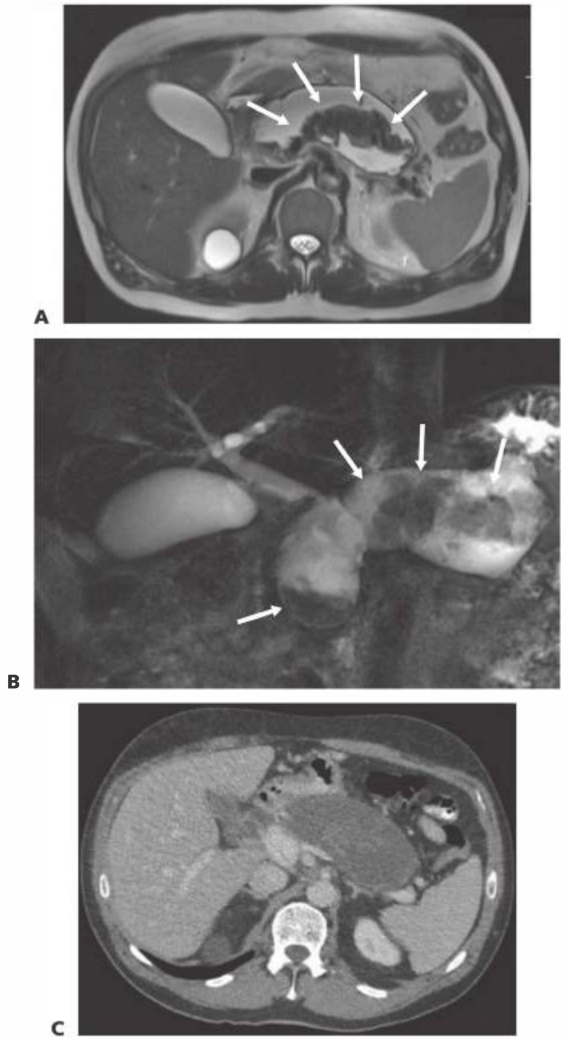


FIG 2 ● **A,B.** MRI revealing WON in a patient presenting with abdominal and back pain 2 months after an episode of necrotizing pancreatitis. In both images, the *arrows* represent necrosis inside the pancreatic and peripancreatic collection. **C.** CT scan image of same patient with WON.

PATIENT HISTORY AND PHYSICAL FINDINGS

- Two-thirds of patients with pancreatic necrosis in the setting of necrotizing pancreatitis have sterile necrosis and can be managed conservatively without any intervention.[2]
- Interventions performed in patients with sterile pancreatic necrosis can increase the risk of introduction of infection into the necrotic tissue, resulting in requirements for additional interventions and its associated morbidity and mortality.[3]

- Sterile pancreatic necrosis requires drainage only in patients with symptoms. External mechanical obstruction of the biliary system (elevated liver enzymes with a dilated bile duct) or gastric outlet with symptoms of nausea, vomiting, early satiety, and inability to resume oral intake. Persistent, narcotic-requiring pain or recurrent acute pancreatitis are indications for drainage.[4]
- However, the main role for endoscopic intervention is the presence, or suspicion, of infected necrosis with concomitant clinical deterioration.
- Debridement should be delayed, if at all possible, until the necrosis is walled off and a well-defined capsule is present, which usually takes around 4 weeks. WON is a prerequisite for successful endoscopic therapy.[4]
- The goal of therapy needs to be well defined and a multimodality approach (clinical pancreatologist, surgery, and interventional radiology) has a higher chance of success and should be considered. Surgical backup during endoscopic drainage is strongly recommended in case of complications at the time of endoscopic debridement.

IMAGING AND OTHER DIAGNOSTIC STUDIES

- The morphologic features of acute pancreatitis and resultant complications are diagnosed by high-resolution multidetector contrast-enhanced computed tomography (CT) and can detect most local complications as reported in the revised Atlanta classification.[1]
- The diagnosis of necrosis is based on imaging features of a heterogeneous collection with liquid and nonliquid density with varying degrees of loculations.
- WON is defined based on the presence of necrosis with a well-formed wall and complete encapsulation.
- CT may not readily distinguish with high sensitivity solid from liquid content to distinguish pseudocyst from necrosis.[1]
- WON may be better diagnosed based on magnetic resonance imaging (MRI) or endoscopic ultrasound (EUS) to detect necrosis within the collection.[1]

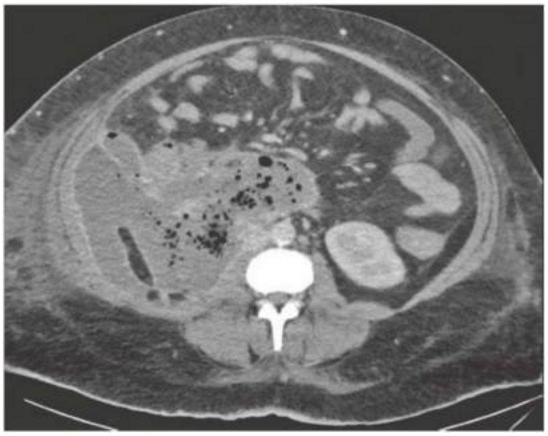


FIG 3 • CT scan image of infected WON with presence of gas within the collection.

- The diagnosis of infection (infected necrosis) of an acute necrotic collection (ANC) or of WON is based on the presence of gas within the collection on CT (**FIG 3**). This extraluminal gas is present in areas of necrosis. The diagnosis must be suspected in a patient with persistent organ failure, fevers, and elevated white blood count after the first week of admission. In situations where the diagnosis of infected necrosis is unclear, FNA for Gram stain and culture may be performed.

SURGICAL MANAGEMENT

Positioning

- The positioning of the patient needs to be selected based on the patient and the nature of the WON. In patients who are unstable, supine position is generally safer.
- In patients with posteriorly located collections, the prone position may allow for better gravitational drainage of WON for better success.

TECHNIQUES

INITIAL ENDOSCOPY

- Initial endoscopy is performed by using a therapeutic, side-viewing video duodenoscope, gastroscope, or echo-endoscope.
- We favor the use of general anesthesia to prevent aspiration.
- Although we use air routinely, carbon dioxide (CO_2) insufflation is always used during these procedures to minimize the theoretical risk of air embolism.
- Antibiotics with good pancreatic penetration should be routinely given prior and after the procedure to patients who are not already on broad-spectrum antibiotics.

ENDOSCOPIC ULTRASOUND

- Endoscopic ultrasound (EUS)-guided access is strongly recommended when gastric varices are present or when no gastric or duodenal compression with bulge formation is present. EUS-guided drainage can avoid local complications related to blind endoscopic drainage.[5]
- Under EUS guidance, the appropriate site of access to drain the WON can be established. This is particularly useful in patients without any bulging visible on endoscopy. The site in the gastric or duodenal lumen needs to be chosen and use of EUS is associated with fewer complications and higher success rates, particularly with those WON in the tail and those patients with varices to permit a safe passage of the needle.[5]
- The most appropriate site of transmural puncture should be through a wall less than 10 mm in thickness. In those

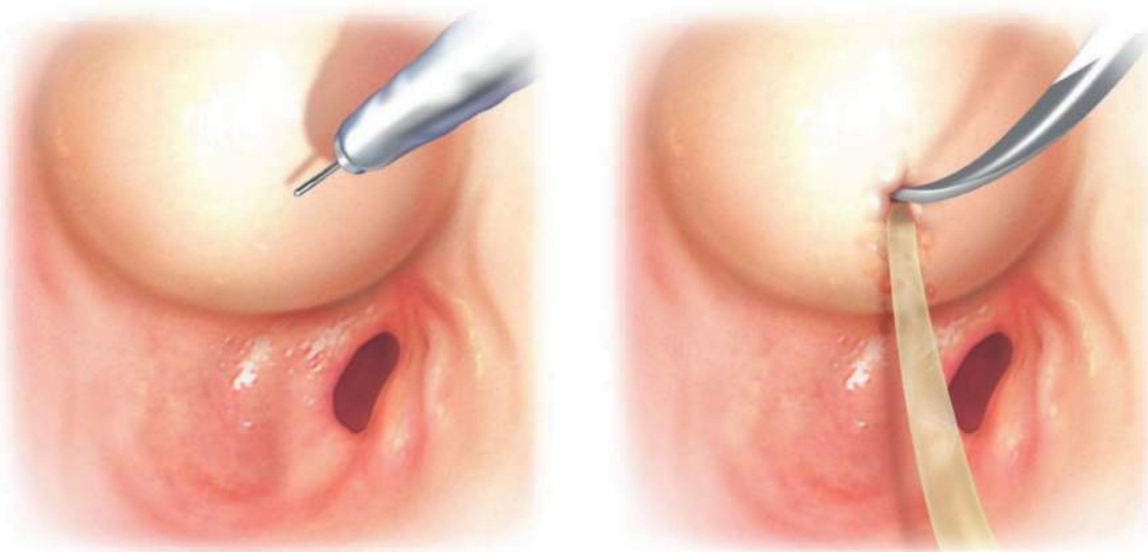
who do not use EUS and in those patients in which no bulging on the gastric or duodenal wall is visible, the most recent cross-sectional imaging may help decide the site of puncture.[6]

- When the appropriate site is identified, the posterior gastric or medial duodenal walls are targeted and punctured.
- In patients undergoing EUS, the use of color-flow Doppler can avoid hitting blood vessels at the time of wall puncture.[5]
- Use a 19-gauge FNA needle for puncture and subsequently the needle sheath for initial dilation of the tract (**FIG 4**).

FIG 4 ● EUS-guided access of pancreatic pseudocyst and necrosis. Loops of guidewire inside the pancreatic fluid collection and inflated balloon dilating the pseudocyst-gastrostomy track for stent placement.

THERAPEUTIC GASTROSCOPE OR DUODENOSCOPE

- A needle knife through a side-viewing duodenoscope can be used to initially enter the necrotic cavity when a bulge is clearly apparent and there are no varices (**FIG 5A–C**).
- Aspiration of the cavity fluid is performed and sent for fluid analysis (amylase, Gram stain, and culture). Contrast injection into the cavity, under fluoroscopic guidance, is also performed to confirm location inside of the cavity.
- Balloon dilation of the tract can be done in diameters ranging from 15 mm or 20 mm in size to allow for forward-viewing gastroscope to enter the cavity for direct endoscopic necrosectomy (**FIG 5C,D**).
- A standard long 460-cm guidewire (0.018 in up to 0.035 in) is advanced into the collection under fluoroscopic guidance, forming at least two loops in order to reduce the risk of inadvertent loss of guidewire access.
- The fistula tract is then created (**FIG 5D,E**).



A **B**

FIG 5 ● Direct endoscopic-guided access of pseudocysts and necrosis. **A.** Bulge present in the posterior wall of the gastric body and needle knife in place. **B.** Puncture site with guidewire in place and fluid drainage. *(continued)*

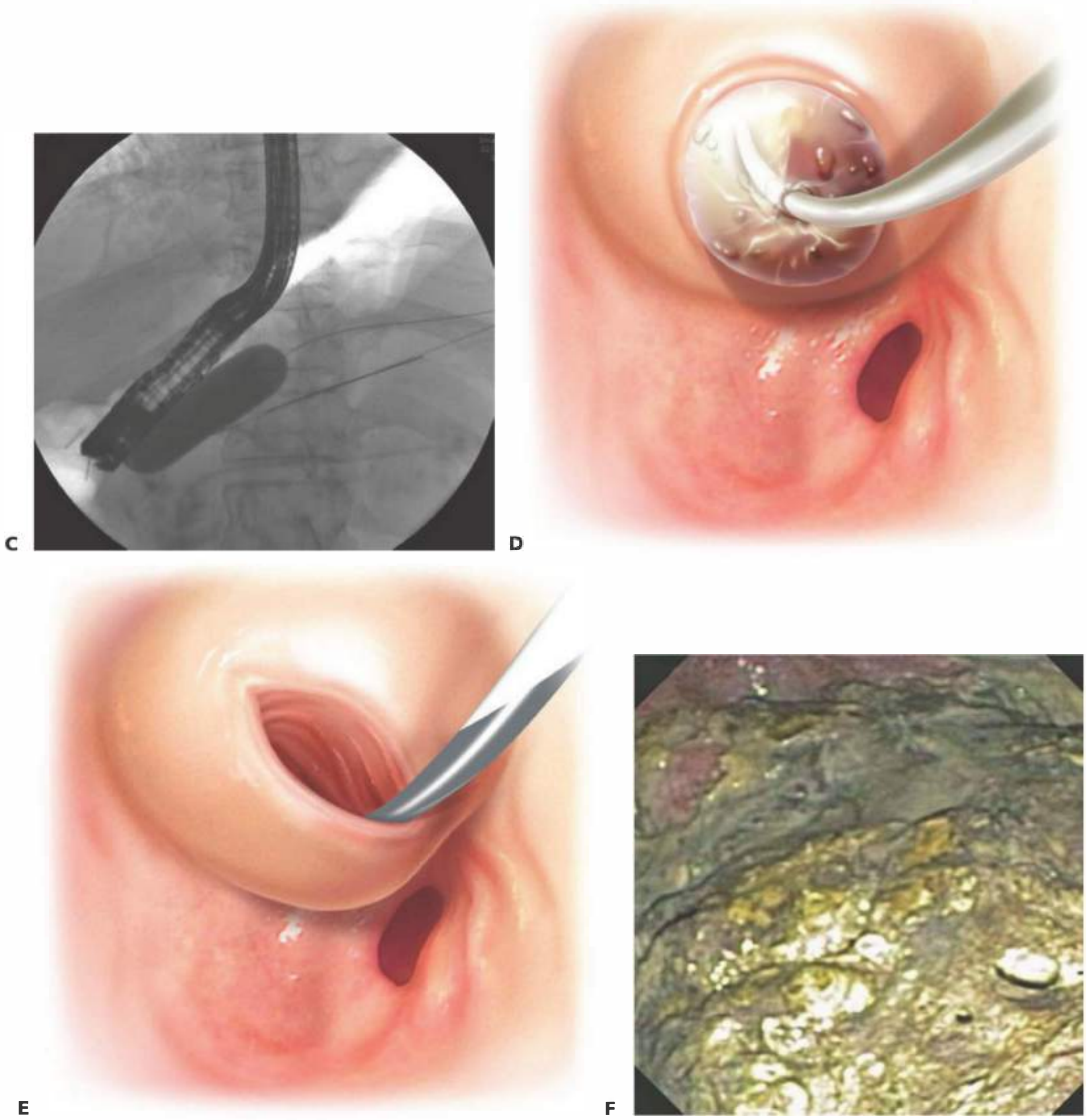


FIG 5 • *(continued)* **C.** Fluoroscopic view of guidewire inside the cavity with inflated balloon. **D.** Endoscopic view of the inflated balloon for fistula tract dilation. **E.** The cyst gastrostomy tract after balloon deflation. **F.** Appearance of the cavity upon entry. Large amount of necrotic debris. *(continued)*

- It is important to emphasize that the tract needs to be dilated enough to facilitate the passage of the endoscope into the cavity.
- Debridement of the intracavitary solid debris is done by using a forward-viewing gastroscope across the gastric or duodenal wall into the necrotic cavity.
- The fluid contents are first aspirated through the endoscope until dry, and devitalized necrotic tissue is then removed (**FIG 5F,G**).
- Several accessories can be used to remove the devitalized pancreatic tissue including snares, grasping forceps, snare with nets, and stone removal baskets.
- The degree of necrosectomy performed at each session is at the discretion of the therapeutic endoscopist; we favor removing as much as possible during the initial intervention to minimize the need for subsequent endoscopic interventions. The goal is to uncover the pink granulation tissue lining the wall.

Stent Placement

- After necrosectomy is performed, stent placement is performed. The stents keep the cyst gastrostomy or cyst duodenostomy site open and help drain the WON during

FIG 5 ● *(continued)* **G.** Large fragments of necrotic debris are removed endoscopically. Most of the necrotic debris are left in the gastric lumen or suctioned with the endoscope. **H.** Multiple soft double-pigtail stents are placed to keep the patency of the cyst gastrostomy site and facilitate further drainage. **I.** Fluoroscopic view of stent placement after cavitary debridement. A nasojejunal feeding tube was also placed to ensure adequate nutrition. **J.** Suctioned fluid during and soon after wall puncture.

liquefaction of the possible retained devitalized tissue inside the cavity.

- Place multiple 10-Fr parallel soft double-pigtail stents (**FIG 5H,I**). Recently, others have used a fully covered metal stent 10 mm in diameter to facilitate subsequent intracavitary intervention.
- Placement of a double-pigtail stent (inside of the metal stent) is frequently performed to prevent metal stent migration and occlusion (**FIG 6**).
- Placement of a single stent is associated with increased risk of occlusion and increases the risk of treatment failure.
- The fistula tract needs to be kept open for any fluid collection and necrotic debris to drain. There is a theoretical benefit of having gastric acid inside the cavity.
- For WON of 20 cm or larger in size, we favor hybrid therapy with placement of percutaneous catheter to be used as a flushing and transmural drainage (**FIG 7A,B**). Other hybrid therapies have been described. More than one endoscopic intervention is frequently required in large WON collections.
- The plastic stents either fall off spontaneously once the WON is resolved or may require removal. Some centers never remove the cyst gastrostomy stents.
- In patients who have a large WON collection or large amount of necrotic content, repeat endoscopic procedure may be required which involves endoscopic removal of stents and repeat necrosectomy.

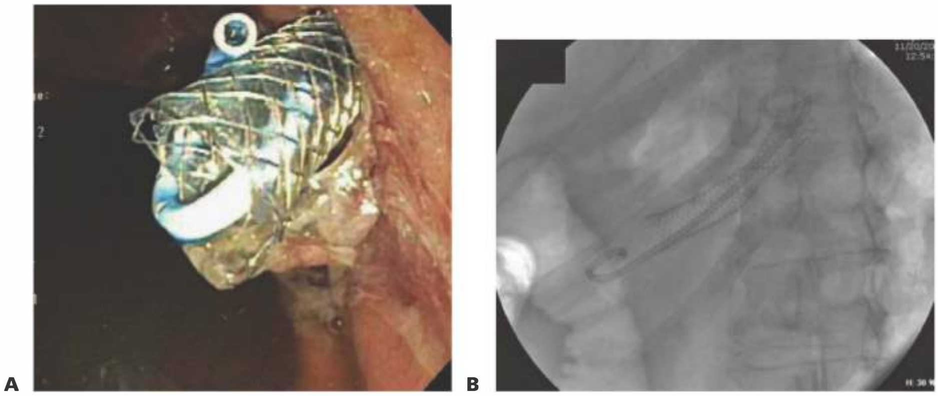
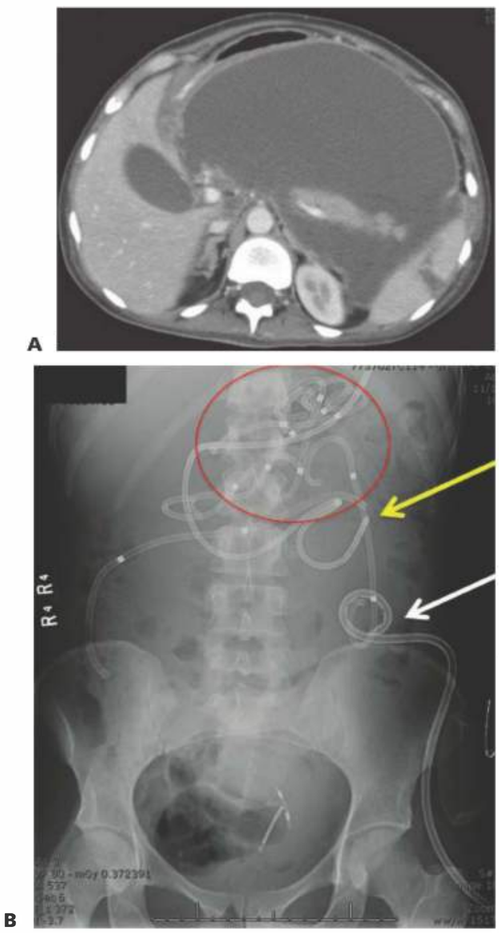


FIG 6 ● **A.** Fully covered metal stent and double-pigtail stent (inside) at cyst gastrostomy site. **B.** Fluoroscopic view of plastic inside metal stent placement at cyst gastrostomy site.



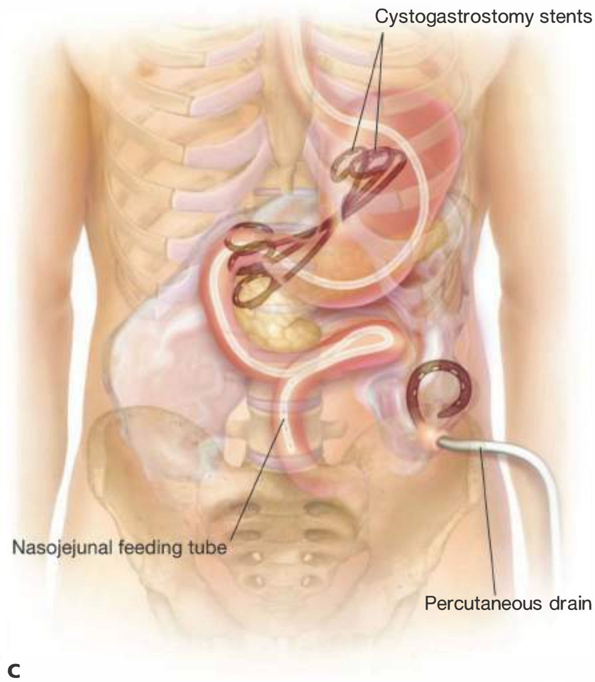


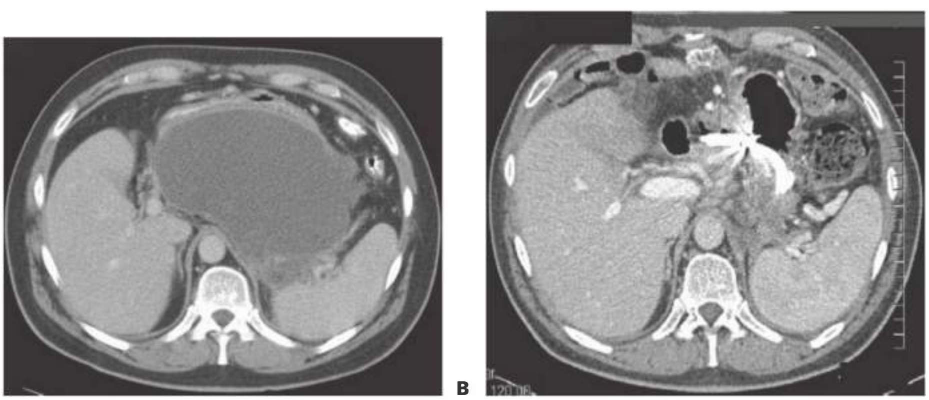
FIG 7 ● **A.** CT scan with giant WON extending to the pelvis. **B.** Abdominal x-ray after cyst gastrostomy stents *(red ellipse)*, nasojejunal feeding tube placement *(yellow arrow)*, and left lower quadrant 12-Fr percutaneous drain placement *(white arrow)*. **C.** Illustration depicting Figure 7B.

PEARLS AND PITFALLS

Indications	■ A thorough history and physical is required to make a decision whether the WON requires intervention or not. ■ Multidisciplinary team approach ■ Two-thirds of patients with pancreatic necrosis in the setting of necrotizing pancreatitis have sterile necrosis and can be managed conservatively without any intervention. ■ Interventions performed in patients with sterile pancreatic necrosis can increase the risk of introduction of infection into the necrotic tissue. Only patients with symptoms are treated. ■ Cystic neoplasm of the pancreas such as an intraductal papillary mucinous neoplasm and serous or mucinous cystic neoplasm can mimic WON. A previous history of documented pancreatitis must be present. In some patients, EUS with FNA needs to be performed before endoscopic drainage.
Endoscopy preparation	■ Antibiotics should be routinely given prior and after the procedure in patients who are not already on broad-spectrum antibiotics. ■ Antibiotic therapy is continued for 10 to 14 days postprocedure. ■ Use general anesthesia to prevent aspiration. ■ Use CO_2 instead of air for endoscope insufflation.
Site of access	■ The appropriate site of access needs to be established under EUS guidance when varices are present or patients without visible bulge on endoscopy. ■ Endoscopic therapy is only indicated when well-demarcated WON is present and, preferably, the collection should be within 1 cm of the gastrointestinal lumen.
Fistula tract size	■ The fistula tract needs to be dilated to at least 10 mm in size for the forward-viewing gastroscope to enter the cavity; for direct necrosectomy, we favor dilating 15 mm or up to 20 mm.
Stent placement	■ After necrosectomy is performed, multiple (4–6) soft double-pigtail stents are placed. ■ Placement of a single 10 mm in diameter cover metal stent with an inner plastic double-pigtail stent is being used in some centers; no clinical studies available.
Failure of endoscopic procedure	■ If the WON fails to resolve or reaccumulates, disconnected pancreatic duct syndrome should be considered, which will require additional procedures. ■ Large or complex collections may benefit from hybrid, endoscopic, and percutaneous drainage.

POSTPROCEDURE CARE

- The symptoms that lead to the procedure rapidly resolve after successful therapy. If related to extrinsic compression, the patient wakes up with immediate relief; when related to infection symptom, resolution depends on the severity.
- Most patients are able to start a clear liquid diet and rapidly advance to low fat soon after successful debridement.
- Cross-sectional imaging is performed (either MRI or CT scan) 1 month after initial necrosectomy to document resolution (**FIG 8**).
- Additionally, if the collection fails to resolve or reaccumulates, disconnected pancreatic duct syndrome should be considered.
- The treatment of disconnected pancreatic duct syndrome includes endoscopic retrograde cholangiopancreatography (ERCP) with transpapillary stenting across or into the cavity



A B

FIG 8 ● Ambulatory patient that presented 6 weeks after an episode of necrotizing pancreatitis with symptoms of gastric outlet obstruction. **A.** CT scan with well-demarcated WON compressing the gastric lumen. **B.** Five weeks after successful transgastric endoscopic necrosectomy.

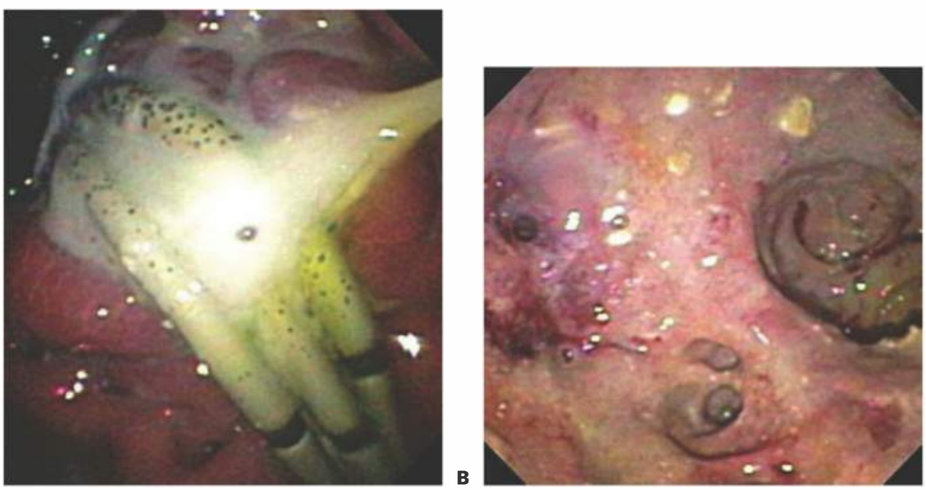
and, in occasions, combined with percutaneous drainage. Resection of the distal remnant must also be entertained.

OUTCOMES

- Endoscopic drainage has been shown to be very successful. A large study in the United States, including more than 100 patients from six academic medical centers, reported that the median number of endoscopic procedures required to treat the WON (of median size of 15 cm) was three and the largest size of cyst enterotomy tract dilation performed was 18 mm. WON resolved in 90% of the patients over a period of 4 months.[7]
- Similarly, in a European study of more than 90 patients who underwent necrosectomy, 54% of the WON was infected. Sixty percent of patients had undergone previous percutaneous or transgastric drainage procedures with failure of necrotic pancreatic fluid collection resolution. Patients require a median number of six endoscopic procedures and the tract was dilated to between 15 and 20 mm.[8] Symptom resolution occurred in 80%, whereas greater than 50% of patients demonstrated radiographic resolution.[8]
- In addition to these studies, smaller cohort studies have reported similar rates of resolution of WON from 75% to 95%.[9,10]
- Thus, the overall efficacy of endoscopic necrosectomy is more than 75% in experienced centers.

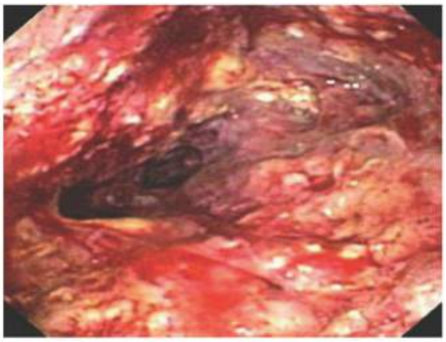
COMPLICATIONS

- Endoscopic treatment of WON is associated with potential complications. Multidisciplinary approach to determine endoscopic debridement candidacy and surgical backup during the endoscopic procedure are strongly recommended.
- The overall complication rate of transmural drainage or debridement in WON is reported between 15% and 25%.[7,8]
- Pneumoperitoneum perforation is reported in about 5% of patients; only symptomatic patients require further intervention.[7,8]
- It is the author's opinion that death and bleeding leading to blood transfusion, arterial embolization, or surgery may be underreported.
- Only symptomatic patients with mature collections are eligible for endoscopic drainage. WON collection should be within 1 cm of the gastrointestinal lumen.
- Stepwise, balloon dilation of the fistula tract; avoiding overinsufflation of the cavity with CO_2; and performing gentle debridement using baskets, soft snares, and retrieval baskets or nets may decrease the risk of bleeding and perforation.
- Bleeding can occur in up to 18% of patients undergoing debridement of WON.
- Most patients with bleeding can be managed endoscopically, although some may require interventional radiology or surgical intervention.
- Air embolism resulting in death has been reported.
- Other complications include infection particularly if the WON is not appropriately debrided (**FIG 9**), pancreatitis, aspiration, stent migration/occlusion, and complications of sedation.
- Adequate advanced therapeutic training with availability of appropriate surgical backup is necessary to avoid and manage complications.



A B

FIG 9 ● Representative images of a patient that underwent successful endoscopic necrosectomy. Two days after completing a full course of antibiotics presented with fever and chills. **A.** Pus drainage at the cyst gastrostomy site. **B.** Reinsertion of the scope inside of the cavity for further debridement. *(continued)*



C

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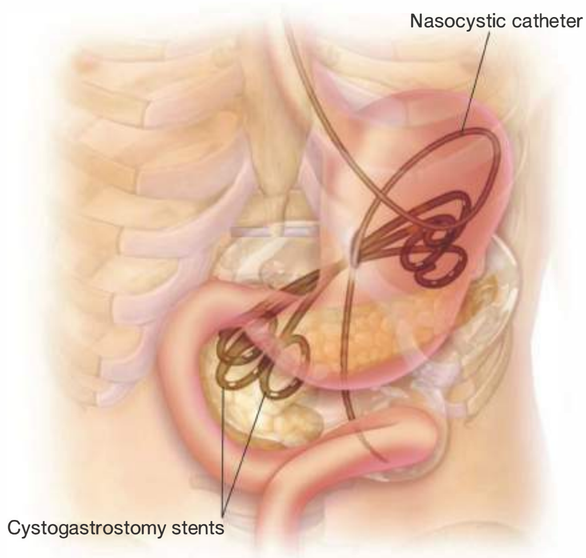

E

FIG 9 ● *(continued)* **C.** After washing and debridement, the pink color of the cavity and minimal oozing is visualized. **D.** Fluoroscopic image of multiple stents in the gastrostomy site and presence of nasocystic catheter for frequent flushing. **E.** Illustration depicting Figure 9D.

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Chapter 52 Splenectomy (Open and Laparoscopic Techniques)

Vanessa Cranford Janeen R. Jordan Frederick A. Moore

DEFINITION

- Splenectomy is defined as the surgical removal of the spleen.

DIFFERENTIAL DIAGNOSIS/INDICATIONS

- Traumatic rupture
- Autoimmune disorders
- Red blood cell disorders
- Genetic disorders
- Lymphomas/leukemias/myeloproliferative disorders
- Vascular disorders
- Idiopathic/iatrogenic
- Miscellaneous (abscesses, tumors, cysts)

PATIENT HISTORY AND PHYSICAL FINDINGS

- A thorough history should be performed prior to surgery, including a detailed past medical history, all signs and symptoms of disordered bleeding and liver failure, as well as a history of abdominal pain or constitutional symptoms. A list of medications, allergies, and personal and family histories of bleeding, clotting disorders, and cancers should be noted.
- A complete physical exam of the patient should be done and *all* patients should be examined for signs of portal hypertension or liver failure as well as the presence or absence of splenomegaly.
- Patients presenting with splenic trauma have variable clinical presentations determined by the severity of injury, ranging from mild abdominal pain with hemodynamic stability to peritonitis and hemorrhagic shock with complete cardiovascular collapse. This hemodynamic instability can be immediate upon presentation or days later in the case of a delayed rupture.
- Hematologic conditions such as leukemia present with a patient history of purpura, epistaxis, petechiae, gingival bleeding, hematuria, gastrointestinal bleeding, myalgia, or fatigue. Although now a rare indication for splenectomy, patients with lymphomas and myeloproliferative disorders present with diffuse lymphadenopathy, constitutional symptoms, pancytopenia, abdominal pain, splenomegaly, or early satiety.
- Patients with hemoglobinopathies and hereditary disorders present with jaundice, abdominal pain, or splenomegaly. Alternatively, they may be asymptomatic and incidentally identified due to an abnormal laboratory value obtained for a different indication.
- Patients with hereditary spherocytosis (HS) benefit from splenectomy. Sequestration of the defective red blood cells (RBCs) results in splenomegaly in 75% of affected patients.[1] Splenectomy eliminates or improves anemia in patients with moderate HS and eliminates the need for regular transfusions in patients with the severe form of the disease.[2,3] These patients often receive splenectomies in childhood to alleviate symptoms and long-term sequela of the disease including skeletal abnormalities and repeated need for blood transfusion. In mild HS, the purpose of splenectomy is to prevent the production of bilirubin gallstones (a common complication that has an increased prevalence with age). In these cases, splenectomy is combined with a cholecystectomy.
- Splenectomy for hematologic disorders such as idiopathic thrombocytopenia (ITP) is a result of failed medical management to control thrombocytopenia or abdominal pain associated with splenomegaly. Most of these patients will be referred to a treating hematologist. Medical management is the first-line treatment for ITP and most patients initially respond to glucocorticoids. However, in one series, only 39% of prednisone-treated patients achieve complete remission, and only one-half of these patients have sustained remission beyond 6 months of cessation of maintenance therapy.[4] Intravenous immunoglobulin (IVIG) can also be used as first-line treatment and can increase the platelet count in over 75% of patients within 5 days of treatment.[5] However, it is not a long-term cure. It is reserved for those patients with life-threatening bleeding and intracranial hemorrhage and those preparing for splenectomy or other surgical procedures. Otherwise, splenectomy is reserved for patients with symptomatic thrombocytopenia following glucocorticoid administration for at least 8 weeks and having a platelet count persistently less than 30,000/μL. Splenectomy is also indicated in patients who recur after cessation of therapy.
- Splenectomies may be performed via open or laparoscopic technique. The approach is determined by the disease process and clinical stability of the patient. Absolute and relative contraindications for laparoscopic splenectomy are listed in Table 1.

IMAGING AND OTHER DIAGNOSTIC STUDIES

- All patients with a known or suspected hematologic, autoimmune, or myeloproliferative disorder should have a blood smear or bone marrow analysis as needed and a hematologist fully involved in the patient's evaluation and treatment plan.
- Computed tomography (CT) scan is the ideal imaging modality for splenic disorders and is a crucial part of planning

Table 1: Absolute and Relative Contraindication of Laparoscopic Splenectomy

Absolute	Relative
Severe cardiopulmonary disease	Splenomegaly
Cirrhosis with portal hypertension	Short gastric varices with coagulopathy
Pregnancy	Previous abdominal surgery

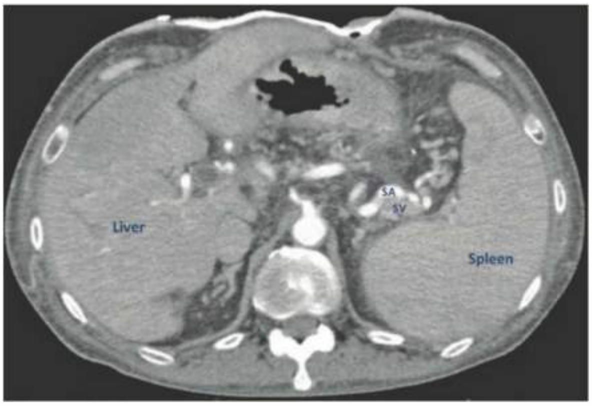

FIG 1 ● CT image demonstrating splenomegaly. The volume of the spleen approaches that of the liver. *SA,* splenic artery; *SV*, splenic vein.

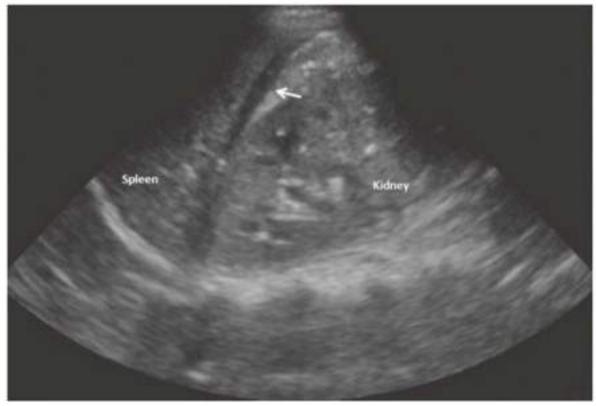

FIG 3 ● Positive FAST showing intraperitoneal fluid. *White arrow* indicates intraabdominal fluid. This would be the appearance of blood in a traumatic injury.

for the operating room (OR). CT has the capability for determining the size of the spleen, the anatomy and size of the splenic vascular supply, the relationship of the spleen to surrounding organs, and potential locations of accessory spleens in the abdomen (**FIG 1**). For stable trauma patients, it can accurately identify the extent of splenic injury (**FIG 2**).

- Ultrasound is a noninvasive modality for the examination of splenomegaly and portal hypertension. In the setting of a trauma, focused abdominal sonography for trauma (FAST) has become an accepted screening tool to diagnose intraperitoneal blood (**FIG 3**).
- Magnetic resonance imaging (MRI) of the spleen is an excellent method for evaluating focal lesions as well as aid in the detection and differential diagnosis of peri- and intrasplenic tumors.[6]

SURGICAL MANAGEMENT

Preoperative Planning

- Certain patients with autoimmune disorders will be treated with prolonged courses of glucocorticoids. It is important to consider administering appropriate stress-dose steroids intraoperatively, with rapid tapering postoperatively.

FIG 2 ● CT of splenic injury. *White arrow* points to one of the lacerations.

- Blood products should be ordered and available intraoperatively. If the need for transfusion arises, it should be given *after* ligation of the splenic artery, provided the splenectomy is performed for hematologic disorders.
- For all elective cases, vaccinations against the encapsulated organisms (*Hemophilus influenza B*, *Streptococcus pneumoniae*, and *Neisseria meningitidis*) should be administered prior to surgery. For emergent cases, vaccinations should also be administered. Timing of vaccination is debated, but 2 to 4 weeks postoperatively is recommended, although for trauma patients, just prior to discharge is acceptable due to a high incidence of patients not returning for postinjury clinic appointments. This is to prevent the incidence of overwhelming postsplenectomy infection (OPSI). It is the most feared complication of splenectomy. OPSI is the development of a fulminant, rapidly fatal bacterial infection following the removal of the spleen. The current incidence of OPSI in the first 2 years postsplenectomy is estimated to be 0.9% for adults and 5% for children.[7] Current guidelines for vaccination to prevent OPSI are listed in Table 2.
- All patients should be given a prophylactic dose of antibiotics to cover skin flora within 60 minutes of making the skin incision in the OR. Nasal or oral gastric tubes should be inserted once the patient is under anesthesia to decompress the stomach and aid in visualization. This will often be left in postoperatively for 24 to 48 hours to prevent gastric distention and subsequent disruption of the ligated short gastric vessels.

Table 2: Guidelines for Overwhelming Postsplenectomy Infection Prophylaxis

Haemophilus influenzae B, pneumococcus, and meningococcus 2 weeks preoperatively (elective cases) or at discharge or 2 weeks postoperatively (nonelective cases)
If patient received immunosuppression therapy, vaccinate 3 months after treatment.
Booster vaccinations for pneumococcus +/− meningococcus every 5 years
H. influenza AB titers can be followed to assess the need for booster dose.
Consider monitoring antibody titers of all three pathogens in immunocompromised patients.

- Laparoscopic splenectomy is the operation of choice for most elective splenectomies. However, other options include hand-assisted or open approaches. Indications for conversion from laparoscopy to an open procedure include intolerability or inability to insufflate the peritoneum, uncontrollable coagulopathy or hemorrhage, massive splenomegaly that is unable to be placed in the extraction bag, or need for another procedure.
- In cases of massive splenomegaly or portal hypertension, preoperative embolization of the splenic artery by interventional radiology will decrease the amount of blood loss and may aid in the technical aspects of the procedure. Embolization of the splenic artery causes decreased perfusion and thereby results in involution of the spleen, making mobilization of the spleen technically easier.

POSITIONING

- Patients undergoing laparoscopic splenectomy can be positioned supine or in the right lateral decubitus position. In the latter position, the beanbag or kidney rest is placed to maximize exposure between the costal margin and iliac crest. The table may also be flexed to assist in widening this space. Ensure that all pressure points are properly padded and the shoulders, extremities, and spine are in comfortable, neutral positions (**FIG 4**).
- For open splenectomies, most patients are placed in a supine position, with both arms extended, and a midline laparotomy incision is made. Indeed, in the case of an exploratory laparotomy in the setting of a trauma, this is the recommended approach as the surgeon will need to evaluate the entire abdomen for other injuries. An additional option in isolated nontraumatic open cases is to make a left subcostal incision.

FIG 4 • Patient positioning in the right lateral decubitus position.

TECHNIQUES

OPEN SPLENECTOMY

Incision

- Prior to incision, ensure adequate monitoring and intravenous access is obtained in preparation for potential bleeding. An arterial line is not mandatory but is recommended. A nasogastric (NG) tube should be placed for optimal gastric decompression, which will be imperative for visualization of the spleen.
- After endotracheal intubation and standard prepping and draping of the patient, a midline laparotomy incision is used to enter the peritoneal cavity (**FIG 5**). If this is an isolated splenectomy with no concern for other injuries, a supraumbilical incision can be made initially with extension inferiorly as needed for exposure. If the operation is done in the setting of an exploratory laparotomy with concern for other intraabdominal injuries, a generous incision from xiphoid to pubis should be made. Quickly evacuate all fluid and particulate matter (if present) and place a retractor to aid in visualization. This step is imperative. Without good exposure from retraction and adequate visualization, the propensity for bleeding will increase, making the operation much more technically difficult.

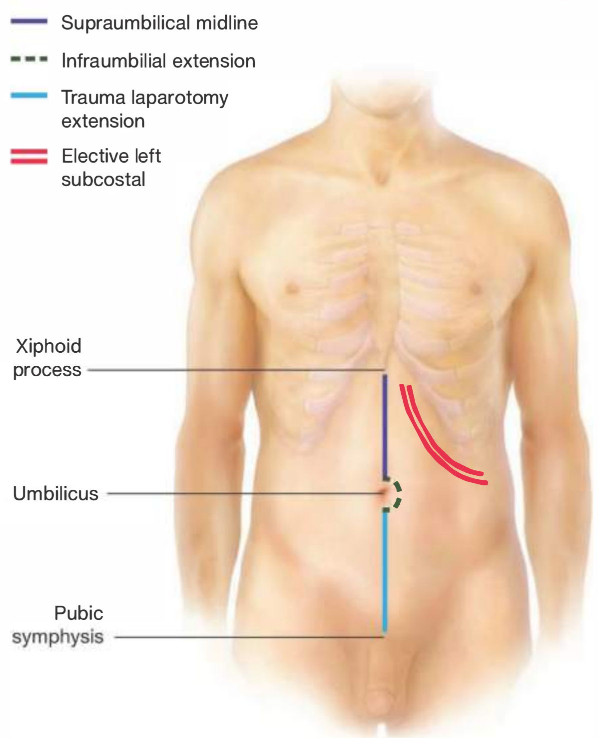

FIG 5 • Various incisions for an open splenectomy.

Mobilization

- The spleen resides high and posterior in the upper left abdomen. In order to remove the spleen, all peritoneal and visceral attachments must be removed. These include the splenorenal attachments to the kidney; the splenophrenic attachments to the diaphragm; the splenocolic

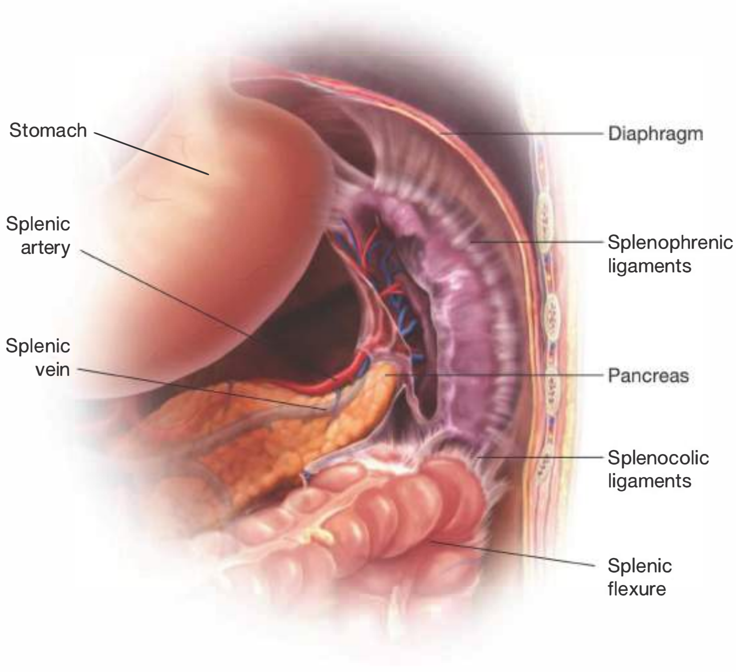

FIG 6 ● Attachments of the spleen in the left upper quadrant.

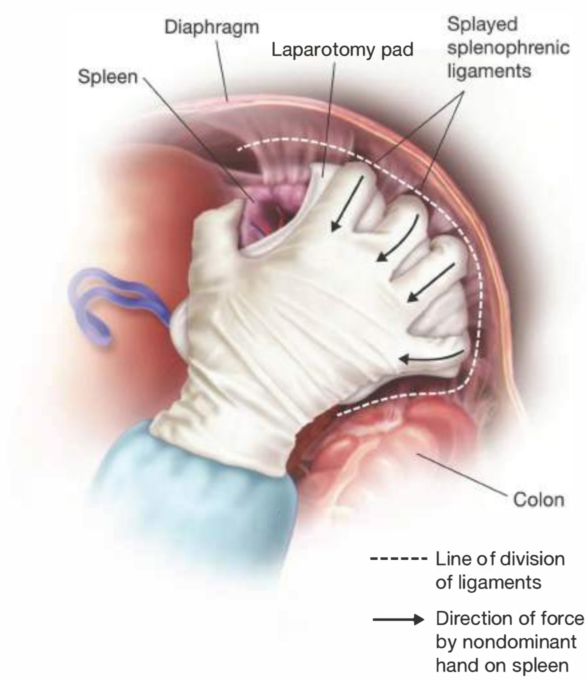

FIG 7 ● Direction of force applied to the spleen and line of division of the splenic attachments.

attachments to the splenic flexure of the colon; and the gastrosplenic ligament, which contains the short gastric vessels (**FIG 6**).

- Splenic mobilization is accomplished using traction and countertraction. The operating surgeon places a splayed, nondominant hand (usually with the aid of a lap sponge for better grip) and applies dorsal and medial traction on the spleen. This will help clearly define the splenorenal and splenophrenic ligaments. Be sure to first mobilize all attachments of the spleen to the anterior abdominal wall or you will find this maneuver cannot be done.
- Downward dorsal and medial traction is important as a tendency for a lifting out of the left upper quadrant often occurs. This can result in capsular tearing, with unnecessary bleeding or hemorrhage.
- Division of the ligaments is initiated with the splenocolic ligament. Mobilization of the splenic flexure displaces the colon away from the spleen (**FIG 7**). This is best done sharply or by using electrocautery. Once this is done, continue laterally toward the splenorenal ligaments, which when divided, separate the spleen from Gerota's fascia of the kidney. Finally, continue superiorly to the splenophrenic ligaments. Again, the importance of traction and countertraction cannot be overemphasized. The first assistant provides countertraction with tissue forceps to divide the ligaments, whereas the surgeon continues to maintain midline traction on the spleen.

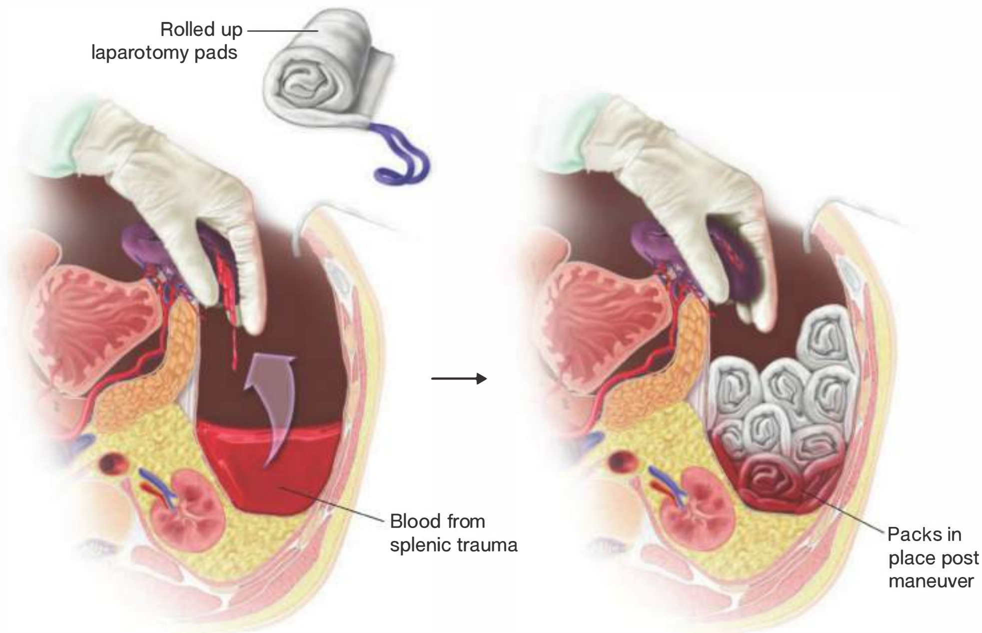

FIG 8 ● Quick blunt mobilization and posterior packing with laparotomy pads in a traumatic injury.

- Even in the setting of trauma and hemorrhage, mobilization of the spleen medially is the key to gaining vascular control. The steps are the same, simply done in a quicker fashion. In many traumatic splenic injuries, the dissection may be done for you by the trauma and resultant hematoma, and much of the remaining dissection can be done bluntly. If facing an exsanguinating spleen in a sea of blood, it may be difficult to see the attachments; however, you will be able to palpate them. Digital traction and blunt mobilization is employed, then laparotomy pads are sequentially placed posteriorly (**FIG 8**). This bluntly dissects the attachments of the spleen for you and aids medial and anterior mobilization. Generally, 5 to 10 laparotomy pads are used for this maneuver.
- Division of the ligaments should be made 1 to 2 cm from the spleen to avoid injury to both the spleen and other organs. As the spleen is mobilized anteriorly, deeper layers of connective tissue are brought into view and can be easily divided either bluntly or sharply.
- Once free from the retroperitoneal attachments, digital control of the hilar vessels can be accomplished and will stop any ongoing hemorrhage and improve visualization.
- As dissection continues lateral to medial, the left adrenal gland will come into view and should remain untouched. The tail of the pancreas and the splenic vein will also come into view. This visualization is crucial and paramount to preservation of the pancreas without disruption (**FIG 9**).

FIG 9 ● Appropriate plane of dissection to mobilize the spleen and pancreas medially.

Ligation of Vessels and Excision

- With the spleen fully mobilized midline, one can turn attention to the vascular supply. Gentle traction can be placed on the gastrosplenic ligament which will allow exposure of the short gastric vessels (**FIG 10**). Traction will also allow visualization of the stomach wall, of which injury should be avoided. The short gastric vessels are then divided using either bipolar electrocautery, ultrasonic shears, or sutures as desired (**FIG 11**).
- The splenic artery is seen on the superior border of the pancreas and is visualized entering the hilum of the spleen. The artery and vein are individually isolated or ligated en bloc, using suture ligature (such as 0-silk), LigaSure (Valleylab, Boulder, Colorado, CA), or vascular load stapler. The spleen is now free and can be passed off for pathologic examination.
- The tail of the pancreas will often extend into the splenic hilum. In 75% of patients, it lies within 1 cm of the hilum, and of these, 30% actually touch it.[8] Care must be taken to ensure a pancreatic injury is avoided when dividing and ligating the splenic vessels (**FIG 12**).
- Once the spleen is removed and hemostasis is obtained, if electrocautery was used for division, the short gastric vessels are oversewn along the greater curvature of the stomach. Careful attention should be made to the apical vessels; this is the most frequent site of missed, surgical bleeding requiring reoperation.
- If the splenectomy was undertaken for hematologic disorders, close inspection for accessory spleens *must* be undertaken or the operation has a high chance for failure to cure. Accessory spleens are identified in up to 30% of patients. Common locations for accessory spleens are the splenic hilum, the splenorenal ligament, the greater omentum, the retroperitoneal area surrounding the tail of the pancreas, the splenocolic ligament, and the small bowel mesentery. These areas must be examined after splenectomy, and if splenic tissue is found, it must be excised as well.

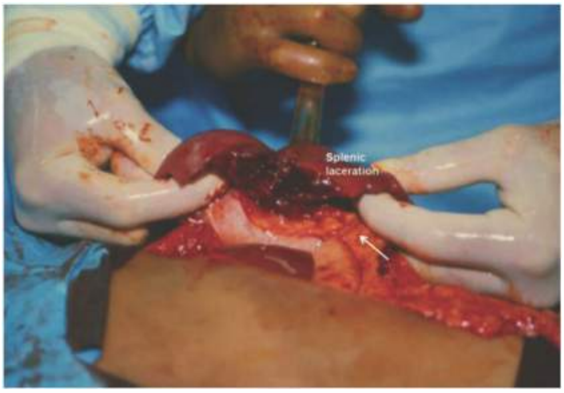

FIG 10 ● Mobilization of the spleen medially and exposure of the gastrosplenic ligament, containing the short gastric vessels *(arrow)*.

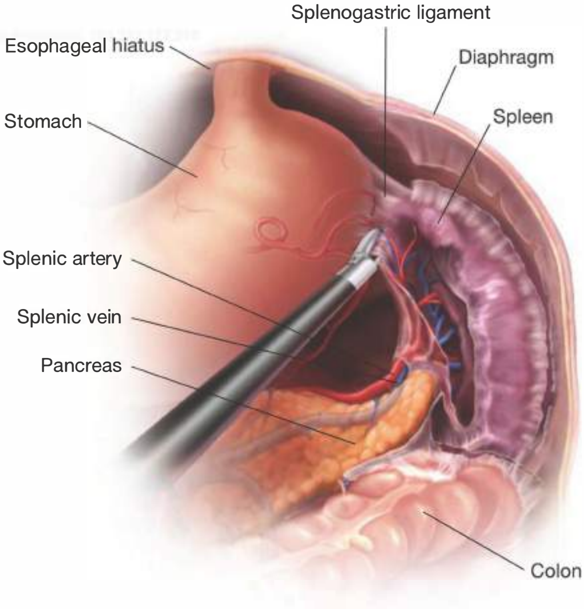

FIG 11 ● Division of the short gastric vessels.

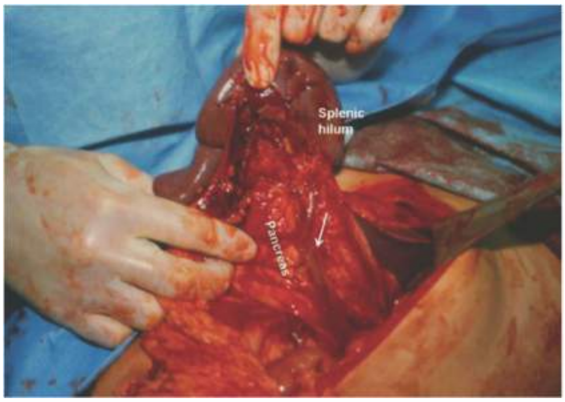

FIG 12 ● The tail of the pancreas abuts the splenic hilum. *White arrow* indicates the splenic vein.

Closure

- Once the spleen is removed, attention must be made to ensuring hemostasis is achieved. All laparotomy pads are removed and careful examination of the splenic bed must be undertaken. Oozing from the splenic bed can usually be controlled with selected cauterization, argon beam, or hemostatic agents.
- Once hemostasis is achieved and assessment for accessory spleens is completed, irrigation of the abdominal cavity may be necessary and the abdomen is closed in the usual fashion. There is no reason to place a closed suction drain

in the splenic bed, unless injury of the tail of the pancreas is known or suspected.

- If the splenectomy occurred in the setting of a damage control laparotomy and multiple injuries are treated, the abdomen is often left open. This allows for a second-look laparotomy and treatment of impending abdominal compartment syndrome. In this situation, it is appropriate to obtain hemostasis as able, then leave laparotomy pads in the left upper quadrant and reevaluate after correction of coagulopathy and sufficient resuscitation.

LAPAROSCOPIC SPLENECTOMY

Incision

- The position of the operating surgeon and placement of the port sites can be seen in **FIG 13**. Once pneumoperitoneum is established, the operation is begun with a thorough exploration of the abdominal cavity, looking for accessory spleens, in locations stated earlier. If found, all accessory spleens need to be excised.

Mobilization

- There are two main approaches for mobilization of the spleen, the supine (anterior) approach and the lateral decubitus approach. As the lateral approach is the one most commonly used when performing laparoscopic splenectomies, it will be the operation described in the following text.
- Following placements of proper monitors, vascular access, antibiotic administration, and endotracheal intubation, the patient is placed in the right lateral decubitus position, with beanbag support and proper padding and positioning of the head, shoulders, neck, and extremities.
- Dissection begins similar to an open procedure, with mobilization of the splenic flexure of the colon from the spleen. This is done using sharp dissection under direct visualization and can be done using hook electrocautery or an ultrasonic dissector. It is important to note that this division of the splenocolic ligament should be done without disturbing the spleen itself, decreasing the risk of a capsular tear (**FIG 14**). As with an open procedure, the technique of traction and countertraction is also employed with the laparoscopic technique.
- Dissection is approached in an inferior to superior counterclockwise direction. The superior splenophrenic attachments are left intact, however, to help facilitate exposure for dissection of the splenic hilum.
- Small accessory vessels can be seen with attachments to the greater omentum. These vessels can be individually divided using electrocautery.
- With the complete release of the splenocolic ligament and posterior dissection up to the splenophrenic ligament, dissection of the hilum itself can now begin.

Ligation of Vessels and Excision

- Similar to the open procedure, the lesser sac is entered and progression moves in a cephalad direction, exposing the anterior surface of the hilum. The posterior aspect of the hilum should already be cleared. This allows the surgeon to have quick access for any unexpected bleeding should it arise before isolating the vessels themselves.

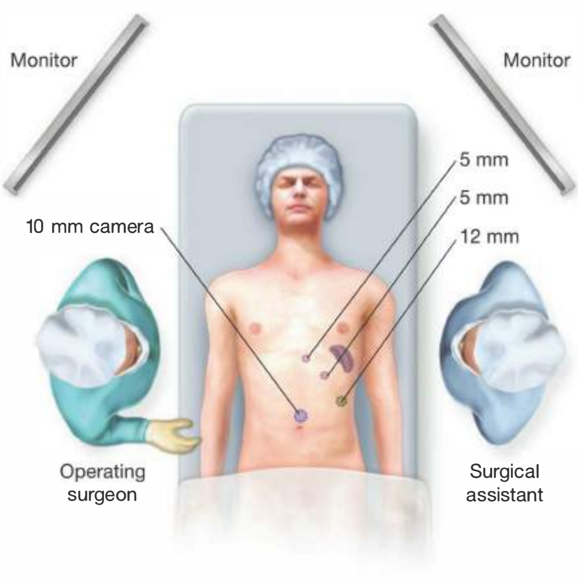

FIG 13 ● Arrangement and port site placement for a laparoscopic splenectomy. Note that patient is drawn supine to clearly show port site placement.

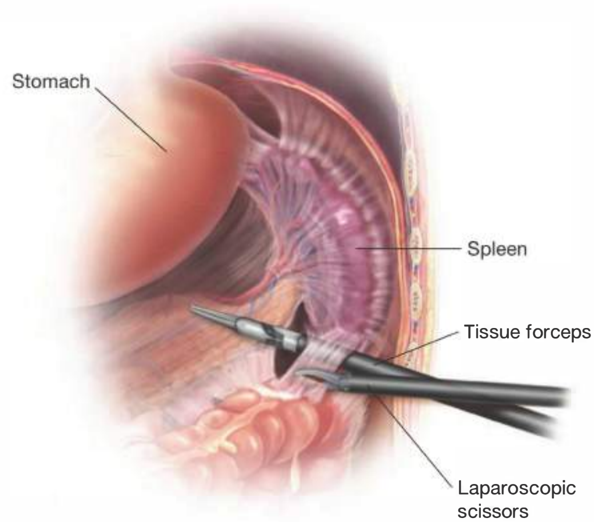

FIG 14 ● Laparoscopic division of the splenocolic ligament.

- The short gastric vessels and main vascular pedicle are visualized. The short gastric vessels are divided using an ultrasonic or bipolar electrocautery dissector along the greater curvature of the stomach. With this released, the hilum of the spleen is easily accessible.
- Once the splenic artery and vein are dissected free using a combination of blunt dissection and hook electrocautery, the vessels are ligated in a similar fashion to the open approach, using suture ligature or (more commonly) an endoscopic vascular stapler (**FIG 15**). Ligating and dividing the artery and vein individually to prevent a future arteriovenous fistula was once standard practice; however, resection of the vessels en masse with an endoscopic vascular stapler is acceptable.
- As with the open procedure, close attention must be given to the tail of the pancreas when dividing the hilar vessels to avoid injury.
- With the spleen completely devascularized, it is now suspended by the small cuff of splenophrenic attachments. These attachments can be transected at this time, or, if necessary, used to assist placing the spleen in the extraction bag. Introduction of an extraction bag is done using one of the port sites (usually the left lateral port). Once the bag is deployed in the peritoneal cavity, the spleen is placed inside. The remaining attachments are then divided (if not done previously), the drawstring of the bag closed, and the open end of the bag brought out through a large trocar site (usually the hand port or the umbilical or epigastric sites). The extraction site occasionally will need to be lengthened to facilitate removal of the spleen.
- The spleen often requires finger fraction or morcellation with ring forceps and removed piecemeal (**FIG 16**). As the spleen is rarely excised in the setting of malignancy, this is an accepted practice. Although a rare occurrence, there have been case reports of splenic implants in the surgical wound and contamination should be avoided.
- The abdomen is then examined for hemostasis, pneumoperitoneum is stopped, and the port sites are closed by usual means. We recommend fascial closure for all incisions measuring greater than 1 cm to avoid future hernias.
- Drainage of the splenic bed is performed selectively, as stated earlier.

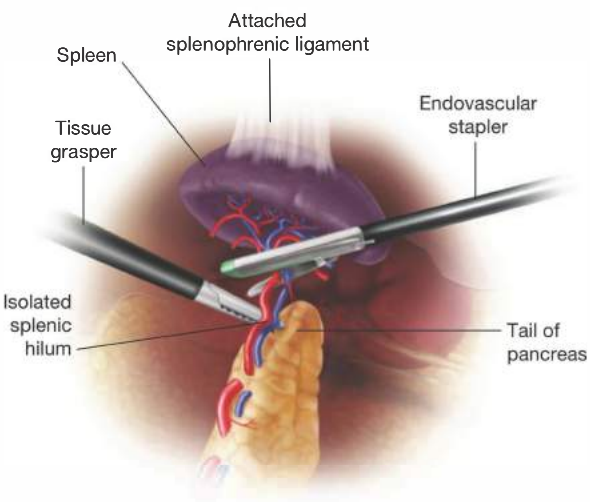

FIG 15 ● Laparoscopic ligation of the splenic artery and vein.

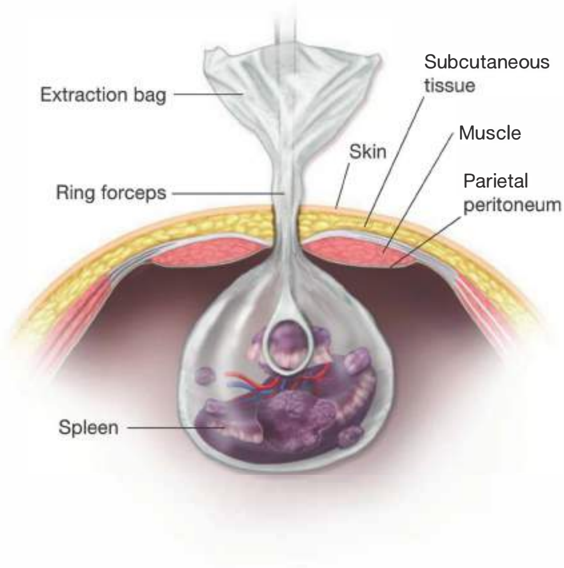

FIG 16 ● Extraction and morcellation of the spleen.

PEARLS AND PITFALLS

Imaging and other diagnostic modalities	■ Involvement of a hematologist is essential for proper diagnosis and preoperative medical management. ■ For elective splenectomies, CT of the abdomen is pivotal in the preoperative planning.
Preoperative planning	■ All elective splenectomy patients need vaccinations 2 weeks preoperatively. ■ Consider prophylactic embolization for splenomegaly or portal hypertension. ■ Have blood products with a current type and screen, type and crossmatch readily available intraoperatively.
Technique—open splenectomy	■ Quick mobilization to the midline is a key maneuver in a hemorrhaging spleen. ■ Keep dorsal and medial traction when mobilizing to avoid capsular tears. ■ Work lateral to medial. ■ Leave a 1- to 2-cm cuff of peritoneum to prevent damage to surrounding organs or further injury to the spleen. ■ Ligate the splenic artery and vein, with close attention not to injure the pancreatic tail.
Technique—laparoscopic splenectomy	■ Positioning the patient with maximal exposure between the iliac crest and costal margin is key. ■ Examine the entire abdomen for accessory spleens. ■ Let gravity help you in the dissection.
Technique—closure	■ No need for a drain unless there is a known or suspected pancreatic injury, infection, or bleeding.

POSTOPERATIVE CARE

- Most patients who undergo laparoscopic splenectomy have a swift recovery and short hospital stay. In one review, hospital stay ranged from 1.5 to 6.4 days.[9] Most patients are able to return to work in a week.
- Patients who undergo open splenectomy have a longer hospital stay, longer return to a full diet, and increased need for narcotics.[10,11] This is not a surprising finding, however, given that most patients undergoing open splenectomies either have a contraindication for laparoscopic procedures or have surgery under emergent conditions (i.e., in the setting of a trauma).

OUTCOMES

- The hematologic and long-term cure rates are the most important factors when patients undergo elective laparoscopic splenectomies. For some disorders (i.e., the hemoglobinopathies), cure is not possible, and the goal of splenectomy is to alleviate the symptoms of the disease. For other diseases, splenectomy offers the relief of pain and early satiety that can accompany splenomegaly.
- Patients undergoing splenectomy for ITP generally have excellent outcomes. It has the highest rate of complete and durable remission; in fact, two-thirds of patients treated with splenectomy for ITP achieve a complete remission (defined as a normal platelet count with no further glucocorticoid requirements). An additional 20% will have a partial response, with a platelet count greater than 50,000 μL, with or without continuation of steroids. Younger patients have a more favorable response.[12] Also, favorable response to splenectomy is also found in patients with a postoperative platelet count greater than 150,000 by postoperative day 3.
- Patients undergoing splenectomy for HS have reasonable outcomes. Coupling the splenectomy with a cholecystectomy obviates the need for a cholecystectomy later in life if pigmented stones are present. For severe HS, splenectomy eliminates the need for regular blood transfusions; however, an anemia will still persist. Growth failure or skeletal changes from the high degree of erythropoiesis needed to compensate for the hemolytic anemia is reversed for children after the spleen is removed.[13]

COMPLICATIONS

- Bleeding 4% to 16% (most common)
- Thromboembolic events/thrombosis 2% to 4%
- Pancreatic injury
- Seroma
- Hematoma
- Incisional hernia
- Wound dehiscence
- OPSI

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Chapter **53** Splenorrhaphy

Shawn D. Larson Saleem Islam

DEFINITION

- Splenorrhaphy literally translates to "suturing of the spleen." Broadly applied, splenorrhaphy encompasses numerous operative strategies aimed at preserving splenic tissue and maintaining normal physiologic function in the setting of injury. Other terms for splenorrhaphy include splenic salvage, splenic preservation, and partial splenectomy. Partial splenectomy may be preferred to control disease or repair injury in selected cases. Understanding various operative techniques for splenorrhaphy is a required component of the armamentarium of all general surgeons.

DIFFERENTIAL DIAGNOSIS

- Splenic trauma: grades I to IV (Table 1).[1]
  - Grade V splenic injuries are *not* amenable to splenorrhaphy (see Part 3, Chapter 52).
- Iatrogenic injuries—commonly during retraction of the transverse colon/stomach or during left upper quadrant laparoscopic operations
- Hemoglobinopathies
  - Hereditary spherocytosis (HS)
  - Thalassemia/sickle cell disease
- Splenic cysts (e.g., epithelial or epidermoid cysts)
- Splenic hamartomas

PATIENT HISTORY AND PHYSICAL FINDINGS

- Prior to elective surgery, a thorough history should be obtained, including an account of abdominal pain or constitutional symptoms, detailed past medical/surgical history, and all current medications and allergies. Particular attention should be directed to eliciting any symptoms of liver disease, clotting or bleeding disorders, and a blood product transfusion history.
- Patients presenting with splenic trauma require rapid assessment making use of the principles outlined in the American College of Surgeons Advanced Trauma Life Support (ATLS®) protocol. Hemodynamic instability is a general contraindication to splenorrhaphy. A thorough history should be obtained as outlined earlier. Particular attention must be paid to associated injuries as these will influence decisions regarding nonoperative management (NOM), splenorrhaphy, or splenectomy (**FIG 1**). In *pediatric patients*, NOM is the preferred treatment choice and early consultation with a pediatric surgeon is highly recommended. Adult trauma patients with low-grade splenic injuries may be managed with NOM (Table 2).
- Patients presenting with hemoglobinopathies have abnormal laboratory profiles and often present with abdominal pain/discomfort, a history of jaundice, or splenomegaly. Rarely, patients will be completely asymptomatic. Patients with HS often present with sequestration of abnormal red blood cells (RBCs) and may have splenomegaly.[2,3] Historically, these patients benefited from splenectomy. Recently, clinical evidence demonstrates that patients with HS are amenable to partial splenectomy (PS), eliminating the need for repeat transfusions and significantly reducing the risk of overwhelming postsplenectomy infection (OPSI). Additionally, patients with sickle cell anemia have shown improvement following PS.[2–4]
- A complete and thorough physical examination should be performed on *all* patients. The presence or absence of splenomegaly should be noted. All signs of portal hypertension or liver failure should be elicited. Presence or location of surgical scars must be considered prior to determining operative approach.
- Splenorrhaphy is best performed via an open technique, which allows full visualization of the injury. An open approach allows easy conversion to a splenectomy should the clinical situation warrant this. Elective PS may be performed via an open or laparoscopic technique. Laparoscopic PS requires substantial experience in minimally invasive surgery and therefore, we prefer an open or a laparoscopic-assisted technique.

Table 1: American Association for the Surgery of Trauma Organ Injury Scaling: Spleen

Grade	Injury	Description
I	Hematoma	Subcapsular, <10% surface area
	Laceration	Capsular tear, <1 cm parenchymal depth
II	Hematoma	Subcapsular, 10%–50% surface area; intraparenchymal, <5 cm in diameter
	Laceration	Capsular tear, 1–3 cm parenchymal depth not involving trabecular vessel
III	Hematoma	Subcapsular, >50% surface area or expanding; ruptured subcapsular or parenchymal hematoma; intraparenchymal hematoma >5 cm or expanding
	Laceration	>3 cm parenchymal depth or involving trabecular vessels
IV	Laceration	Laceration involving segmental or hilar vessels producing major devascularization (>25% of spleen)
V	Laceration	Completely shattered spleen
	Vascular	Hilar injury with devascularized spleen

Adapted from Moore EE, Cogbill TH, Jurkovich GJ, et al. Organ injury scaling: spleen and liver (1994 revision). J Trauma. *1995;38(3):323–324.*

IMAGING AND OTHER DIAGNOSTIC STUDIES

- All patients with a suspected or known hemoglobinopathy require input from a hematologist. Patients should have a blood smear and/or bone marrow analysis, a complete blood count (CBC), and specialized blood studies as indicated by the disease process.
- Computed tomography (CT) scanning should be performed for all hemodynamically stable patients with suspected splenic trauma. CT is an excellent modality for preoperative

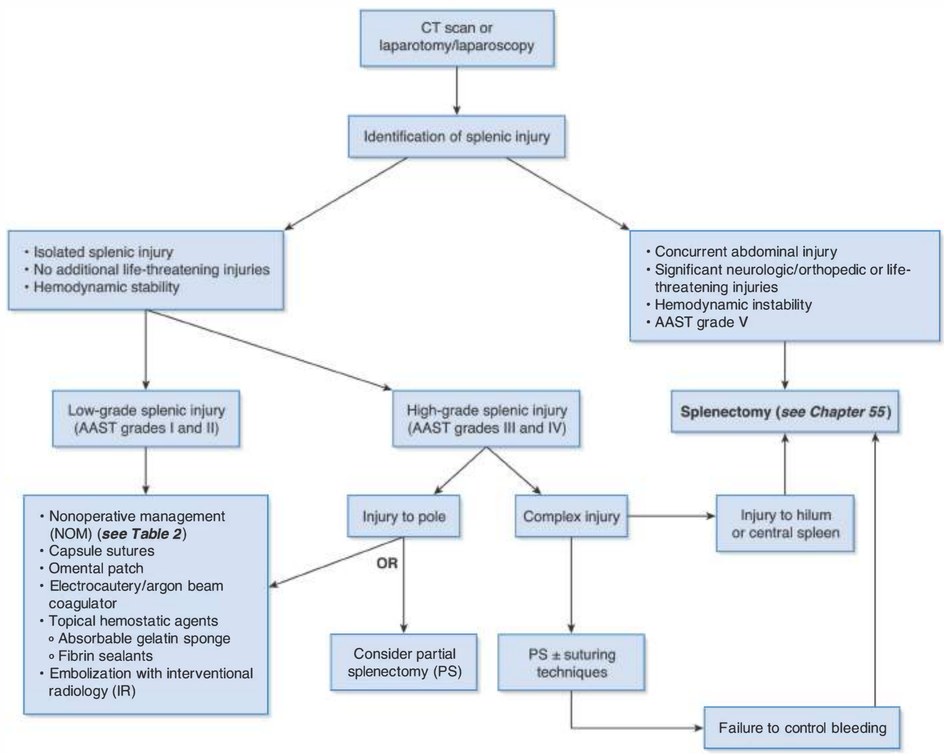


FIG 1 ● Treatment algorithm for splenic injury outlining various options based on grade of injury. AAST, American Association for the Surgery of Trauma.

planning to evaluate injury extent and to delineate vascular anatomy. CT is recommended for elective PS to determine the relationship of the spleen to adjacent organs, splenic size, and potential locations of accessory spleens (**FIG 2**).

- Ultrasound (US) is a noninvasive imaging modality to assess for splenomegaly, presence of splenic cysts/masses, and determination of portal hypertension in selected patients. US is particularly useful in assessing the spleen in children with the added advantage of minimizing ionizing radiation exposure. In the evaluation of trauma patients, focused abdominal sonography for trauma (FAST) is an accepted screening tool to diagnose intraperitoneal fluid or blood. Preoperative US should be performed for all patients with symptomatic biliary colic and patients with hemoglobinopathies to evaluate for cholelithiasis. Patients with cholelithiasis should be considered for concurrent cholecystectomy.
- Magnetic resonance imaging (MRI) is a recognized method for evaluating splenic lesions without the use of ionizing radiation. MRI is not recommended in the setting of splenic injury.

Table 2: Criteria and Contraindications to Nonoperative Management for Splenic Injury

Criteria for Nonoperative management (NOM)

- Hemodynamic stability
- No additional comorbid injuries (e.g., head injury, significant orthopedic trauma)
- Limitation of splenic-related blood transfusion (≤2 units)
- CT scan documenting splenic injury and grade
- Absence of active intrasplenic bleeding on CT
- Absence of other intraabdominal injuries on CT requiring operative intervention

Contraindications for NOM

- Hemodynamic instability ± peritonitis
- Associated intraabdominal/retroperitoneal organ injury
- Inability to perform reliable serial abdominal exams
- Need for anticoagulation
- Inability to correct coagulopathy
- Ongoing blood transfusion requirement
- AAST grade V splenic injury

CT, computed tomography; AAST, American Association for the Surgery of Trauma.

SURGICAL MANAGEMENT

Preoperative Planning

- Patients undergoing PS for elective indications should receive vaccinations for encapsulated organisms (*Haemophilus influenzae B*, *Streptococcus pneumoniae*, and *Neisseria meningitidis*) 2 to 4 weeks prior to surgery. Although PS should theoretically eliminate the risk of OPSI, vaccinations should be administered in the event that a total splenectomy is performed. Patients undergoing PS in the setting of splenic injury should receive vaccinations 2 to 4 weeks postoperatively. Current guidelines for OPSI prevention are outlined in Part 3, Chapter 52, Table 2.
- Blood products should be ordered and available intraoperatively including packed red blood cells (PRBCs), platelets, and fresh frozen plasma (FFP).

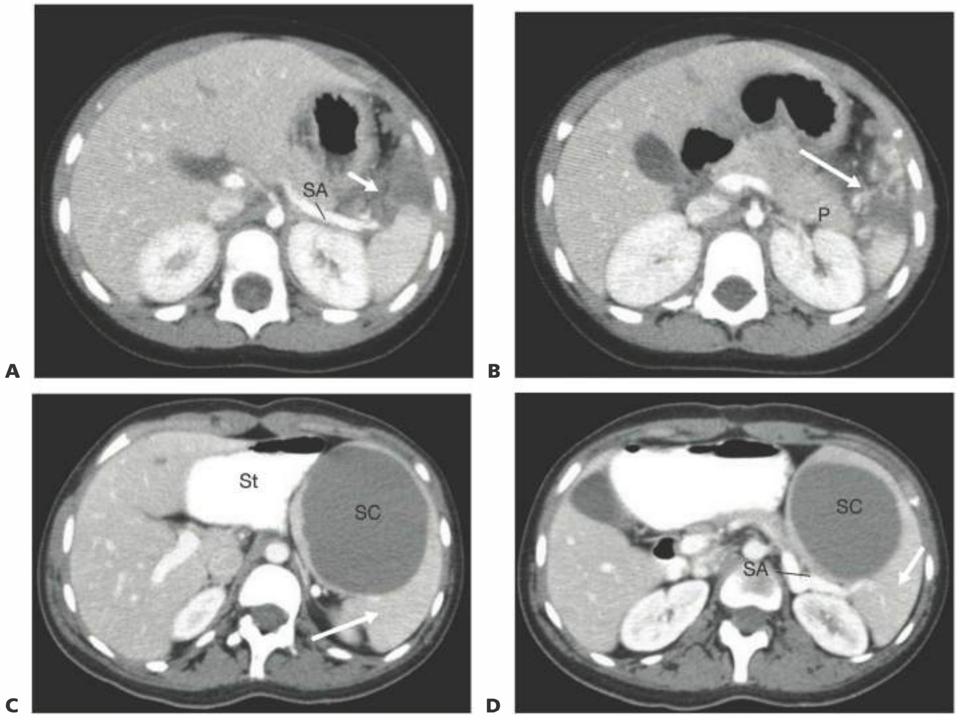


FIG 2 ● CT scan of splenic laceration **(A,B)** and splenic cyst **(C,D)**. **A.** CT demonstrating isolated injury to the spleen *(white arrow)* from blunt abdominal trauma with hemoperitoneum. Note the proximity to the splenic artery (SA). **B.** CT from same patient demonstrating extent of splenic injury *(white arrow)* extending to inferior pole. Note the proximity of the spleen to the tail of the pancreas (P). **C.** CT demonstrating a large splenic cyst (SC) compressing normal splenic parenchyma *(white arrow)*. The cyst is compressing the stomach (St). **D.** CT image from same patient demonstrating the relationship of the SC to the SA. This patient underwent successful laparoscopic PS with preservation of normal splenic parenchyma. *Large white arrow*, splenic laceration; *narrow white arrow*, normal spleen.

- All patients should receive prophylactic antibiotics to cover skin flora within 60 minutes prior to the skin incision.
- Appropriate antithrombotic precautions should be instituted, including sequential compression devices (SCDs) for all patients age 12 years and older. Appropriate anticoagulation medications (e.g., low-molecular-weight heparin) should be administered preoperatively per hospital protocol.
- A nasogastric tube (NGT) should be inserted following induction of anesthesia to decompress the stomach and aid in visualization. Consideration should be given to leaving the NGT in situ for 24 to 48 hours postoperatively to prevent gastric distension.
- An open approach is recommended for patients undergoing splenorrhaphy for splenic injury. The human hand as a retractor to provide compressive hemostasis is invaluable in the successful performance of PS. This approach also provides good exposure and allows for possible splenectomy should attempts at splenorrhaphy prove unsuccessful.
- PS may be performed by a laparoscopic approach in the elective setting. Laparoscopic PS requires advanced laparoscopic skills and should only be undertaken by a surgeon familiar with the procedure.
- In adult splenic trauma patients, consideration should be given to preoperative splenic artery embolization (SAE) by interventional radiology. SAE has been demonstrated to improve the use of NOM, with improvement in splenic salvage, length of hospital stay, and mortality.[5] Pediatric patients with splenic trauma rarely require embolization and consultation with a pediatric surgeon is highly recommended before treatment with SAE is commenced.[6]

Positioning

- For open splenorrhaphy, patients are placed in a supine position with both arms extended. For patients with isolated splenic trauma, an upper midline incision from the xiphoid process to the umbilicus allows adequate exposure. This incision can be extended inferiorly if additional exposure is required or other intraabdominal injuries are identified. For pediatric patients, a left subcostal incision or a transverse incision starting at the left 12th rib tip can be used (see Part 3, Chapter 52, FIG 5).
- Patients undergoing laparoscopic PS can be positioned supine with both arms tucked at the side. A beanbag or kidney rest is placed under the left flank to increase exposure between the 12th rib and iliac crest. The table may be rotated to allow near-supine positioning for port placement and then rotated during the operation to achieve a right lateral decubitus position. As with all operations, all pressure points should be appropriately padded (see Part 3, Chapter 52, FIG 4).

SPLENORRHAPHY

Incision

- A variety of incisions can be used to perform splenorrhaphy depending on the clinical situation.
  - Trauma patients. A midline incision extending from the xiphoid process to the pubis is used to enter the peritoneal cavity. This incision allows maximal exposure. A quick thorough inspection of each quadrant and the pelvis should be performed. Active bleeding should be immediately addressed. Retractors should be placed to maximize visualization and determine if additional sources of bleeding are present. All fluid and particulate matter should be quickly evaluated. Additional abdominal/retroperitoneal injuries discovered at the time of laparotomy should be prioritized and dealt with as outlined in corresponding chapters.
  - Isolated splenic injury. A midline incision extending from the xiphoid process to the level of the umbilicus can be used. Should additional exposure be required, the incision can be extended inferiorly. Retractors are placed to allow maximal exposure of the left upper quadrant. If a splenic injury occurs while performing an upper abdominal laparoscopic procedure, consideration should be made to convert to an open procedure depending on the extent of the injury. For higher grade injuries (American Association for the Surgery of Trauma [AAST] grades III and IV), a left subcostal incision can be made approximately 3 cm inferior to the costal margin (see Part 3, Chapter 52, FIG 5).
  - Pediatric patients. A midline incision can be used similar to adult patients in the setting of trauma. For isolated splenic injuries, either a left subcostal incision or a transverse incision can be used. For a transverse incision, the tip of the 12th rib is identified and the incision is extended medially to allow for exposure of the spleen.

Mobilization

- Anatomically, the spleen resides superiorly and posteriorly in the left upper abdomen. For adequate assessment of a splenic injury and successful splenorrhaphy, the spleen must be completely mobilized by removing all peritoneal and visceral attachments. This includes the splenophrenic attachments to the diaphragm, the splenocolic ligament to the splenic flexure of the colon, the splenorenal ligaments, and the gastrosplenic ligament (see Part 3, Chapter 52, FIG 6). The splenophrenic and splenorenal ligaments are avascular and can be divided sharply. Conversely, the gastrosplenic ligament (containing short gastric vessels) and the splenocolic ligament require careful attention to ensure excellent hemostasis. Vessels in these ligaments should be ligated with ties or an energy-based sealant device.
- Division of the ligaments begins first with the splenocolic ligament, allowing the splenic flexure of the colon to be mobilized away from the spleen. Splenic mobilization is further achieved by the operating surgeon placing their left hand posteriorly on the spleen (a laparotomy pad may improve the grip) and rotating it anteromedially. This maneuver will better expose the splenophrenic and splenorenal ligaments. Once the spleen is free of these attachments, it can be carefully mobilized into the wound. The gastrosplenic ligament is then carefully divided. Laparotomy pads can be carefully placed posteriorly to further aid in mobilization.
- Division of the ligaments should be made 2 to 3 cm from the spleen to avoid injury to both the spleen and adjacent organs (i.e., pancreas).
- The tail of the pancreas extends to the splenic hilum in most patients. Care must be taken during mobilization of the spleen to avoid iatrogenic injury. The tail of the pancreas should be fully visualized, particularly as the spleen is rotated into the operative field. The splenic artery and vein are located on the superior border of the pancreas and must be carefully isolated to avoid injury.
- Once the spleen is mobilized from the retroperitoneal attachments, control of the hilar vessels can be quickly achieved if necessary to control bleeding. Active bleeding can be controlled by direct compression of the hilar vessels between the surgeon's thumb and forefinger. This maneuver allows for thorough assessment of the extent of splenic injury.
- Note: Full splenic mobilization may be unnecessary for small isolated injuries (e.g., capsular tear) that occur intraoperatively and can be completely visualized. In all other situations, complete splenic mobilization should be performed.

Repair of Low-Grade Splenic Injuries (AAST Grades I and II)

- After mobilizing the spleen, a thorough inspection can occur to allow complete assessment of the injury (see Table 1 and **FIG 1**). If necessary, vascular control can be obtained by compression of the hilar vessels as discussed earlier.
- Grades I and II injuries can generally be controlled by simple techniques including the following:
  - Direct compression (for minor capsular tears <1 cm)
  - Application of topical hemostatic agents
    - Absorbable gelatin sponge
    - Absorbable oxidized regenerated cellulose
    - Fibrin sealants
  - Electrocautery or argon beam coagulator (ABC) (**FIGS 3** and **7**)
  - Absorbable sutures placed in the capsule (interrupted or running) (**FIGS 3** and **8**). For most low-grade injuries, suture pledgets are not required.
- Following repair, the injury should be observed for 5 to 10 minutes to ensure that bleeding is controlled. Ongoing bleeding may require a combination of techniques listed earlier to repair the injury. Once the injury is controlled, the spleen is carefully returned to the left upper abdomen.

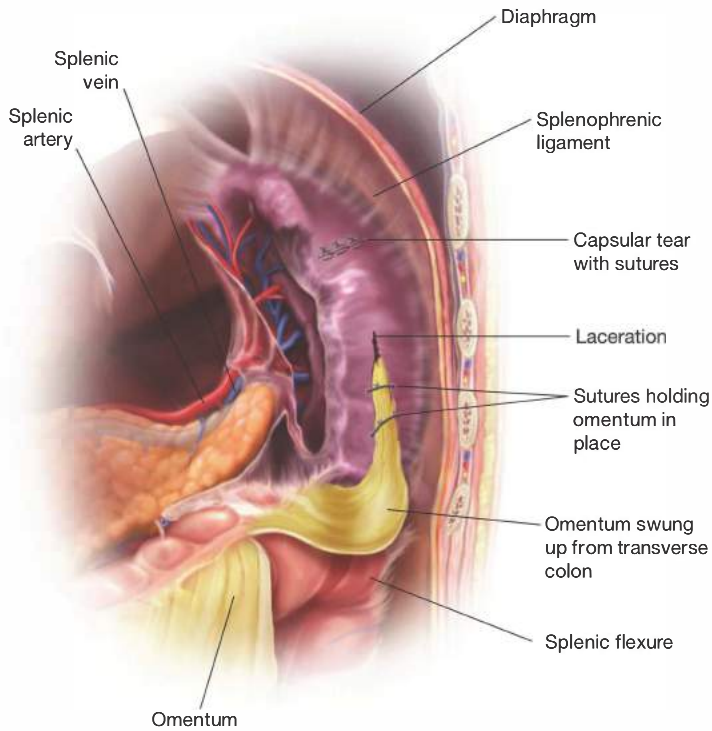


FIG 3 ● Splenorrhaphy technique demonstrating (1) use of interrupted sutures for linear capsular tear and (2) patch with omentum mobilized and rotated upward. Sutures are placed into splenic capsule and around omentum to buttress injury.

Repair of Moderate to High-Grade Splenic Injuries (AAST Grades III and IV)

- After complete mobilization of the spleen, a thorough inspection is performed. The vascular supply of the spleen is carefully inspected and if an injury is present, PS may be possible if 20% or more of the spleen can be salvaged (**FIG 1**). If significant injury to the splenic artery or vein is present, then consideration for a splenectomy should be strongly considered (see Part 3, Chapter 52). Vascular control is achieved by compression of hilar vessels as discussed earlier.
- Devitalized tissue should be debrided either sharply or with electrocautery to healthy splenic tissue (**FIG 4**).
  - Penetrating vessels to a devitalized segment should be ligated. If a line of demarcation is present, the splenic capsule can be incised with electrocautery. A linear stapling device can be used to transect a devitalized pole.
  - Clips can be applied to trabecular vessels. Gentle compression of the cut of the edge of the spleen will help control bleeding.
  - An ABC can be used to achieve hemostasis. Alternatively, mattress sutures can be placed along the cut edge. Pledgets are recommended to prevent further capsular damage (see **FIGS 7** and **8**).
  - Topical hemostatic agents can be applied and pressure held with a laparotomy pad for 10 minutes. Continued bleeding will require additional hemostatic agent and compression.
  - Alternatively, omentum from the transverse colon can be swung up and placed in the splenic laceration. Mattress sutures can then be placed to compress the edges and secure the omentum in place (**FIG 3**). Hemostatic mesh can be used in place of omentum.
- PS can be considered for segmental injury and will be discussed in the following text.

AAST Grade V Splenic Injuries

- Splenorrhaphy is *not* indicated for AAST grade V injuries. Patients with these injuries require expeditious splenectomy (see Part 3, Chapter 52).

Closure

- Once splenorrhaphy has been successful, the spleen is carefully inspected to ensure hemostasis. The spleen is then carefully returned to the upper left abdomen.
- Careful inspection of the abdomen should be undertaken by the surgeon and assistant surgeon independently to ensure all laparotomy pads have been removed. A preliminary count should be simultaneously performed. The abdomen is then irrigated to remove all blood clots.
- The abdomen is then closed in the usual fashion. Drains in the left upper abdomen are unnecessary unless there is a suspected or known injury to the tail of the pancreas. In the setting of abdominal trauma, a decision may be made to leave the abdomen open, allowing for a "second look" operation in 24 to 48 hours.

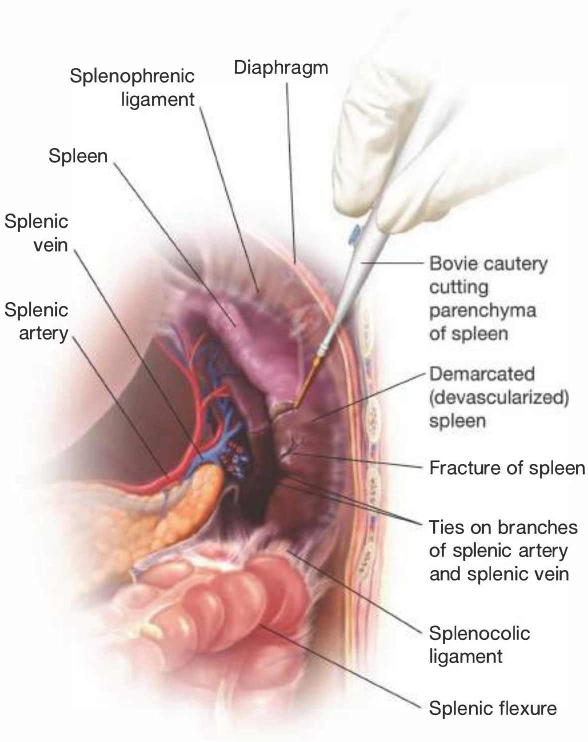


FIG 4 ● Division of spleen using electrocautery. A splenic fracture of the lower pole is present. Branches of the splenic artery and vein have been ligated and divided with subsequent demarcation of the avascular lower pole. The splenic capsule is now divided along the line of demarcation. The splenic artery and vein can be compressed between the thumb and finger of the operative surgeon to control blood loss while the parenchyma is divided.

PARTIAL SPLENECTOMY

Incision

- For open PS, the incision will be dependent on the age of the patient and indications for surgery.
  - Adult patients. An upper midline incision extending from the xiphoid process to the umbilicus should allow adequate exposure. This incision can be extended inferiorly should additional exposure be required. Alternatively, a left subcostal incision can be used for isolated splenic lesions. Caution should be exercised in using this incision if splenomegaly is present.
  - Pediatric patients. A left upper abdominal transverse incision can safely be used, starting from the 12th rib tip and extending medially. Alternatively, a left subcostal incision can be used.
- For laparoscopic-assisted PS, ports are placed in a similar fashion to a laparoscopic splenectomy (see Part 3, Chapter 52). After mobilization of the spleen, a left transverse or left subcostal incision can be used to perform the PS.

Mobilization

- The spleen should be completely mobilized by dividing the splenophrenic, splenorenal, splenocolic, and gastrosplenic ligaments (see earlier discussion).
  - For open PS, mobilization begins in a similar fashion to open splenectomy (see Part 3, Chapter 52) and as discussed under the "Splenorrhaphy" section. The spleen needs to be completely mobilized.
  - For laparoscopic-assisted PS, mobilization begins in a similar fashion as discussed in preceding chapters (see Part 3, Chapter 52). Once the spleen is completely mobilized laparoscopically, an open incision can be made as described in the preceding section. The spleen needs to be mobilized to allow it to be brought completely into the incision.

Division of Spleen

- Once the spleen is completely mobilized into the incision, the splenic vessels can be identified. Depending on the location of the lesion, branches of the splenic artery and splenic vein can be ligated (**FIG 3**). The main splenic artery and vein branches at the hilum should be preserved. Once the penetrating vessels are ligated, the spleen will demarcate (**FIGS 3–5**).
- For PS to be effective, approximately 10% to 20% of the spleen should remain vascularized after ligation of penetrating vessels to preserve physiologic function of the splenic remnant.[4] Care must be taken to ensure that the remaining blood supply is from a splenic artery branch. Relying solely on short gastric arteries will not be adequate to maintain adequate blood flow to the splenic remnant.
- Once the spleen demarcates, the splenic capsule can be incised using electrocautery (**FIG 4**). Potential blood loss can occur; anesthesia team should be notified and blood

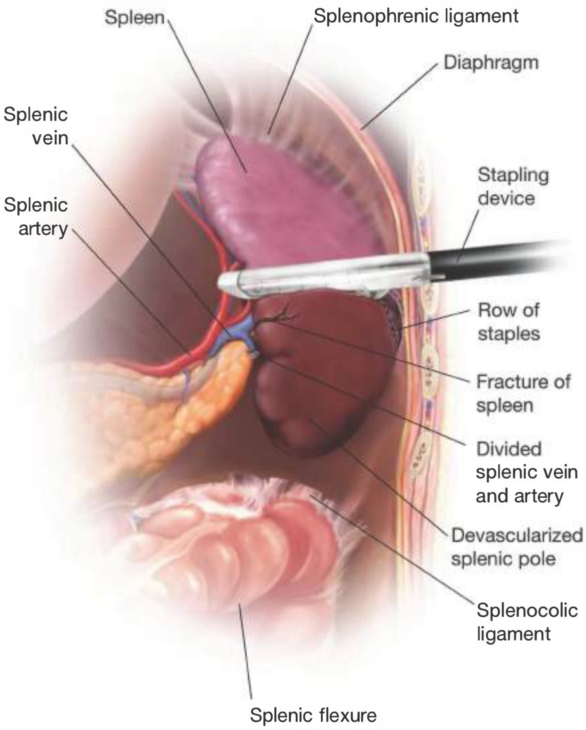
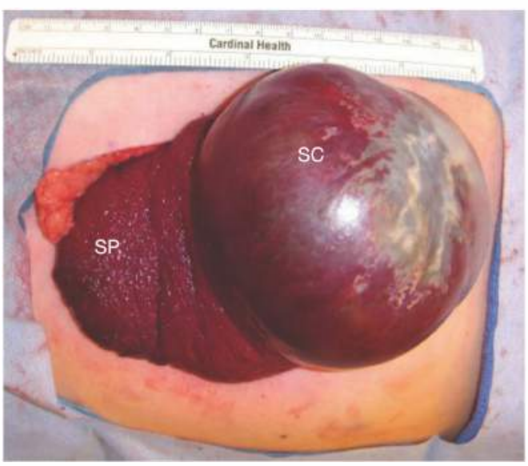


FIG 5 ● Division of the spleen with a linear stapling device. Following ligation and division of branches of the splenic artery and vein to the lower pole, the demarcated spleen is then divided using multiple fires of a linear stapling device. Staple size is dictated by the size of the spleen. Vascular control can be achieved by compression of the main branch of the splenic artery and vein between the surgeon's thumb and index finger until the spleen is divided.

should be available in the operating room (OR) preoperatively. Vascular control can be achieved by compression of the main splenic artery and vein (between the thumb and forefinger as discussed earlier).

- The splenic parenchyma can be divided using electrocautery or a linear stapling device (**FIGS 4** and **5**). Gentle compression can be applied to vascularized splenic edge to assist in controlling bleeding.
- Once the splenic parenchyma is completely divided and the specimen passed off the table, an ABC is used to control bleeding from the cut edge. The ABC is used until bleeding is minimized and the cut edge is thoroughly cauterized (**FIG 7**). Note that the source of argon gas is not pressure regulated. During laparoscopy, intraabdominal pressure must be closely monitored and the abdomen vented as indicated to prevent intraabdominal hypertension.
- An absorbable topical hemostatic agent is then applied to the cut edge and pressure is held with a laparotomy pad (**FIG 6**). Pressure is held for 5 minutes and the laparotomy pad is then carefully removed and ongoing bleeding is assessed. Additional use of ABC may be necessary to control points of bleeding.
- Bleeding from the cut edge of the spleen can be further controlled by placement of absorbable mattress sutures as discussed in the "Splenorrhaphy" section (**FIG 8**).
- Once hemostasis is meticulously achieved, the remainder of the spleen is observed for adequate blood flow. Again, 10% to 20% of the total splenic tissue should remain viable to preserve splenic physiologic function. The splenic remnant is then carefully returned to the left upper abdomen.
  - To prevent torsion of the splenic remnant, consideration can be given to performing splenopexy. Sutures are carefully placed in the splenic capsule and then attached to the lateral abdominal wall or retroperitoneum for fixation. At least two points of fixation should be used. Once placed, these sutures should have minimal tension to avoid tearing the capsule.
  - Depending on the site of PS, omentum can be placed against the cut surface of the spleen. Sutures can be placed to hold the omentum in place as discussed in the preceding section.
- In the case of PS for hemoglobinopathies (e.g., HS), a thorough search for accessory splenic tissue should be performed. The incidence of accessory spleens is 10% to 30%. The most common location for an accessory spleen is at the splenic hilum (approximately 75%), followed by the tail of the pancreas (approximately 20%). The



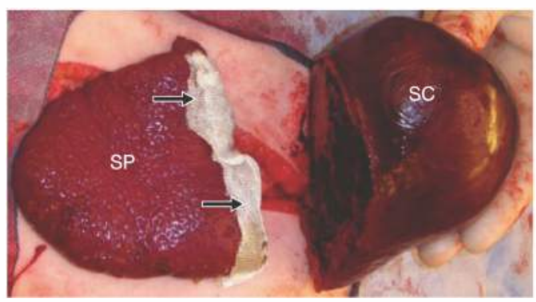


FIG 6 ● **A.** Large epidermoid cyst *(SC)* of the lower pole of the spleen. **B.** Following division of the splenic parenchyma, the superior pole *(SP)* remains perfused. Absorbable hemostatic agent is applied to the cut edge following coagulation with an ABC *(arrows)*. SC, splenic cyst; SP, superior pole of spleen; arrows, absorbable hemostatic agent.

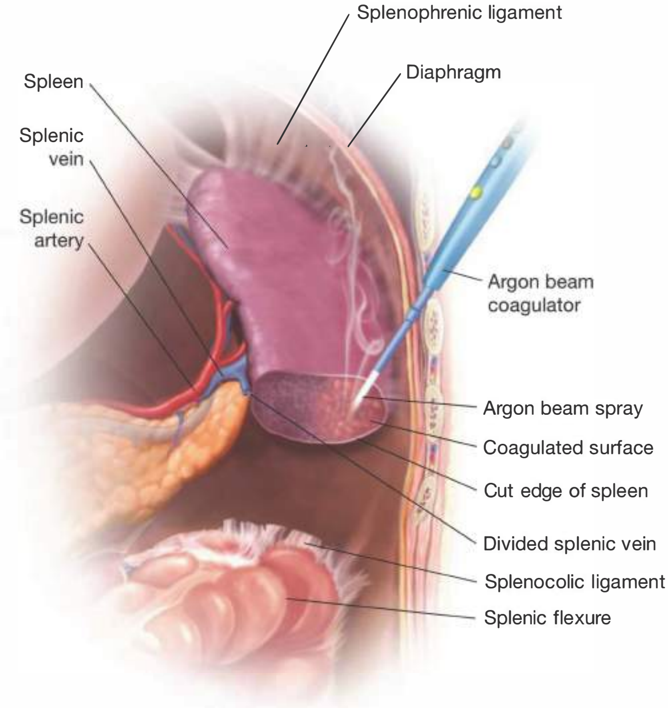


FIG 7 ● Use of ABC to coagulate cut surface of spleen. Branches of the splenic artery and vein to the lower pole have been ligated. The splenocolic ligament has been divided for splenic mobilization.

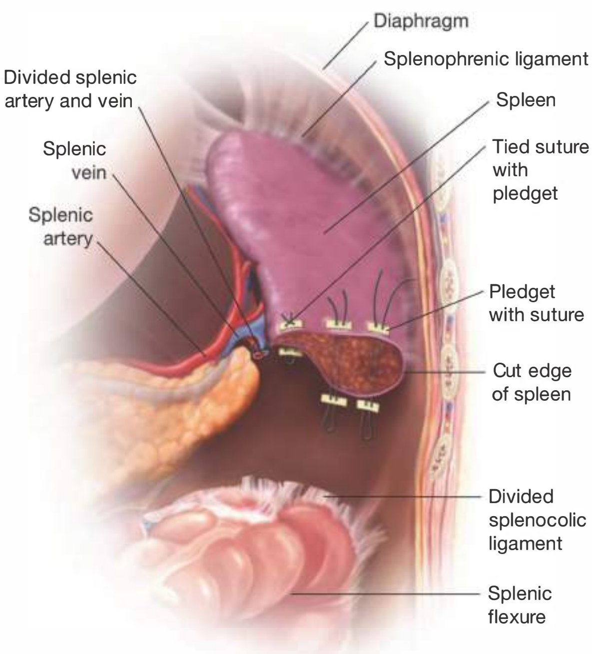


FIG 8 ● Use of interrupted horizontal mattress sutures with pledgets for hemostasis following PS. The splenic artery and vein branches have been divided to the lower pole and the lower pole removed. Sutures are placed in close proximity to reapproximate the capsule. The use of pledgets is recommended to prevent sutures from tearing the splenic capsule.

remainder is located along the splenic artery, in the mesentery, or in the omentum.[7] If accessory splenic tissue is located, it should be completely removed with careful attention to hemostasis.

- Consideration should be given to a concurrent cholecystectomy for patients with symptomatic biliary colic or preoperative US evidence of cholelithiasis.

Closure

- After returning the spleen to the left upper abdomen, a thorough inspection of the peritoneal cavity is performed to ensure there are no retained laparotomy pads. A preliminary count should be performed prior to closing.
- The abdomen is thoroughly irrigated with warmed normal saline. All blood should be removed from the abdomen. The spleen should be inspected to ensure exquisite hemostasis.
- The abdominal incision is then closed in the standard fashion. Drains are not necessary. If the procedure was performed with laparoscopic assistance, ports are removed and port sites are closed in the standard fashion.

PEARLS AND PITFALLS

Indications	■ Splenorrhaphy is used to repair an injured spleen (AAST grades I–IV). ■ Splenorrhaphy is *contraindicated* in AAST grade V injuries. ■ PS can be used as a splenorrhaphy technique or to treat various hemoglobinopathies (e.g., HS), splenic cysts, or splenomegaly.
Imaging and other diagnostics	■ CT scanning is recommended for hemodynamically stable patients with suspected intraabdominal trauma. ■ Patients with hemoglobinopathies should have preoperative imaging to plan operative approach (i.e., vessel location, splenic size) ■ Patients undergoing PS for hemoglobinopathies are recommended to have preoperative US evaluating for cholelithiasis. ■ Involvement of a hematologist is essential for patients with hemoglobinopathies for proper diagnosis and preoperative medical management.
Preoperative planning	■ Vaccinations need to be administered 2 weeks prior to elective PS. ■ Crossmatched blood and blood products should be readily available intraoperatively. ■ Consideration of stress-dose steroids for patients with hemoglobinopathies (review past medication history) ■ CT imaging (see earlier discussion) available in the OR for intraoperative guidance ■ Placement of an NGT for gastric decompression
Technique—splenorrhaphy	■ Hemodynamically *unstable* patients are not candidates for splenorrhaphy. ■ Complete mobilization of the spleen is key to assessing injury and performing splenorrhaphy. ■ Work lateral to medial for mobilization. ■ Leave a 1- to 2-cm cuff of peritoneum to prevent damage to surrounding organs. ■ Lower grade injuries can often be repaired with sutures. ■ Moderate to high-grade injuries may require a combination of techniques including PS. ■ Be prepared to proceed to total splenectomy should splenorrhaphy techniques fail.
Technique—PS	■ May be performed via open or laparoscopic approach ■ Laparoscopic PS requires advanced minimally invasive skills and an elective setting. ■ Identify the splenic artery and vein. A viable splenic remnant requires blood supply from the artery. ■ Do not rely on short gastric blood supply for remnant. ■ After division of blood supply, allow spleen to demarcate prior to dividing spleen. ■ Approximately 30% of the spleen should remain viable for splenic function postoperatively. ■ A thorough search for accessory spleens should be undertaken (and removed if found). ■ Consider performing splenopexy to prevent torsion of remnant. ■ Consideration for concurrent cholecystectomy for patients with symptomatic biliary colic or preoperative US evidence of cholelithiasis.
Technique—closure	■ Drains should not be used unless there is a known or suspected pancreatic injury.

POSTOPERATIVE CARE

- Patients undergoing splenorrhaphy will require ongoing hemodynamic monitoring in the immediate postoperative period. Hemodynamic instability should prompt further investigation for bleeding from the splenic repair.
- The NGT can be removed when evidence of bowel function is present. A diet can be initiated and advanced as tolerated.
- Careful attention to pulmonary toilet should be made, including the use of incentive spirometer, early mobilization, and pain control.
- Most patients undergoing splenorrhaphy will have concurrent injuries that will require continued attention.

OUTCOMES

Splenorrhaphy

- NOM should be considered the standard of care for low- to moderate-grade splenic injuries. NOM has demonstrated splenic preservation rates ranging from 81% to 91% for AAST grades I to III injuries.[8]
- Splenectomy has been demonstrated to be an independent risk factor for infectious complication following blunt splenic trauma. The authors recommend broader consideration for the use of splenic-preserving techniques.[9]
- Splenorrhaphy has been shown to be successful in 86% of patients with intraoperative splenic injury.[10] However, some caution is warranted in interpreting these findings as most reports of this nature are based on small sample sizes.
- The use of ABC dramatically improved rates of successful splenorrhaphy. ABC can be used for many splenic injury types/grades. The ABC can also be used successful with laparoscopic procedures.

Partial Splenectomy

- PS for HS leads to clinically significant improvements in hematologic profiles and symptoms in the pediatric population. Hemoglobin levels significantly increased, whereas reticulocyte count and bilirubin levels decreased.[2]
- PS for other congenital hemolytic anemias (i.e., sickle cell disease) has been demonstrated to control symptoms of hypersplenism and splenic sequestration. Splenic immune function also appears to be preserved in patients following PS who were followed for 4 years from surgery.[3,4]
- PS can be safely performed with few conversions to total splenectomy. Consideration should be given at the time of operation for cholecystectomy for children with symptoms of biliary colic and/or preoperative US demonstrating cholelithiasis.

COMPLICATIONS

Splenorrhaphy

- Bleeding (most common)
- Pancreatic injury/fistula
- Atelectasis/pneumonia/left pleural effusion
- Intraabdominal abscess (3% to 13%; higher rates with use of drains)
- Wound complications (higher rates with open procedures)
  - Seroma
  - Infection
  - Wound dehiscence

Note: Complication rates will be higher in multisystem trauma patients.

Partial Splenectomy

- Bleeding
- Splenic regrowth
- Disease recurrence (may occur when too large of a splenic remnant remains)
- Need for total splenectomy
- Splenic remnant torsion
- Pancreatic injury/fistula
- Wound complications (higher rates with open procedures)

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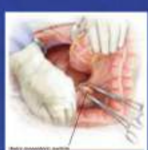
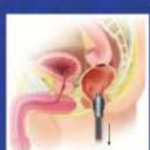
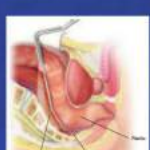
Part 4 Operative Techniques in Colon and Rectal Surgery







Chapter 1

Laparoscopic Small Bowel Resection

Oliver Varban

DEFINITION

- Laparoscopic small bowel resection involves laparoscopic segmental resection of a portion of the duodenum, jejunum, or ileum as well as its associated mesentery. A small bowel resection may be performed in the setting of obstruction, bleeding, or malignancy.

DIFFERENTIAL DIAGNOSIS

- The following conditions represent pathology that may require a small bowel resection:
  - Inflammatory bowel disease (Crohn's disease)
  - Polyp
  - Tumor. Tumors of the small intestine are rare and represent only 1% to 3% of all gastrointestinal neoplasms. (Table 1)
  - Ulcer
  - Diverticula
  - Stricture
  - Intussusception

PATIENT HISTORY AND PHYSICAL FINDINGS

- Obstruction results in nausea, vomiting, obstipation, abdominal pain, and distension with absent bowel sounds. Peritoneal signs and fever may indicate ischemia, necrosis, or perforation.
- Bleeding may result in hematemesis, hematochezia, or heme-positive stools. Additionally, a brisk bleed may result in hemodynamic instability with hypotension and tachycardia. Abdominal pain is typically absent, unless bleeding is associated with ulcer disease or obstruction.

IMAGING AND OTHER DIAGNOSTIC STUDIES

- Computed tomography (CT) with oral and intravenous (IV) contrast can assist with the location and etiology of obstruction. A transition point is noted when the proximal small bowel is dilated and the distal small bowel is decompressed.
- Magnetic resonance imaging (MRI) and magnetic resonance enteroclysis (MRE) along with CT may assist with the diagnosis of small bowel tumors.[1]
- Tagged red blood cell (RBC) scan and CT angiogram may localize intraluminal bleeding in cases where bleeding rates are at least 0.1 to 1.0 mL per minute.
- A technetium-99m pertechnetate, or Meckel scan, can detect gastric mucosa associated with a Meckel's diverticulum.
- Small bowel enteroscopy and capsule endoscopy may also be used to identify the location of a tumor or site of bleeding in a stable patient. If small bowel enteroscopy is performed, the location of the tumor can be tattooed for easy intraoperative identification.
- Diagnostic laparoscopy can assist with localization of disease and can help avoid unnecessary laparotomy.
- An elevated white blood cell (WBC) count and lactate level is concerning for ongoing ischemia or necrosis.
- A decrease in hemoglobin or hematocrit is indicative of bleeding.

Table 1: Tumors of the Small Bowel

Benign	GIST (benign or leiomyoma) Adenoma Lipoma Hemangioma
Malignant	Adenocarcinoma Carcinoid Lymphoma GIST (malignant)

GIST, gastrointestinal stromal tumor.

SURGICAL MANAGEMENT

Preoperative Planning

- The patient requires adequate IV access for resuscitation and, if necessary, blood transfusion if bleeding.
- A nasogastric tube assists in gastric and proximal small bowel decompression. This decreases the risk of aspiration during intubation as well as injury to the stomach or small bowel during port placement.
- A Foley catheter is placed for accurate intraoperative assessment of urine output and also to decompress the bladder for safe port placement.
- Preoperative antibiotics should cover enteric organisms in the event of spillage.

Positioning

- The patient is placed in the supine position. Arms may be out at 90 degrees or tucked at the side of the patient. Tucking the arms may assist with the ergonomics of the operation as both surgeon and assistant may stand on the side of the patient comfortably.
- For operations that take place on the proximal small bowel, it is optimal for the surgeon to stand on the patient's right (**FIG 1**). Meanwhile, for operations that take place in the distal small bowel, it is optimal for the surgeon to stand on the patient's left.
- Operations that take place solely on the duodenum may be performed in split-leg position.

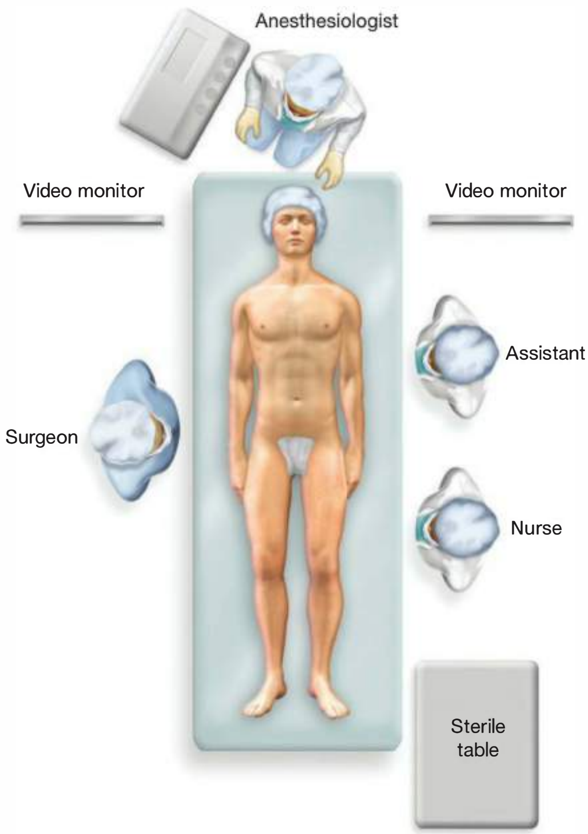


FIG 1 ● Room setup for laparoscopic small bowel resection.

ACCESS TO THE ABDOMINAL CAVITY

- Accessing the abdominal cavity can be performed in a variety of ways based on surgeon's comfort (i.e., open cut-down technique vs. Veress needle insufflation). An open cut-down technique may be advantageous in the setting of obstruction because the chance of blindly injuring dilated bowel is lower.
- Typical insufflation settings for laparoscopy include an intraabdominal pressure of 15 mmHg and a flow of 20 L per minute.
  - Veress needle entry
    - With a nasogastric tube in place and the stomach decompressed, a stab incision with a no. 11 blade is made through the dermis in the left upper quadrant of the abdomen, below the costal margin in the midclavicular line (**FIG 2**).
    - A Veress needle is placed through this incision and advanced until two distinct clicks are heard, signaling that the blunt-tip portion of the Veress needle has sprung forward. The second click is heard as the needle enters the peritoneal cavity.
    - A "drop test" can be performed by placing 10 mL of saline through the needle using

FIG 2 ● Veress needle entry in the left upper quadrant.

FIG 3 ● Drop test performed with saline using a syringe without a plunger. Saline is expected to enter the abdominal cavity freely by gravity alone.

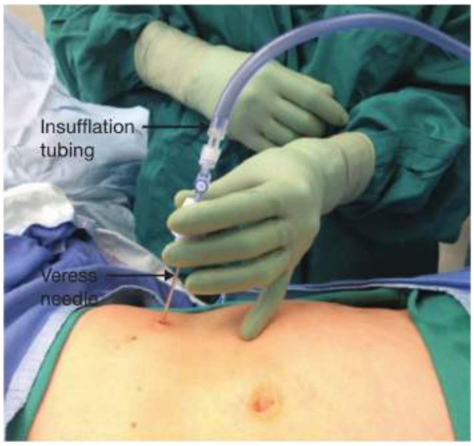


FIG 4 ● Veress needle connected to insufflator tubing for creation of pneumoperitoneum.

a syringe without a plunger (**FIG 3**). If the saline drops into the abdominal cavity with gravity alone, then the needle may be connected to the insufflator (**FIG 4**).
    - Once the abdomen is fully insufflated to an intraabdominal pressure of 15 mmHg, the Veress needle is removed and a 5-mm port is placed through the same incision. The port is then connected to the insufflator.
- Open cut-down technique
    - A 2-cm curvilinear incision is made with a no. 11 blade just below the umbilicus and tissue is dissected down to the level of the fascia.
    - S-shaped or L-shaped retractors are placed to assist with exposure.
    - The umbilical stalk is then grasped with a Kocher and elevated, thus pulling the fascia away from the underlying bowel.
    - A 2-cm longitudinal incision is made in the fascia with a no. 15 blade, and the edges are grasped and retracted using Kocher clamps. The peritoneum is identified below, grasped with DeBakey forceps in two separate locations, and then incised under direct vision.
    - A Hasson port is placed into the abdominal cavity and then connected to the insufflator.

PORT PLACEMENT

- After the first port is placed, a laparoscope is introduced into the abdominal cavity. A 5-mm or 10-mm, 30-degree angled laparoscope is used to perform the operation.
- After placement of the first port, the laparoscope is used to examine the bowel and organs just below the site of port entry to ensure no inadvertent injury occurred during insufflation/entry of the abdominal cavity.
- The remaining ports are placed under laparoscopic visualization, which assists in avoiding injury to intraabdominal organs and the inferior epigastric vessels.
- The 5-mm ports accommodate most laparoscopic grasping and dissecting instruments (**FIG 5**).
- The 12-mm ports accommodate laparoscopic stapling devices and autosuturing devices.
- Port placement for optimal exposure and manipulation of the proximal small bowel is demonstrated in **FIG 6**.
- Port placement for optimal exposure and manipulation of the distal small bowel is demonstrated in **FIG 7**.

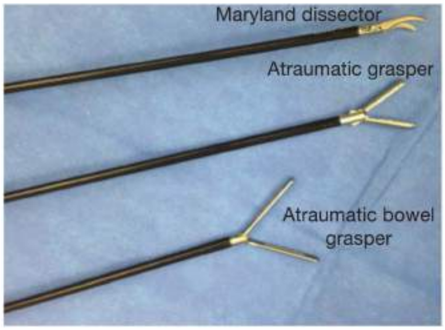


FIG 5 ● Laparoscopic atraumatic graspers and dissectors that can be used through a 5-mm port.

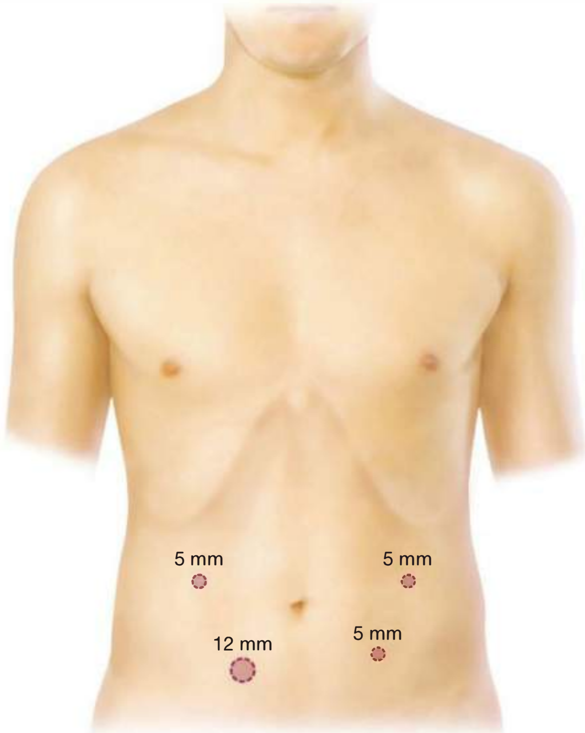


FIG 6 ● Optimal port placement for exposure of the proximal small bowel.

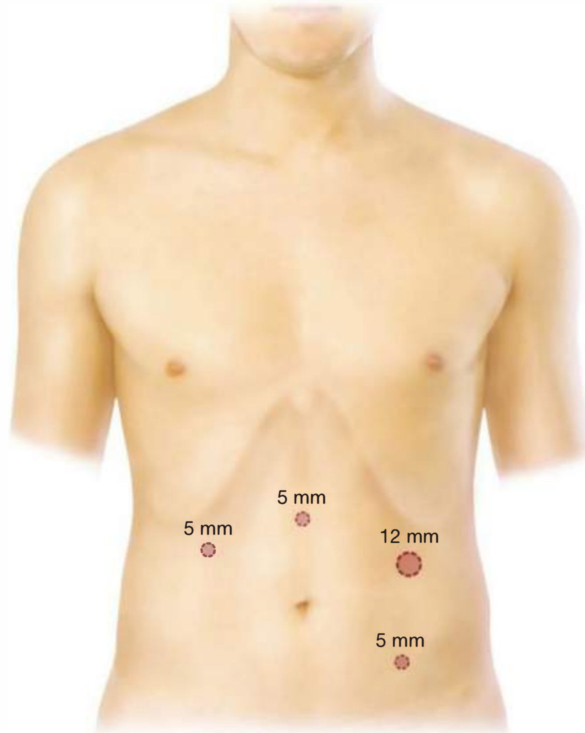


FIG 7 ● Optimal port placement for exposure of the distal small bowel.

IDENTIFICATION OF DISEASE

- The small bowel is run from the ligament of Treitz to the terminal ileum using atraumatic nonlocking graspers.
- To identify the ligament of Treitz, the assistant grasps the epiploicae of the transverse colon and retracts it cephalad, gaining exposure to the base of the colon mesentery. The surgeon then grasps the small bowel and follows it back hand over hand toward the base of the mesentery until they feel resistance and see the proximal jejunum emanate from the retroperitoneum (**FIG 8**).
- With the proximal small bowel identified, the small bowel can be run, hand over hand to the terminal ileum until the diseased portion can be identified.

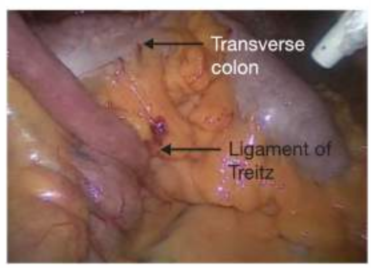


FIG 8 ● Identification of the ligament of Treitz requires elevation of the transverse colon and exposure of the transverse mesocolon. The small bowel is grasped and followed hand over hand proximally until it can be seen emanating from the retroperitoneum.

SMALL BOWEL RESECTION

- The surgeon grasps the proximal small bowel, and the assistant grasps the distal small bowel.
- Creation of a mesenteric window is performed using a Maryland dissector (**FIG 9**) at a location both proximal and distal to the diseased portion of small bowel.
- A laparoscopic dividing stapler (gastrointestinal anastomosis [GIA] type) is then placed through this window and the bowel is divided at proximal and distal points of resection. A stapler loaded with 2.5-mm staples is typically used (**FIG 10**).

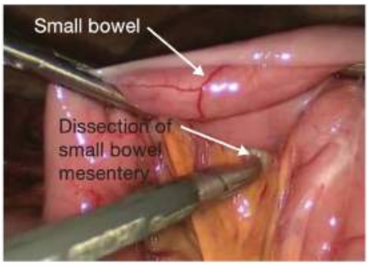


FIG 9 ● Creation of mesenteric window, allowing for placement of the laparoscopic dividing stapler.

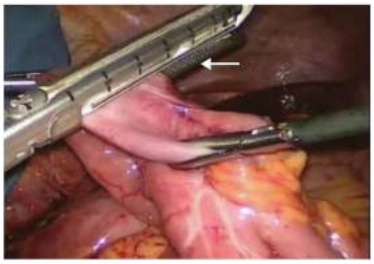


FIG 10 ● Placement of the laparoscopic dividing stapler through the mesenteric window. Arrow represents: Laparoscopic stapler.

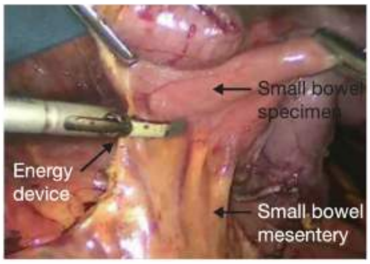


FIG 11 ● Mesenteric division using an energy device (i.e., ultrasonic scalpel).

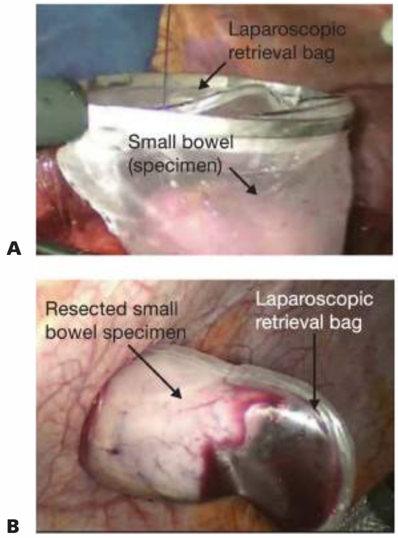


FIG 12 ● Placement of specimen in a laparoscopic retrieval bag **(A)** and removal from 12-mm port site **(B)**.

- The mesentery is divided using an energy device, such as an ultrasonic scalpel or laparoscopic bipolar device (**FIG 11**).
- The segment of resected bowel is then placed into a laparoscopic specimen retrieval bag (**FIG 12A**) and removed through the 12-mm port site (**FIG 12B**). This can be performed either before or after the anastomosis.

SMALL BOWEL ANASTOMOSIS

- The two divided ends of small bowel are placed side-to-side and a seromuscular traction suture is placed using 2-0 absorbable suture, approximately 8 to 10 cm from the ends along the antimesenteric surface of the bowel. A freehand suture may be performed or may be placed using an autosuture device. The tails of the suture are cut approximately 5 cm long so that they may be grasped and used for retraction.
- With the assistant holding the traction suture, the surgeon creates an enterotomy in each segment of bowel, approximately 1 cm from the stapled ends. Enterotomies may be created with an L-hook cautery or with an ultrasonic scalpel. The enteric contents are suctioned in order to contain spillage.
- Each limb of a laparoscopic linear stapler (2.5-mm staples, 60 mm in length) is placed separately into each enterotomy and aligned along the antimesenteric border (**FIG 13**). The stapler is closed and fired to create the anastomosis. Once the stapler is removed, the inside of the staple line is examined for hemostasis.
- The common enterotomy can be closed using a running suture or in a stapled fashion.
- When closing the common enterotomy with a stapler, three traction sutures are placed (one at each end and one in the middle) to approximate the enterotomy and elevate the edges. The tails of each suture are left long (approximately 5 cm) to allow for easy manipulation. A laparoscopic stapler (2.5-mm staples, 60 mm in length) is positioned beneath the cut edges and fired. Care is used to avoid including excessive amount of tissue in the stapler as it can narrow the anastomosis (**FIG 14A**).
- When closing the common enterotomy with suture, a running 2-0 absorbable suture may be placed for the inner layer and interrupted 2-0 permanent sutures may be placed in the seromuscular layer for the outer layer. Sutures may be placed freehand or with an autosuture device (**FIG 14B**).
- The mesenteric defect (**FIG 15A**) is closed with either a running or an interrupted series of 2-0 permanent sutures to prevent an internal hernia. Sutures are placed superficially in order to avoid injuring the blood supply (**FIG 15B**).

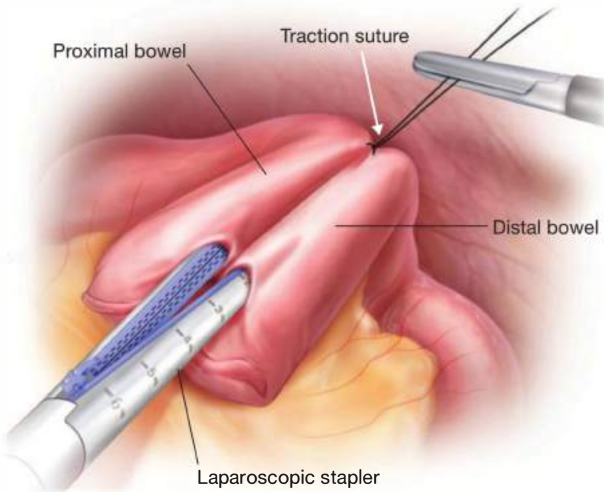
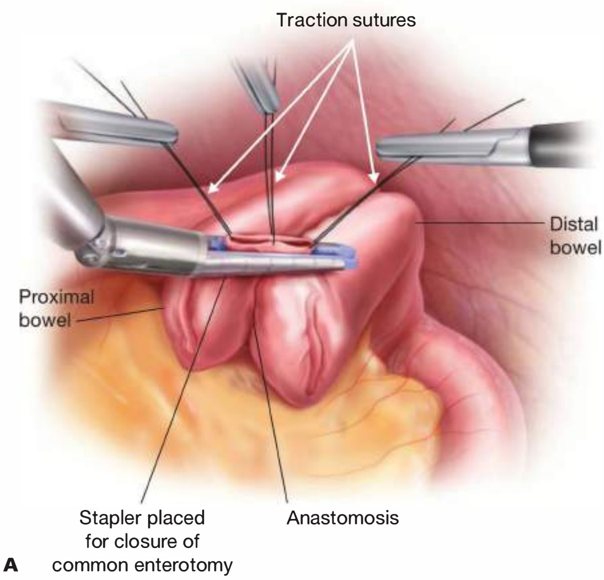


FIG 13 ● Placement of a laparoscopic linear stapler in separate enterotomies made on each limb of bowel for creation of anastomosis. A traction suture placed 8 to 10 cm from the ends is held by the assistant.



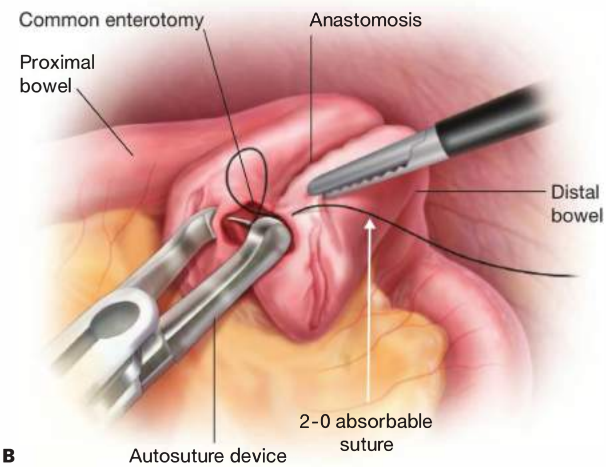


FIG 14 ● **A.** Stapled closure of the common enterotomy is performed by placing traction sutures at either end of the enterotomy and one in the middle. The tails of the sutures are left long so they may be grasped and assist with placement of the stapler. The enterotomy is closed transversely so as to avoid narrowing the anastomosis. **B.** Suture closure of the common enterotomy is performed using an autosuture device. It may be performed with freehand suturing as well. The first row is performed with a 2-0 absorbable suture in a running fashion, closing the enterotomy transversely. The second layer consists of interrupted seromuscular imbricating sutures using a 2-0 nonabsorbable suture.

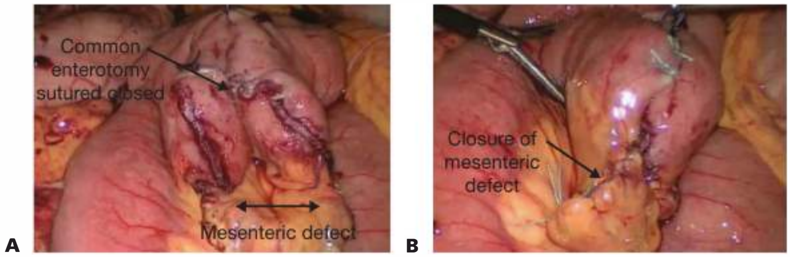


FIG 15 ● The mesenteric defect **(A)** is approximated with a running permanent suture **(B)**.

REMOVAL OF SPECIMEN

- Once the specimen is placed in a laparoscopic retrieval bag, it may be removed by expanding the size of one of the port sites. Alternatively, the specimen may be removed from a separate incision and with the use of a wound protection device.

CLOSURE

- It is recommended to close the fascia for all port sites greater than 10 mm. This may be performed using a single absorbable or permanent 0-suture and a Carter-Thomason suture-passer device (**FIG 16A–C**).
- The site of specimen extraction may be closed in a similar fashion; however, larger defects do not maintain pneumoperitoneum and are more difficult to close laparoscopically. As such, these may be closed by placing interrupted sutures in an open fashion using a suture on a UR-6 needle.
- The skin is closed with interrupted absorbable subcuticular sutures.
- Drains are not required.

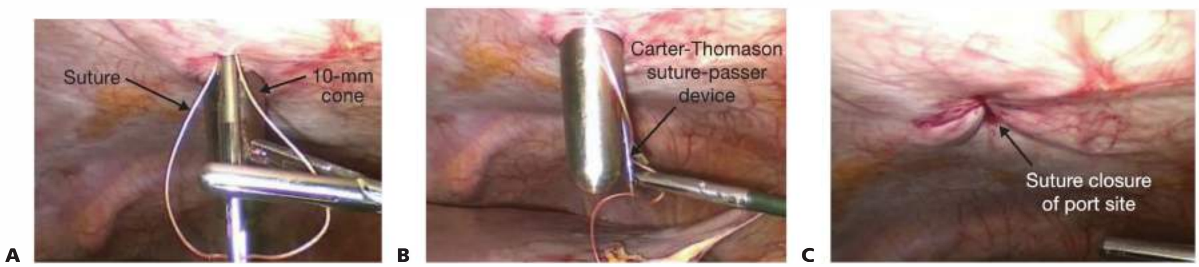


FIG 16 ● **A.** A Carter-Thomason suture-passer device is used to pass a free suture through the port site defect using a cone to direct the passage of the suture through one side of fascial defect. **B.** The Carter-Thomason is then passed without the suture on the opposite site of the defect in order to grasp the suture. **C.** The end of the suture is then pulled up through the fascia and tied.

PEARLS AND PITFALLS

Port placement	■ Optimal port placement enhances operative exposure and use of laparoscopic instruments in an ergonomic fashion. ■ Ports should be placed at least 10 cm apart and allow for triangulation of camera and instruments. ■ An open cut-down technique may reduce the risk of inadvertent injury in the case of obstructive disease and dilated bowel.
Identification of disease	■ Localization of intraluminal tumors can be facilitated with MRE or preoperative double-balloon enteroscopy and tattooing. ■ If unsure, areas of suspected disease can be marked with a suture laparoscopically and then a hand-port or minilaparotomy incision can be used for a tactile evaluation.

Small bowel resection	■ Creation of a mesenteric window allows for easy placement of a laparoscopic GIA stapler. ■ Edematous or thicker bowel may require 3.5-mm stapler cartridge.
Small bowel anastomosis	■ Traction sutures placed along the common enterotomy assist in accurate placement of a laparoscopic GIA stapler during closure of the common enterotomy. If the anastomosis appears narrowed with placement of the stapler, a sutured closure is preferred. ■ Ensure that the bowel undergoing anastomosis is well vascularized and not under tension. Edematous bowel is best approximated by a hand-sewn anastomosis. This may also be performed as an extracorporeal anastomosis through a small incision.
Removal of specimen	■ Use of a laparoscopic catch bag or wound protector can reduce the risk of wound infection.
Closure	■ Remove ports under laparoscopic visualization and inspect for bleeding prior to closure.

POSTOPERATIVE CARE

- After a laparoscopic small bowel resection, patients are admitted to the hospital for observation. If an extensive adhesiolysis is performed, a nasogastric tube may be placed at the end of the operation. Return of bowel function is signaled by production of flatus or formed bowel movements.
- A clear liquid diet may be started on postoperative day 1 after an uncomplicated laparoscopic small bowel resection. A solid diet may be started after return of bowel function.
- The patient may ambulate immediately after laparoscopic surgery and does not require prolonged bladder catheterization.
- Patients are usually seen in follow-up within 2 weeks of surgery.

OUTCOMES

- Laparoscopic small bowel resection is safe and effective resulting in lower lengths of hospital stay, less wound complications, and better cosmesis when compared to an open approach.[2,3] Laparoscopy also minimizes pain and severity of ileus as well as adhesive disease.[4]
- Small bowel obstruction makes laparoscopic surgery challenging and increases the likelihood for conversion to an open procedure.[5,6]
- Surgeons must acquire suturing skills to assure safe performance of advanced laparoscopic surgery.[7]
- Complete recovery is expected after small bowel resection. However, results depend on the condition prior to the procedure, the patient's overall health, and the length of bowel removed.

COMPLICATIONS

- Postoperative ileus
- Wound infection
- Anastomotic leak
- Anastomotic stricture
- Small bowel obstruction
- Port site incisional hernia

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Chapter 2

Strictureplasty and Small Bowel Bypass in Inflammatory Bowel Disease

Douglas W. Jones   Kelly A. Garrett

DEFINITION

- Strictureplasty and small bowel bypass are methods used to avoid bowel resection in patients with Crohn's disease.
- The technique of strictureplasty was initially described in the treatment of tuberculous strictures as an alternative to resection. This procedure is mainly used in patients with jejunoileal Crohn's disease but may also be used in select patients with duodenal disease. There are different techniques, but all involve division of the strictured area either transversely or longitudinally with a distinctive closure that serves to widen the lumen.
- Small bowel bypass involves bypass of an affected segment of small intestine that is deemed unsuitable for resection or strictureplasty. Resection of the diseased segment is usually preferred. Bypass may be used in gastroduodenal Crohn's disease, complex small bowel disease, or ileocolic disease when a patient's comorbidities preclude resection.

PATIENT HISTORY AND PHYSICAL FINDINGS

- A thorough history and physical examination should be performed. History should include duration and distribution of disease as well as current or prior medical therapy.
- Crohn's disease may manifest in one of three disease patterns: fibrostenotic, inflammatory, or perforating. Fibrostenosing disease is the most common and typically presents with a progressive course in which stricturing of the small bowel leads to obstructive symptoms.[1]
- Pattern of disease distribution should be determined prior to operative intervention. Anatomic location of disease can be classified as terminal ileal, colonic, ileocolonic, and upper gastrointestinal (GI). Over time, 15% of patients experience a change in anatomic location and 46% of patients demonstrate an alteration in disease behavior.[2]
- Past surgical history is of particular importance because many Crohn's disease patients have had prior abdominal surgery and this may affect operative planning. A detailed surgical history also allows for an estimation of the length of remaining small bowel.
- A detailed description of the patient's medical management should be obtained. The disease can be managed with antiinflammatory medications such as derivatives of 5-aminosalicylic acid; with immunosuppressors such as corticosteroids, azathioprine, 6-mercaptopurine, and methotrexate; and/or with immunomodulators such as antibodies targeting tumor necrosis factor-α. These medications can influence perioperative morbidity.
- A detailed history should also be obtained in order to distinguish Crohn's disease from ulcerative colitis. The two inflammatory bowel diseases can have similar patterns of presentation, although they have different principles of surgical management.

IMAGING AND OTHER DIAGNOSTIC STUDIES

- The distribution of active disease needs to be mapped out preoperatively. Thought should be given to the risk of exposure to ionizing radiation as many patients with Crohn's disease can have flares over the course of many decades and hence require repeat imaging studies.
- Conventional radiologic techniques for imaging the small bowel include small bowel enteroclysis (SBE) and small bowel follow-through (SBFT). Strictures may appear as narrowed areas with delayed passage of contrast. Dynamic images may reveal impaired peristalsis in strictured areas. Computed tomography (CT) and magnetic resonance (MR) enterography have almost completely replaced the use of these studies at most academic centers.
- CT performed with intravenous and oral contrast is helpful in identifying abscesses and other inflammatory processes outside the bowel lumen. Recent developments have also improved the ability of CT to identify strictures, fistulas, and areas of active inflammation. CT enterography uses low-density oral contrast in place of barium or iodine-based oral contrast used in standard scans. This in combination with intravenous iodinated contrast allows for better definition of the mucosa and thickness of the bowel wall.
- MR enterography is being increasingly used to evaluate extent of active disease.[3] MR enterography can also be performed using low-density oral contrast and offers the additional benefit of sparing patients' exposure to radiation.
- Ultrasound, although not as widely used, may be able to identify areas of bowel wall thickening, strictures, and decreased peristalsis. It is also useful for identifying abscesses and fistulas. Although ultrasound spares patients' exposure to ionizing radiation, it is operator dependent and may not be able to distinguish inflammatory versus fibrotic strictures.
- All of the previously described imaging studies may help determine whether an area of stricture has an active inflammatory component that may respond to medical therapy, aid in determining the extent of disease prior to surgery, and facilitate operative planning.

SURGICAL MANAGEMENT

Preoperative Planning

- Indications for surgery in patients with Crohn's disease include the following: failure of medical therapy, perforation, obstruction, worsening inflammation, hemorrhage, neoplasia, growth retardation, and/or extraintestinal manifestations.[3]
- When preoperative imaging reveals stricturing small bowel disease with minimal area of inflammation in patients with obstructive symptoms, additional medical therapy is unlikely to resolve the symptoms and the patient should be considered for surgery. Patients with suspected active inflammation who have failed medical therapy should also be considered for surgery.

- Strictureplasty should not be performed in every patient with stricturing Crohn's disease. In most patients, simple resection and reanastomosis is sufficient. Indications for strictureplasty are the following:[4]
  - Diffuse jejunoileitis causing obstructive symptoms unresponsive to medical therapy
  - Recurrent stricturing disease in patients with multiple prior intestinal resections (high risk for short bowel syndrome)
  - Recurrence of strictures within 12 months of prior resection
  - Isolated ileocolonic anastomotic strictures
  - Selected duodenal strictures such as proximal lesions near the pylorus[5]
- Contraindications to strictureplasty are the following:[4]
  - Diffuse peritonitis
  - Free intraabdominal perforation of the affected bowel segment
  - Phlegmon or abscess of affected bowel segment
  - Fistulous disease with significant inflammation of affected bowel segment
  - Multiple areas of stricture, within a short distance of each other, more amenable to single resection
  - Suspicion for neoplasia
  - Hypoalbuminemia
- In some cases, bypass of affected segments of the GI tract are indicated. These include the following:
  - Gastroduodenal Crohn's disease—The duodenum is involved in 0.5% to 4% of patients with Crohn's disease and can cause obstruction or hemorrhage.[6] In this scenario, resection is excessively morbid, so strictureplasty and bypass play a larger role.
    - With obstruction of the first or second portions of the duodenum, a gastrojejunostomy should be performed. Although traditionally performed to prevent marginal ulceration, current use of effective acid-suppressing medications have rendered vagotomy unnecessary.[6,7] Furthermore, vagotomy may increase morbidity in patients already predisposed to diarrhea from extensive or poorly controlled Crohn's disease or short-gut syndrome.
    - In patients with obstruction of the third or fourth portions of the duodenum, a duodenojejunal bypass should be performed.
  - Active inflammation of the duodenum and small bowel can lead to duodenoenteric fistula formation, commonly involving recurrence at a previous ileocolic anastomosis. Resection of diseased areas may require partial resection of involved duodenum as well. In these cases, bypass with a gastrojejunostomy may be required.
  - In complex small bowel or ileocolonic Crohn's disease.[8] Bypass should be considered when resection would be unsafe as in the presence of an ileocecal phlegmon that is adherent to the retroperitoneum or iliac vessels.
- Bypass of small bowel disease should be avoided if resection is possible. An excluded segment should eventually be resected in order to avoid development of perforation, recurrent disease, carcinoma, or blind loop syndrome.[8]

Preparation

- A mechanical bowel preparation is not necessary for patients who are undergoing small bowel or ileocolic resection and should be avoided in patients with stricturing disease.
- If there is a chance that a stoma will be created, the patient should be evaluated by an enterostomal nurse to help avoid the development of pouching problems postoperatively.
- Appropriate antibiotic and venous thromboembolism prophylaxis are administered prior to incision.

Positioning

- Supine position is useful for patients who have uncomplicated ileocolic disease or gastroduodenal disease.
- Modified lithotomy position is preferred if patients have distal disease that may require intervention. This allows for intraoperative colonoscopy to be performed for diagnostic purposes or to interrogate an anastomosis or repair if necessary. This position is also advantageous if the procedure will be done laparoscopically as it allows the surgeon to stand between the patient's legs, which can assist with running the small bowel or with mobilization of the flexures if needed.

APPROACH

Placement of Incision

- The procedure can be performed via a laparoscopic or open approach.
- Laparoscopy for ileocolic Crohn's disease has been shown to result in earlier return of bowel function, shorter length of stay, and decreased postoperative pain.[9] This approach may not be feasible for all patients, however, as many will have had extensive previous abdominal surgery.
- For open surgery, a standard midline laparotomy incision is usually performed. This can be limited to the upper midline if minimally active disease is suspected.
- In patients with multiple abdominal operations, entering the abdomen in an area that has not previously been opened is recommended to avoid inadvertent bowel injury.

Evaluation of the Bowel

- Adhesiolysis may be necessary to allow for complete evaluation of the small bowel. Strictured areas are often identified by fibrotic, narrowed bowel with proximal dilation. Other external indications of stricture are fat wrapping, thickened mesentery and serosal corkscrew vessels.[4] Areas of suspected stricture are marked with a stitch on the antimesenteric bowel surface.
- In patients with multiple previous abdominal operations and obliterative scar tissue, the use of injectable saline can be useful to help delineate bowel loops.
- After the most obvious area of stricture is identified, the lumen is opened longitudinally along the antimesenteric border in preparation for strictureplasty or resection. A Foley catheter is placed into the bowel lumen and

filled with varying amounts of water. The catheter is then advanced or withdrawn through bowel in both directions to identify area of stricture that may not be externally evident.

- Patients may have multiple areas of disease that require a combination of resection and strictureplasty. Resections should be performed first.
- Once the decision is made to perform a strictureplasty, the length of affected small bowel must be determined as this dictates the type of strictureplasty performed.
  - Less than 8 to 10 cm: Heineke-Mikulicz strictureplasty
  - 10 to 25 cm: Finney strictureplasty
  - Extensive, long-segment disease: side-to-side isoperistaltic strictureplasty

HEINEKE-MIKULICZ STRICTUREPLASTY

- The stricture is isolated proximally and distally using umbilical tape or bowel clamps. The stricture is opened longitudinally on the antimesenteric border, beginning in normal bowel approximately 2 to 3 cm from the stricture. A clamp is placed into the bowel lumen and the incision is carried across the stricture using electrocautery and ending 2 to 3 cm into normal bowel.
- Two 3-0 polyglactin sutures are placed on opposite sides of the incision in the center of the stricture. These are used to create tension perpendicular to the incision, thereby opening the incised area of bowel and allowing the bowel to be closed transversely.
- Interrupted seromuscular 3-0 polyglactin sutures are then placed to close the incision transversely.[10] (**FIG 1**)

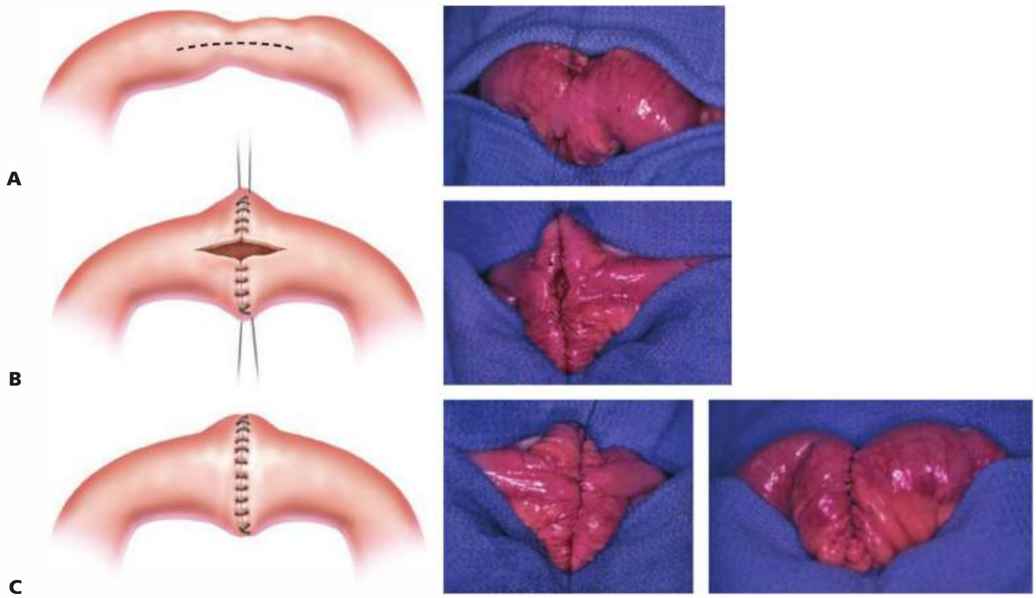

FIG 1 ● Heineke-Mikulicz strictureplasty. The bowel is opened longitudinally across the stricture **(A)** and then closed transversely **(B)** to increase the bowel lumen **(C)**.

FINNEY STRICTUREPLASTY

- For strictures 10 to 25 cm in length, a Heineke-Mikulicz strictureplasty creates excessive tension, so the Finney strictureplasty is preferred. A Finney strictureplasty should not be performed in a strictured segment that is longer than 25 cm, however, because this may risk a blind loop syndrome.
- The strictured area of bowel is isolated as previously described and the bowel is placed in a U shape with the midpoint of the stricture as the apex in order to simulate the finished strictureplasty and guide the bowel incision.
- The bowel is incised on the antimesenteric border beginning in normal bowel 2 to 3 cm from the stricture. This incision is then carried through the stricture using electrocautery. As the incision reaches the apex of the U shape, it should take a gradual course toward the mesenteric border as this allows for better tissue apposition. The incision finishes in 2 to 3 cm of normal bowel after having been brought back to the antimesenteric border.
- Interrupted, full-thickness 3-0 polyglactin sutures are used as marking sutures to approximate normal bowel edges at the base of the strictureplasty and are also used to fix the diseased bowel at the apex. Continuous 3-0 polyglactin suture is then used to close the posterior wall followed by the anterior wall of the strictureplasty. Interrupted sutures may also be used to reinforce the continuous suture at various points and maintain tissue apposition[4] (**FIG 2**).

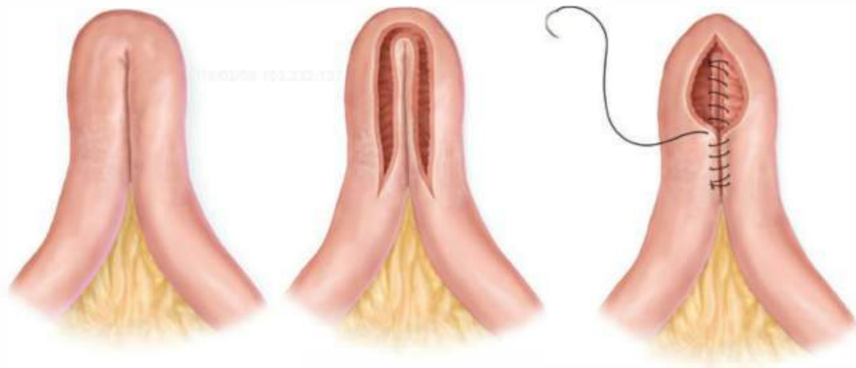

FIG 2 ● Finney strictureplasty. The bowel opening is made longitudinally across the stricture along "an omega loop" and is then closed side-to-side (posterior and anterior rows).

SIDE-TO-SIDE ISOPERISTALTIC STRICTUREPLASTY

- For extensive stricturing Crohn's disease not amenable to strictureplasty of isolated segments, the side-to-side isoperistaltic strictureplasty can be performed.
- The affected bowel is first transected at the midpoint. The proximal bowel is then brought to overlie the distal segment in an isoperistaltic fashion (**FIG 3**). An enterotomy is performed on the antimesenteric border and extended 2 to 3 cm into normal mucosa (**FIG 4**).
- The transected ends of bowel are spatulated in order to avoid creation of blind stumps.
- Similar to the Finney strictureplasty, tissues are brought together at both ends of the treated segment with interrupted 3-0 polyglactin sutures. The posterior layer is closed with a running 3-0 polyglactin suture followed by closure of the anterior layer (**FIG 5**).

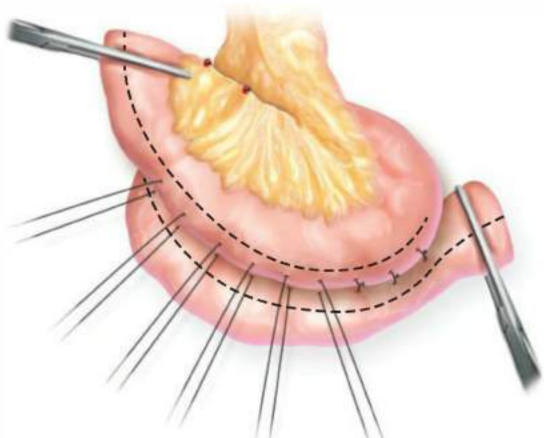

FIG 3 ● Side-to-side isoperistaltic strictureplasty. The affected bowel is first transected at the midpoint. The proximal bowel is then brought to overlie the distal segment in an isoperistaltic fashion.

FIG 4 ● Side-to-side isoperistaltic strictureplasty. An enterotomy is performed on the antimesenteric border and extended 2 to 3 cm into normal mucosa.

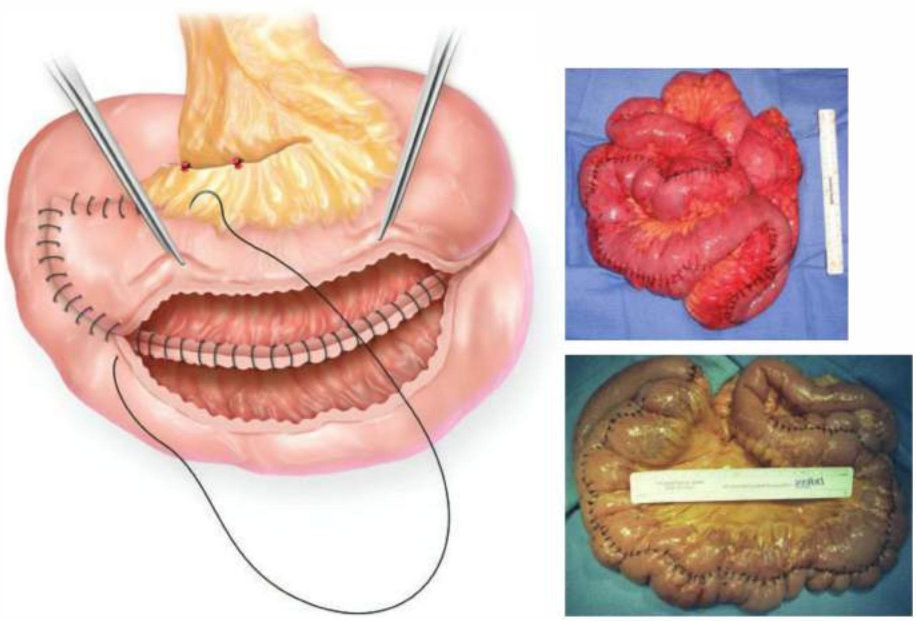

FIG 5 ● Side-to-side isoperistaltic strictureplasty. Similar to the Finney strictureplasty, tissues are brought together at both ends of the treated segment with 3-0 polyglactin sutures.

SMALL BOWEL BYPASS

Gastrojejunal Bypass

- Gastrojejunostomy is performed by bringing the most proximal loop of jejunum that easily reaches the greater curvature of the stomach. The anastomosis can be done using either a hand-sewn (**FIG 6**) or stapled technique (**FIG 7**). It can also be done antecolic or retrocolic. The antecolic approach avoids dissection through the transverse colon mesentery and also keeps the anastomosis away from the retroperitoneum.

Duodenojejunal Bypass

- A longitudinal enterotomy in the proximal jejunum is made in an area that is free of disease. A Foley catheter is inserted and passed proximally through the duodenal sweep and filled with varying amounts of water to assess for duodenal stricture. If there is a stricture isolated to

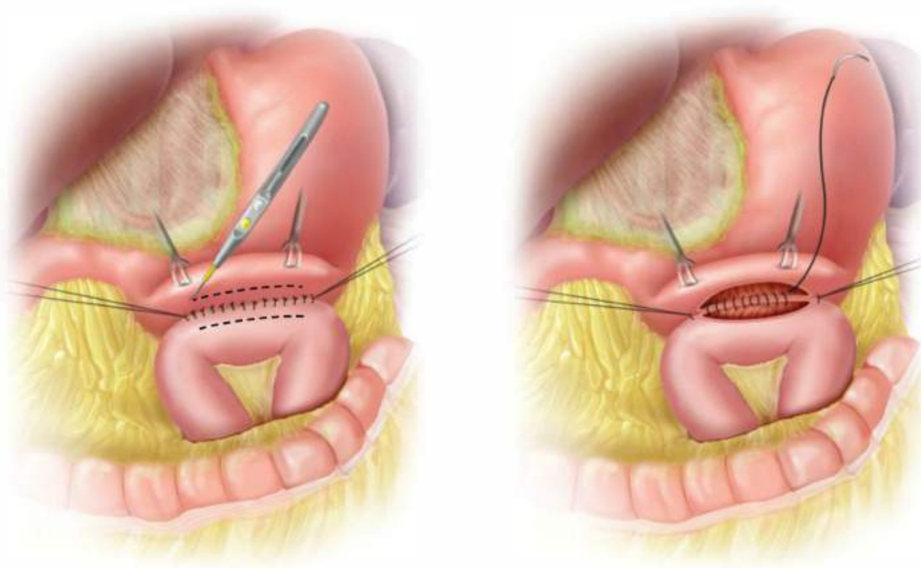

FIG 6 ● Gastrojejunal bypass: hand-sewn technique.

the third and fourth portions of the duodenum and it is determined that there is healthy, patent bowel in the first and second portion, then a bypass may be performed. A longitudinal duodenotomy is performed in the healthy portion of the duodenum. 3-0 polyglactin sutures are placed to approximate the jejunal enterotomy to the duodenotomy.

- A posterior layer of interrupted 3-0 silk sutures is placed to approximate the duodenal and jejunal segments (**FIG 8**). This is followed by a continuous inner suture layer of 3-0 polyglactin suture. A layer of interrupted 3-0 silk is then placed on the anterior surface to complete the anastomosis (**FIG 9**). The use of a stapler is not recommended.[8]

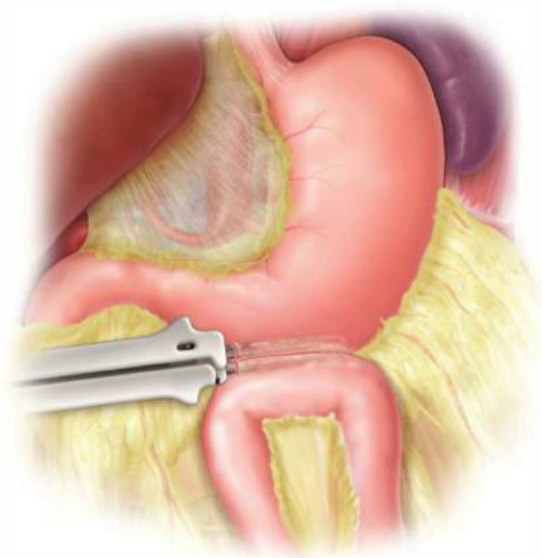

FIG 7 ● Gastrojejunal bypass: stapled technique.

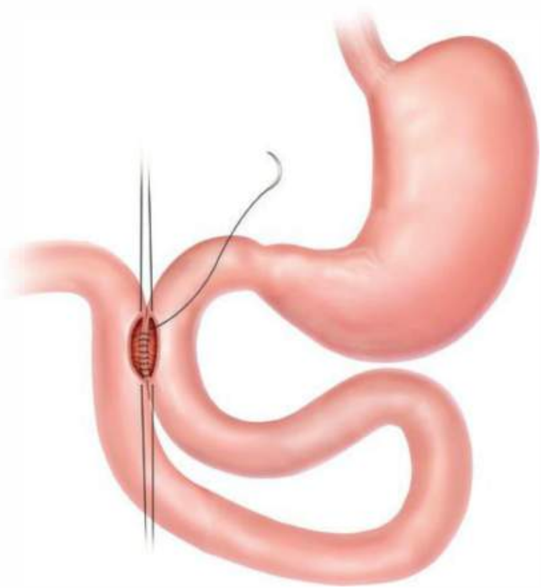

FIG 8 ● Duodenojejunal bypass: A posterior layer of interrupted 3-0 silk sutures is placed to approximate the duodenal and jejunal segments.

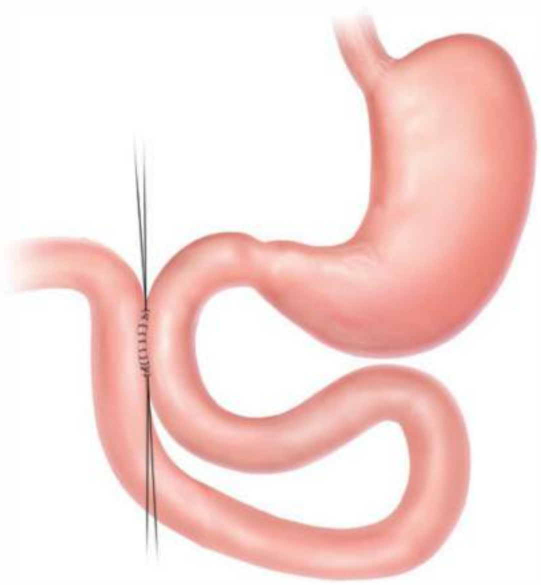

FIG 9 ● Duodenojejunal bypass: A continuous inner suture layer of 3-0 polyglactin suture and a layer of interrupted 3-0 silk are then placed on the anterior surface to complete the anastomosis.

ILEOTRANSVERSE BYPASS

- When ileocolic disease is severe and resection is deemed unsafe, an ileotransverse bypass may be performed.
- The small bowel is transected proximal to the involved ileum.
- A hand-sewn anastomosis is performed in an end-to-side fashion with the end of the transected ileum anastomosed to the side of a segment of transverse colon (**FIG 10**). This is done in a similar fashion as described for the duodenojejunal bypass. Alternatively, the anastomosis can be performed in a side-to-side fashion using a gastrointestinal anastomosis (GIA) stapler[8] (**FIG 11**).

FIG 10 ● Ileotransverse bypass: hand-sewn technique.

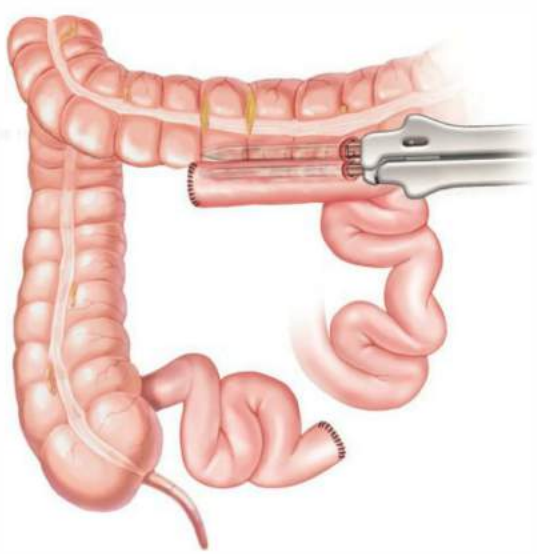

FIG 11 ● Ileotransverse bypass: stapled technique.

OTHER CONSIDERATIONS

- Duodenal strictures
  - Patients with nonperforated, nonphlegmonous strictures of the duodenum can undergo Heineke-Mikulicz strictureplasty.
  - Patients with refractory obstruction, pain, or extensive duodenal stricturing may require bypass with gastrojejunostomy or duodenojejunostomy. The role of vagotomy in this setting has been debated; however, as stated previously can most often be omitted.
  - Duodenal resection is not indicated for Crohn's disease due to its excessive morbidity.
- Colonic strictures that cannot be evaluated by colonoscopy biopsy or cytology should be resected as approximately 7% of these may contain occult malignancy.[11] Biopsy of the strictured bowel wall should be considered to evaluate for possible occult malignancy.[12]

PEARLS AND PITFALLS

Imaging	■ Preoperative imaging studies should be used to determine the extent of disease and to facilitate surgical planning. ■ Extent of active inflammation should be estimated preoperatively as this is potentially responsive to medical therapy.
Choice of procedure	■ Resection with simple reanastomosis should be performed for most patients with small bowel and ileocolic disease. ■ Strictureplasty should be performed in patients with previous resections who are at risk for short bowel syndrome or patients with diffuse or recurrent stricturing disease. ■ Bypass of affected segments is most useful for gastroduodenal Crohn's disease and should only be employed in small bowel or ileocolonic Crohn's disease if resection is deemed too unsafe. ■ When a strictured area is identified, a longitudinal incision is made and the proximal and distal bowel is evaluated with a Foley catheter to determine extent of disease. ■ Metallic clips should be placed on the mesentery at the strictureplasty sites for future identification during imaging or surgery. ■ The length of remaining small bowel should be measured and recorded, especially in patients who are having reoperations. This will help in planning during possible future operations.

POSTOPERATIVE CARE

- Patients undergoing resection, strictureplasty, or bypass for Crohn's disease often have proximally dilated small bowel. Chronically dilated intestine should be expected to have dysfunctional peristalsis, and as such, recovery of full bowel function may take up to 1 week or more. For severe obstruction, nasogastric tube decompression may be indicated. Total parenteral nutrition may also be useful in the postoperative period to allow adequate healing at anastomosis or strictureplasty sites.

OUTCOMES

- Resection: Recurrence of stricturing disease requiring surgery occurs in 25% and 50% of patients at 5 and 10 years, respectively.[1] Recurrence is unaffected by the presence of active microscopic inflammation at the resection margin and as such, only macroscopically involved segments of bowel should be resected.[10]
- Strictureplasty: Recurrence following strictureplasty occurs in 28% and 34% of patients at 3.5 and 7.5 years, respectively. Younger patients are at higher risk for recurrence following stricturoplasty.[1] Overall recurrence rates are comparable to those following resection.
- Duodenal Crohn's disease: Bypass or strictureplasty of the duodenum are relatively uncommon procedures but have been performed with good results. Major morbidity of these procedures may be as high as 27%. It is thought that use of laparoscopy to perform gastrojejunostomy may decrease complication rates.[6] Recurrence and reoperation rates are variable.

COMPLICATIONS

- Surgical site infection
- Intraabdominal infection
- Anastomotic leak
- Anastomotic hemorrhage
- Ileus
- Small bowel obstruction
- Short bowel syndrome

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Chapter 3

Surgical Management of Enterocutaneous Fistula

William Sanchez

DEFINITION

- A fistula is an abnormal communication between two epithelialized surfaces. An enterocutaneous fistula (ECF) is an abnormal communication between the bowel lumen and the skin. An enteroatmospheric fistula (EAF) is the communication between the bowel and the environment, with absence of skin continuity (open abdomen fistula).
- Anastomotic leaks occurring during the first postoperative week are considered anastomotic line failures and not fistulas (no epithelialized tract has formed during that short period of time). They are usually detected because of drainage of intestinal material in the peritoneal cavity leading to the formation of an abscess or diffuse peritonitis. These patients are taken to surgery urgently either to repair the leak or to perform proximal diversion ostomies to ensure patient recovery.

CLASSIFICATION AND PROGNOSTIC FACTORS

Classification

- Anatomic: on the basis of the affected segment
  - Gastrocutaneous, duodenocutaneous, enterocutaneous, and colocutaneous
- Etiology: Multiple causes are described, including the following[1,2]:
  - Infectious and inflammatory (Crohn's disease, ulcerative colitis, tuberculosis, mycosis, diverticulitis, salmonellosis, amoebic abscess)
  - Iatrogenic (postoperative, open abdomen, postradiation)
  - Traumatic
  - Cancer
  - Foreign bodies
- Fistula output:
  - High output: more than 500 mL per day. These fistulas are associated with a severe electrolyte and nutritional abnormalities.
  - Intermediate output: 200 to 500 mL per day
  - Low output: less than 200 mL per day

FIG 1 ● Patient with open abdomen and multiple EAFs.

Prognostic Factors

- Deep EAFs drain the intestinal content into the abdominal cavity, giving rise to peritonitis. Mortality associated with this condition is higher than that of the superficial fistula that drains its content to the outside, creating an abdominal granulation wound with no diffuse contamination of the abdominal cavity.[3]
- In surgical patients with secondary fistula, we characterize the most important adverse prognostic factors associated with the course of treatment, which are analyzed following the initial resuscitation and stabilization stage (48 to 72 hours). These factors include the following:
  - Open abdomen
  - Diameter larger than 5 mm; output greater than 500 mL per day
  - Presence of abscess and/or diffuse peritonitis, generalized sepsis
  - Need for mechanical ventilation
  - Inability to provide enteral feeding
  - Presence of multiple fistulas (**FIG 1**)
  - Severe comorbidities (cancer, immunosuppression, radiation therapy, etc.)
- The probability of a spontaneous fistula closure is related to different factors summarized in Table 1. Three risk groups are then established in order to arrive at an objective determination of the degree of complexity of the fistula, the goals of the proposed treatment, and the predicted clinical course (Table 2).
  - Risk group I: good prognosis. This group includes patients with no debilitating disease who are in good general condition and no systemic inflammatory response syndrome (SIRS), with fistulas that have a good probability of closing spontaneously (diameter <5 mm, output <200 mL per day, single). Treatment is limited to support, and surgical closure is not considered initially.

Table 1: Probability of Fistula Closure

Spontaneous Closure	No Spontaneous Closure
Esophageal, duodenal stump, jejunal	Gastric, Ligament of Treitz, Ileal
Enteric wall defects <1 cm	Enteric wall defects >1 cm
Fistula tracts >2 cm	Fistula tracts <2 cm
No abdominal wall defect	Open abdomen
Albumin level >25 g/L	Albumin level <25 g/L
No FRIEND factors[a]	FRIEND factors
Output <200 ml/d	Output >500 ml/d
Conservative treatment	Surgical treatment

[a]*Nonhealing ECFs are associated with FRIEND factors: **F**oreign body, **R**adiation, **I**nflammation, **I**nfection, **I**nflammatory bowel disease, **E**pithelization of the fistula tract, **N**eoplasms, and **D**istal obstructions.*

Table 2: Fistula Treatment Outcomes, Prognostic Risk Groups

Prognostic Group	I	II	III
Degree of complexity of the fistula	Low	Intermediate	High
Goals of the proposed treatment	Spontaneous closure	Early surgical closure	Late surgical closure
Predicted clinical course (mortality)	Exceptional mortality	Mortality 10%–25%	Mortality >25%

FIG 2 ● CT scan showing aortoenteric fistula with gas around the aorta.

- Risk group II: intermediate prognosis. This group includes patients in acceptable general condition with no SIRS but with fistulas that have small probability of closing spontaneously (diameter >5 mm, output >500 mL per day, multiple fistulas). The treatment strategy is to initially stabilize the patient and subsequently perform early surgical closure.
- Risk group III: poor prognosis. This group includes patients in poor condition who are malnourished, with debilitating diseases, who exhibit SIRS, and who have fistulas with small probability of closing spontaneously. The initial goal of treatment is to reduce fistula output, to achieve granulation and ostomization of the fistula, as well as to care for the open abdomen. The surgical closure is performed at a later stage (6 to 12 months), once the patient has recovered and both objective and subjective signs of recovery are satisfactory.

IMAGING AND OTHER DIAGNOSTIC STUDIES

- The role of imaging is to define the anatomy, evaluate associated processes, and provide therapeutic alternatives for treatment.
- Fistulograms are the most direct method of linking a cutaneous opening with the gastrointestinal (GI) tract. In the absence of sepsis, fistulograms may be the only imaging study needed. Two classes of contrast media are commonly used to evaluate the fistula tract, each with particular risks and benefits. Barium is a non–water-soluble media with high radiographic density, isotonic osmolarity, and an inert nature. Barium provides high-quality mucosal images, demonstrating areas of inflammation and the presence of fistula tracts with good accuracy. Unfortunately, if extravasated, barium causes significant peritoneal inflammation, including foreign body granulomas and peritoneal adhesions. Aqueous contrast agents, such as Gastrografin, are hyperosmolar and water-soluble. Water-soluble agents provide less mucosal detail; areas of inflammation, mucosal projections, and fistula tracts themselves may be missed. Gastrografin is rapidly absorbed within the peritoneal cavity if extravasated with minimal inflammation. To minimize risk and maximize benefits, water-soluble contrast material is often injected initially, followed by barium if no extravasation is seen and additional information is required.[1,3,4]
- Small bowel follow-through (SBFT) studies provide a more global view of the intestinal tract. Multiple views are typically taken to optimize visualization. Ideally, barium is used for contrast as Gastrografin can be diluted as it moves distally through the GI tract. Fistulas with narrow lumen and distal fistulas may not be detected in SBFT studies. Previously opacified loops of bowel may complicate visualization of the fistula.
- Ultrasound. Limitations of ultrasound include operator dependency, obesity, and difficulty of evaluating certain portions of the small bowel including duodenum and jejunum. Injection of hydrogen peroxide through the fistula orifice has been reported to increase the diagnostic accuracy of ultrasound from 29% to 88% in ECF complicating Crohn's disease.[5]
- Computed tomography (CT) allows for the identification of extraluminal pathology, downstream disease, and inflammation (**FIG 2**).
- Computed tomography enterography (CTE) uses "negative" contrast, which appears dark, allowing for distention of the bowel. With the concomitant administration of intravenous (IV) contrast that will delineate mucosa, negative contrast provides additional information concerning the mucosa surrounding a fistula tract.[4]
- Magnetic resonance imaging (MRI) is a promising adjunct to primary imaging modalities. Its use in ECF evaluation is beginning to be understood.

SURGICAL MANAGEMENT

Preoperative Planning

- The fundamental pillars for fistula management, initially described by Chapman,[6] can be summarized by the **SOWATS** acronym: management of the **S**eptic condition, **O**ptimization of the nutritional status, surgical **W**ound care, fistula **A**natomy, right **T**iming for surgery, and **S**urgical strategy.[1] By adopting this strategy, they reduced ECF mortality from 40% down to 15%.
  - **Sepsis:** Associated infection is the primary cause of death in fistula patients. The initial management of a patient with an ECF, with or without associated infection, is fluid resuscitation to address dehydration and prevent renal

failure. Blood transfusion has to be considered if required. There are two stages associated with the management of infection:

- Early stage. When a fistula is suspected or diagnosed, the goal is to prevent or control generalized contamination of the abdominal cavity and subsequent peritonitis. Treatment at this stage is surgical or percutaneous invasive therapy together with the use of antibiotics.
- Late stage. After the fistula tract has been established, the goal is to prevent or treat any secondary focus of infection, usually nosocomial (catheter-related sepsis, pneumonia, residual abscesses, etc.). Treatment at this stage is systemic or preventive.

- **Optimization of the nutritional status:** Effective nutritional support is a priority. Although parenteral nutrition may be needed in some cases, recent publications favor enteral nutrition as a protective factor against associated infections. The enteral route must be considered when it is suspected that the fistula will not close spontaneously, when it is a low-output fistula, or when it is localized in the terminal ileum or the colon. The use of somatostatin and octreotide, which lower endocrine and exocrine secretion, reduces fistula output. The use of antiperistaltic agents such as loperamide and codeine is also helpful. The basic nutritional requirements consist of carbohydrates and fats 20 kcal/kg/day and proteins 0.8 g/kg/day. Caloric and protein requirements may increase to 30 kcal/kg/day and 1.5 to 2.5 g/kg/day, respectively, in patients with high-output fistulas.[1,3]
- **Surgical wound care:** The goal of treatment is to avoid maceration and excoriation of the skin surrounding the ECF, one of the main causes of chronic pain in these patients. Multidisciplinary treatment is recommended preferably in a specialized wound clinic.
- **Fistula anatomy:** It is crucial to identify the origin and tract of the fistula in order to plan treatment. Diagnostic imaging studies with water-soluble contrast through the fistula tract or through the GI route provide accurate information about the problem. CT scans are useful to assess the entire abdominal cavity and to identify other associated problems requiring treatment (abscesses, free fluid collections, obstructions, etc.). In some cases, endoscopic evaluation is useful, given the possibility of performing therapeutic maneuvers to obliterate the fistulous tract (stent, clips, glue sealant).[7]
- **Right timing for surgery:** The decision on the right timing for the surgical closure of an ECF must be made after analyzing all prognostic variables for each individual patient. A period of 6 weeks is considered the minimum time between the development of the fistula and the surgical repair procedure because it is the time required for the patient to recover from the inflammatory response and to achieve a good nutritional status that will help avoid a new, possibly fatal, complication. Preoperative albumin level of less than 2.5 g/L is a strong adverse prognostic factor associated with mortality ($p < .001$); this result has been replicated in other series.[2] In open abdomens, the time required for regression of the inflammatory state, the nutritional recovery, and the best course of potential abdominal adhesions is between 6 and 12 months. Patients are eligible for surgery when septic foci have been treated adequately and the subjective criteria for a good clinical and nutritional condition are satisfactory. These criteria include a patient who can walk, feels well, interacts actively, and is impatiently waiting for the restorative surgery. The absence of signs of sepsis is determined by the increase in albumin and hemoglobin levels, together with lower leukocyte, reactive protein C, and thrombocytosis values.[1,3]
- **Surgical strategy:** There are multiple surgical techniques and strategies for the treatment of ECFs. There is no single technique, and the combination of several different strategies is usually required. Generally, the surgical goals include the following:
  - Fistula resection
  - Restore continuity of bowel transit.
  - Address the factors that promote fistula formation (obstruction, foreign body, tumors, diverticular disease, inflammations).
  - Abdominal wall closure
  - Perform as few anastomoses as possible, all of which need to be covered by healthy tissue and separated from other anastomosis lines.
  - Avoid the use of nonabsorbable mesh for closure of the abdominal wall.
  - Avoid leaving skin defects that might promote the formation of a new fistula.
  - Ensure adequate nutrition.

Surgical Tips

- In established fistulas with a defect larger than 5 mm in diameter and an output greater than 500 mL per day, attempting a primary closure with sutures is often ineffective and may increase the size of the damage to the intestinal wall. In order to attempt the primary closure of the fistula, all granulation tissue at the edges must be removed, the closure must be done under no tension, and the defect must be covered.
- No balloon catheters (Foley) must be introduced or inflated inside the fistula tract or the gut lumen because this will increase the size of the fistula. When the fistula is close to the ligament of Treitz, a feeding tube may be introduced distally for enteral nutrition.
- In fistulas with an open abdomen, the use of the Bogota bag is not very effective because it does not allow for control of ongoing contamination of the abdominal cavity and there is persistence of skin erosion. These problems are solved with the use of the wound vacuum-assisted closure (VAC®) system (the right foam must be selected in accordance with the clinical situation). In some cases, VAC® therapy together with other strategies results in primary closure of the fistula. If primary closure is not achieved, VAC® therapy promotes granulation and wound healing, maturation of the fistula into a controlled stoma, and patient recovery so that surgical closure and abdominal wall reconstruction may follow (**FIGS 3–5**).[8,9]
- Patients with ECF difficult to reach and/or control (i.e., ECF in frozen open abdomen, duodenal fistulas, aortoenteric fistula, etc.) can develop ongoing peritonitis leading to persistent sepsis. Attempting extensive surgery (pancreatoduodenectomy, diverticulization, etc.) or multiple diversions in this setting usually results in a poor outcome and

FIG 3 ● Soldier wounded in combat with multiple intraabdominal injuries and complex ECF.

FIG 4 ● Wound VAC® therapy is very effective to allow control of fistula fluids or of contamination of the abdominal cavity.

FIG 5 ● Wound VAC® therapy promotes granulation, wound healing, and control of the fistula. This allows the patient to recover in preparation for surgical closure and abdominal wall reconstruction.

extremely high mortality rates. In these critical situations, we pass a self-expandable coated stent or an impermeable corrugated prosthetic tube through the fistula defect and into the intestinal lumen in an attempt to seal off the fistula, to restore intestinal transit, and to prevent ongoing soilage of the peritoneal cavity. The use of the wound VAC® therapy in this setting collects any spillage of bowel fluid leaks that may occur and promotes granulation and healing of the abdominal cavity. Surgery must be performed at an early stage, before the patient goes into multiple organ failure and is beyond rescue. After the patient recovers (weeks or months later), and if the fistula has closed, an attempt is made to recover the prosthesis through enteroscopy or surgery. If the fistula has not closed, the relevant repair surgery is planned. The introduction of this concept is controversial, but its use may be acceptable in extreme situations, based on the wide clinical experience with the use of stents or shunts in other GI, vascular, and colonic diseases (**FIG 6**).[10]

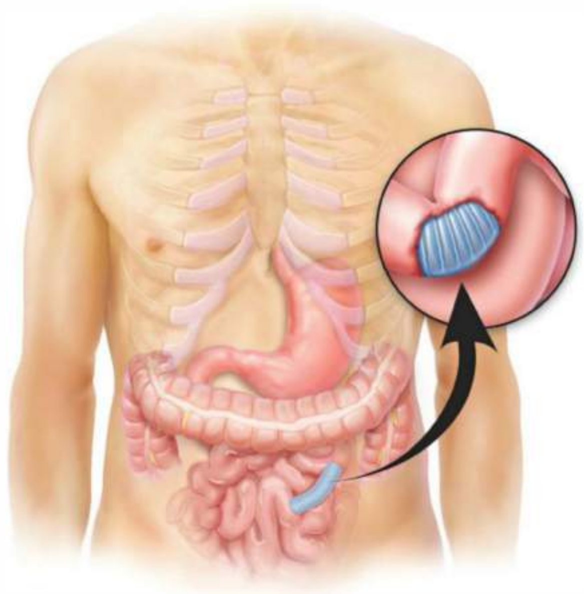


FIG 6 ● Use of a stent or corrugated prosthetic tube with intestinal bypass in a patient with a complex fistula in the fourth portion of duodenum.

SURGICAL CLOSURE OF COMPLEX ENTEROATMOSPHERIC FISTULA

Step 1. Peritoneal Contamination Control

- Remove the Bogota bag (**FIG 7**), wash and clean the abdominal cavity, and then place a tube for enteral feeding, covering the open abdomen partially with a wound VAC® system (**FIG 8**).

FIG 7 ● Temporary abdominal closure with a Bogota bag.

Step 2. Granulation of the Abdominal Wound and Conversion of the Fistula into a Stoma

- Continue with wound VAC® therapy until the peritoneal contamination is under control, promoting granulation of the abdominal wound (**FIG 9**). The end point of this step is to achieve conversion of the fistula into a functional stoma (**FIG 10**).

Step 3. En Bloc Resection of the Fistula and Abdominal Wound

- En bloc dissection is performed of the entire abdominal scar component and the fistula, working inward from the surface (**FIG 11A,B**).

FIG 8 ● Placement of feeding tube and a wound VAC® system.

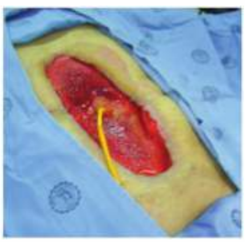
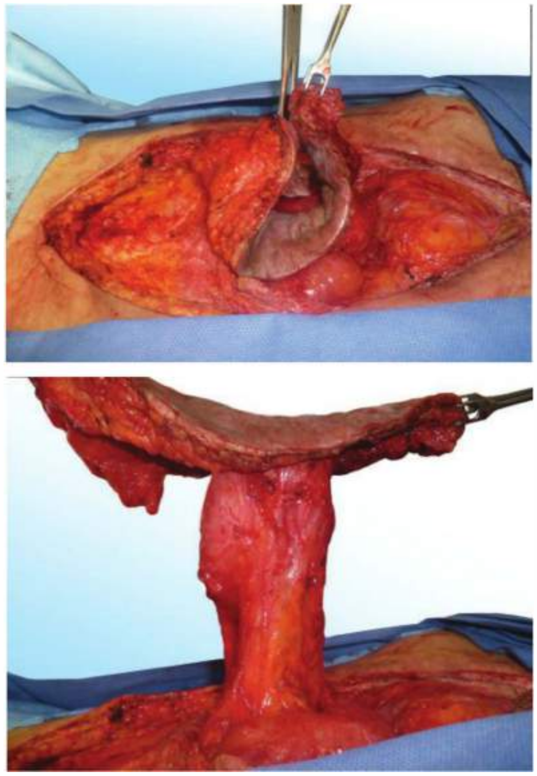


FIG 9 ● This strategy allowed for excellent granulation tissue to form around the ECF in the open abdominal wound.

FIG 10 ● The end point of therapy prior to surgical excision of the ECF is when the fistula has been transformed into a stable stoma.



A

B

FIG 11 ● **A,B.** En bloc dissection of ECF and granulation tissue bed.

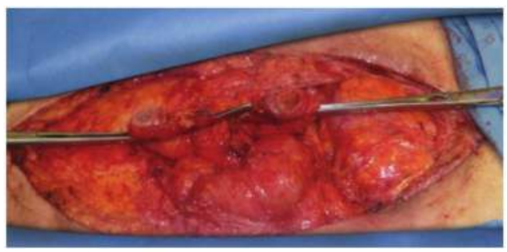


FIG 12 ● Resection of the ECF.

Step 4. Reconstruction of the Intestinal Transit and the Abdominal Wall

- The ECF is then resected (**FIG 12**), and the intestinal tract is reconstructed with a hand-sewn (**FIG 13**) or stapled technique (**FIG 14**). The abdominal wall is reconstructed using partially absorbable mesh with carboxymethyl cellulose coating or, preferably, with a biologic coating (**FIG 15**).

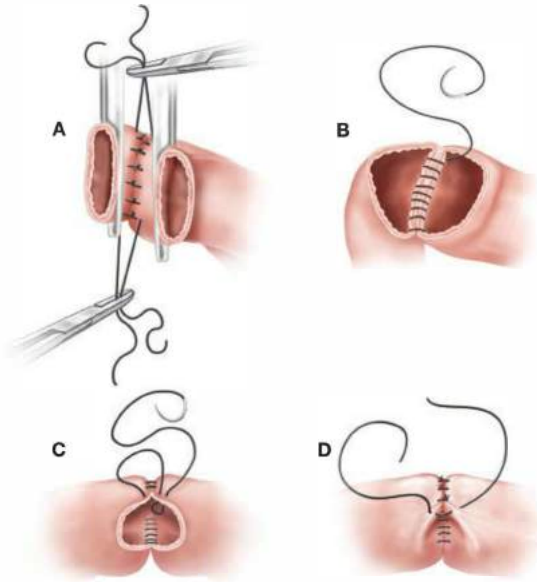


FIG 13 ● Reestablishment of intestinal continuity. End-to-end hand-sewn anastomosis technique.

FIG 14 ● Reestablishment of intestinal continuity. Side-to-side stapled anastomosis technique.

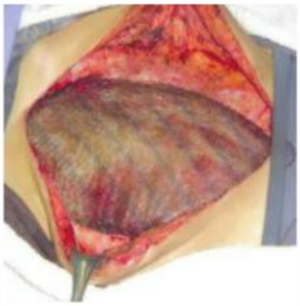


FIG 15 ● The abdominal wall is reconstructed using partially absorbable mesh with carboxymethyl cellulose coating.

NONSURGICAL CLOSURE OF A COMPLEX ENTEROATMOSPHERIC FISTULA

- A newborn, 31 weeks of gestation with necrotizing enterocolitis, develops EAF after right hemicolectomy (**FIG 16**). In patients such as this one, with otherwise no significant comorbidities, a nonsurgical approach to ECF closure may be attempted.

Step 1: Peritoneal Contamination Control

- Start with general resuscitation measures and use of the SOWATS protocol. Control contamination and intestinal fluid leaks using wound VAC® therapy (**FIG 17**).

Step 2: Granulation of the Abdominal Wound and Fistula Control

- Continue the wound VAC® therapy until the peritoneal contamination is under control, promoting granulation of the abdominal wound, and channel the fistula to reduce output gradually (**FIG 18**).

Step 3. Closure of the Fistulous Tract Using Fibrin Glue

- Once the fistula output is down to a minimum, fibrin glue is applied through the fistula tract (**FIG 19**). Continue with general measures and wound VAC® therapy until healing of the fistula and closure of the abdominal wall are achieved (**FIG 20**).

FIG 16 ● Newborn with ECF secondary to necrotizing enterocolitis.

FIG 17 ● A wound VAC® has been placed to control the fistula, protect the skin, and promote granulation tissue formation.

FIG 18 ● Excellent granulation tissue has been achieved.

FIG 19 ● Fibrin glue application into the fistula tract to accelerate ECF closure.

FIG 20 ● Full healing of ECF after nonoperative management of ECF fistula.

PEARLS AND PITFALLS

Burn injury	■ An ECF may occur from a bowel lesion created inadvertently by diathermia during open or laparoscopic surgery (**FIG 21**).
Suture line protection	■ Anastomotic lines should not be in contact with other suture lines or prostheses. An omental pedicle flap is a good option to protect the anastomosis. Although the use of fibrin glue sealants has also been advocated for this purpose, there is no conclusive evidence in the literature about their benefit.
Use of nonabsorbable mesh in direct contact with the bowels should be avoided.	■ A good option is to use biologic mesh or synthetic mesh coated with carboxymethyl cellulose (nonadherent).
Fistulas secondary to adhesions	■ The prophylactic use of antiadhesive substances, such as carboxymethyl cellulose and hyaluronic acid, has been shown to reduce the presence and degree of complexity of the adhesions and, consequently, lower the possibility of fistula formation secondary to surgical injuries.[11]
Open abdomen–related fistulas (25% incidence)	■ The fistula forms as a result of direct injury, desiccation, or erosion due to foreign bodies that become incorporated into the gut wall (Packing, Wittmann Patch). Partial coverage of the abdominal cavity using the VAC® system is a good option for lowering the probability of fistula formation.[8,9]

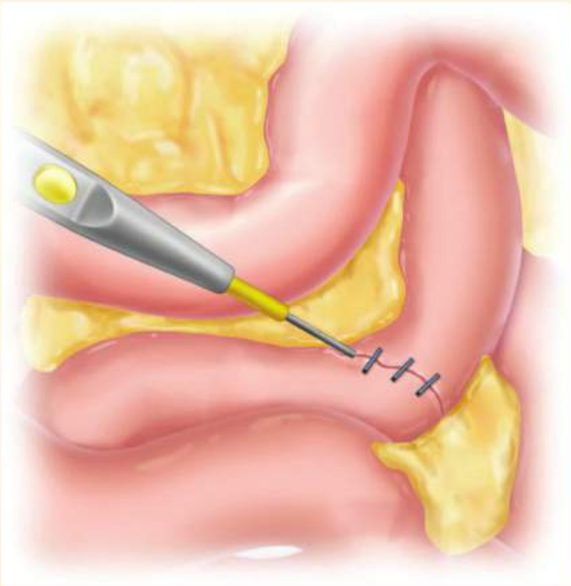


FIG 21 ● A fistula may originate from a bowel lesion created inadvertently by diathermia.

COMPLICATIONS

- **Local:** abscess, diffuse peritonitis, other fistulas, bleeding from erosion of adjacent structures, skin damage
- **Systemic:** fluid and electrolyte imbalances, malnutrition, abscess of distant solid viscera (liver, lung, brain), sepsis, SIRS

CONCLUSION

- Currently, the main causes of ECFs are those associated to the complications of surgery. Review and practice of prophylactic surgical tips can reduce its incidence.
- The treatment of fistulas must be multidisciplinary. Adherence to a driving guide, such as SOWATS, allows for a sequential and ordered therapeutic strategy with an increased chance of better clinical outcomes.
- Patients with intestinal fistulas should be categorized into risk groups in order to predict its prognosis and to define the management strategy necessary. There is no one single standard treatment; the selection of the treatment depends on the individual condition of each patient and the characteristics of the fistula itself.

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Chapter 4

End and Diverting Loop Ileostomies: Creation and Reversal

Kathrin Mayer Troppmann

END AND DIVERTING LOOP ILEOSTOMIES: CREATION

DEFINITION

- An ileostomy is an artificially created opening of the distal ileum that is externalized on the abdominal wall. It can be temporary or permanent.

PATIENT HISTORY AND PHYSICAL FINDINGS

- A thorough review of the patient's history and a physical examination, including a review of all past operative notes and diagnostic studies, are necessary to carefully select patients who are appropriate candidates for an ileostomy and to determine the most appropriate type of ileostomy to be created.
- The history and the physical examination should be obtained with the functional and anatomic implications, treatment plan, and prognosis of the underlying disease in mind.
- Additionally, the patient's comorbidities, ability to perform activities of daily living and self-care, mobility limitations, and body contour must be thoroughly assessed.

PREOPERATIVE IMAGING AND OTHER DIAGNOSTIC STUDIES

- Appropriate imaging studies must be obtained according to the patient's underlying disease and diagnosis. Any abnormal findings should be thoroughly worked up to ensure that the correct operation and diversion techniques are chosen. These tests may include the following:
  - Colonoscopy with biopsy if malignancy or inflammatory bowel disease is suspected
  - Computed tomography (CT) scan, upper gastrointestinal contrast study, and fistulogram to rule out intestinal obstruction or leak and to assess underlying disease severity
  - Anal manometry and endorectal ultrasound to evaluate the anal sphincter
  - Colonic motility study (e.g., SITZMARKS® test) to identify the region of intestinal dysmotility and to tailor the procedure and type of stoma to the patient's needs
  - Prior to ileostomy formation, the nutritional status must be assessed (including albumin and prealbumin levels) and the patient's comorbidities must be addressed (e.g., coronary artery disease, diabetes [HbA_{1c}]) in order to minimize perioperative risk.

SURGICAL MANAGEMENT

General Considerations

- If possible, a stoma should be avoided, as the morbidity of creation and reversal can be significant.
- An ileostomy can be constructed as an end ileostomy (Brooke ileostomy) or as a diverting loop ileostomy. Alternatives to the more commonly used end and loop ileostomy techniques include the divided (or separated) loop ileostomy for maximizing fecal diversion and the end-loop (or loop-end) ileostomy for patients with a short, contracted mesentery and vascular pedicle.
- An end ileostomy is the preferred configuration for a permanent ileostomy because it allows for a symmetric and protruding spout that is more easily constructed and managed.
- Permanent end ileostomies are usually created when the distal intestine is not suitable for restoration of intestinal continuity due to underlying disease or poor intestinal function. Typical scenarios include:
  - Following total proctocolectomy for inflammatory bowel disease or familial adenomatous polyposis
  - Following subtotal colectomy for slow-transit constipation with concomitant severe pelvic floor dyssynergia
  - Fecal incontinence
  - Congenital anomalies
- Temporary end ileostomies are typically created under the following circumstances:
  - Following subtotal colectomy for acute diverticular bleeding or ulcerative colitis–related toxic megacolon
- Temporary or permanent diverting loop ileostomies are created when diversion of the fecal stream and decompression of the distal bowel are necessary:
  - Following distal ileal or colonic anastomoses at high risk for disruption due to:
    - Malnutrition or immunocompromised status
    - Anastomotic location within an irradiated, inflamed, or contaminated field
    - Low pelvic anastomotic location following sphincter-preserving procedures (e.g., ileal pouch-anal anastomoses, coloanal or low colorectal anastomoses)
  - Disruption of a previously created distal anastomosis
  - Distal bowel perforation
  - Pelvic sepsis
  - Rectal trauma
  - Complicated diverticulitis
  - Following anal sphincter reconstruction
  - Following rectovaginal fistula repair
  - Fecal incontinence
  - Severe radiation proctitis
  - Obstructing or nearly obstructing colorectal cancer, carcinomatosis, and Crohn's disease
  - Sacral decubitus ulcer
  - Necrotizing perineal and gluteal soft tissue infections.

Preoperative Planning

- The ideal stoma has no necrosis, prolapse, or retraction. Daily output ranges from 500 to 1000 mL, the appliance does not leak, and the skin is healthy. The importance of appropriate planning to ensure an optimal ileostomy location and to maximize the opportunity for creation of a viable, tension-free, and well-functioning ileostomy cannot be overemphasized. Attention to these principles will decrease the time required for stoma management and minimize patient frustration.

- A comprehensive discussion with the patient about the proposed ileostomy procedure, alternatives, and postoperative lifestyle is imperative.
- Most stoma patients are elderly and many have their stoma care performed by a spouse, offspring, or caretaker; it is thus critical to involve these providers in the stoma education process.
- Ideally, patients must be mentally and physically ready for a stoma and must therefore be informed as early as possible in their course of the disease regarding the potential need for a stoma. For many patients, though, an ileostomy is created in an acute setting at the end of a long, often life-saving procedure.

Stoma Education

- A comprehensive perioperative educational program decreases readmissions and complications related to dehydration and appliance problems and optimizes postoperative patient satisfaction and participation in activities of daily life.
  - Wound ostomy continence nurse (WOCN) or enterostomal therapy (ET) nurse
    - Optimal stoma management begins with preoperative patient education in regard to diet, activities, clothing, and sexuality. The nurse can provide emotional and physical support. The patient must be informed that self-care may be awkward initially but that it can be learned and mastered.
  - Patient support groups, United Ostomy Association visitor
    - Patients should be introduced to other individuals with ileostomies who have similar socioeconomic and disease backgrounds. These encounters and relationships can help to improve morale and can reassure patients that they can have a satisfactory quality of life. Meetings should occur pre- and postoperatively (particularly during the first 3 to 6 months).
  - Stoma preparedness literature
    - The American College of Surgeons has created a comprehensive stoma preparedness kit including an educational DVD and manual, a stoma model, and stoma appliance samples.

Stoma Site Marking

- The stoma location must be carefully planned to minimize complications and to prevent leakage.
- The patient may wear the stoma appliance faceplate prior to the operation. The optimal location of the stoma should be assessed with the patient standing, sitting, and bending. Where does the patient wear the waist of the pants? Range of motion and physical limitations must be evaluated to determine if the patient can visualize the stoma and can manipulate the appliance (e.g., the site may be placed higher on the abdomen for a wheelchair-bound patient). Care must be taken to avoid stoma placement beneath an abdominal pannus to ensure that the stoma remains visible and easy to access for the patient or caretaker.
- In general, the ileostomy should be placed through the rectus muscle (to minimize parastomal herniation), at the summit of the right paramedian infraumbilical fat pad. The umbilicus, bone, scars, skin folds, and abdominal panni should be avoided (**FIG 1**). The skin site can be identified with a permanent marker and a scratch can be made with a small needle.

Intraoperative Positioning

- Supine or lithotomy position may be used based on the need for an adjunctive procedure for assessment of the colon, rectum, or perineum prior to ileostomy creation (e.g., colonoscopy).

Antibiotic Prophylaxis

- Intravenous antibiotics must be given prior to the incision.

FIG 1 ● Preoperative marking of the ileostomy site. The ileostomy is placed in the right lower quadrant of the abdomen in a right paramedian, infraumbilical position.

CREATION OF AN END ILEOSTOMY

- Meticulous construction of an end ileostomy is paramount because the ileal contents are liquid, bilious, and voluminous. An everted, spout-shaped end ileostomy (Brooke ileostomy) is best suited to address these challenges.

Abdominal Wall Skin Incision for Exploratory Laparotomy and/or Bowel Resection

- If an abdominal incision for bowel resection is necessary, a left paramedian skin incision can be made and angled toward the midline. The abdomen can then be entered through the linea alba. This approach maximizes the distance and amount of skin between the ileostomy and the skin incision.

Ileal Mobilization

- The ileum is prepared by releasing the lateral attachments along the pelvic brim and by fully mobilizing the embryonic root of the terminal ileal mesentery to the level of the duodenum.

Stoma Site Skin Incision

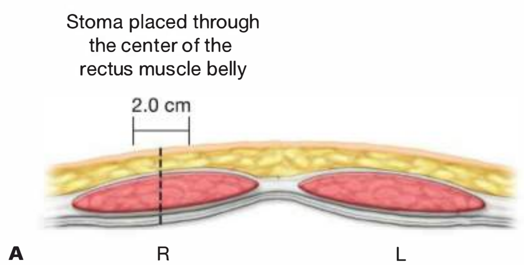
- Following the intestinal resection, the skin opening is created in the right lower quadrant at the premarked site. The skin is grasped with a Kocher clamp and a circular skin incision of 2 cm in diameter (**FIG 2A**) is made tangentially beneath the Kocher clamp with a no. 10 blade. The excised skin disc is removed.

Abdominal Wall Aperture Creation for the Stoma

- Bovie electrocautery is used to perpendicularly divide the subcutaneous fat in the right paramedian plane at the ileostomy site. Handheld retractors can be gently used. The subcutaneous fat should be preserved as much as possible.
- The anterior rectus sheath is identified and incised in a cruciate fashion for approximately 1 cm in both directions. (The horizontal limb should not be placed too close to the midline.)
- Mayo clamps are used to split the rectus muscle bluntly in order to expose the posterior rectus sheath and peritoneum. The rectus muscle fibers are not divided (**FIG 2B**).
- The surgeon places one hand into the abdominal cavity behind the marked stoma site to protect the abdominal contents.
- The abdominal cavity is entered through the stoma incision with a thin-point clamp (e.g., Schnidt or tonsil clamp).
- The defect in the posterior rectus sheath and peritoneum is widened to allow for passage of the ileum without compromising its mesenteric blood supply. The appropriate defect size is obtained by digitally dilating the stoma site with the tips of two digits to create an approximately 2-cm aperture (**FIG 2C**).

Ileal Limb Preparation and Placement

- At least 6 cm of viable distal or terminal ileum with the adjacent marginal artery should be preserved to maintain an optimal blood supply. The mesentery should not be stripped (**FIG 2D**). The ileal limb preparation should be performed as early as possible during the course of the operation to allow for sufficient time to observe and assess the ileum's vascularity. The mesentery must be handled gently to avoid hematomas and mesenteric vascular injury.
- The ileum is gently advanced (pushed rather than pulled) through the split muscle and the abdominal wall to about 4 cm beyond the skin level (using a Babcock clamp to grasp the ileum only if necessary). If the ileum and adjacent tissues are too bulky to pass easily through the aperture, the epiploic fat can be excised.
- To facilitate a future ileostomy reversal procedure, an adhesion barrier (e.g., Seprafilm®) can be used at the time of ileostomy creation. The adhesion barrier is wrapped around the ileal limb used for the ileostomy, extending along the intraabdominal ileal segment for approximately 5 cm.
- The ileal mesentery may be secured to the peritoneum over a length of 3 to 4 cm if a permanent stoma is planned. (This step may prevent torsion, retraction, and prolapse of the ileum.)



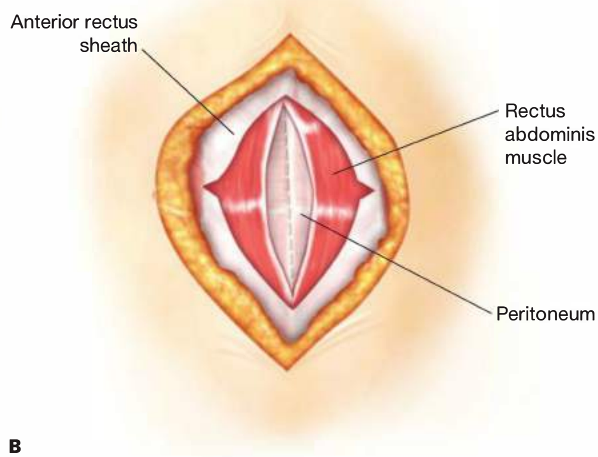


FIG 2 ● Creation of an end ileostomy. **A.** A circular skin incision for the ileostomy is made over the center of the rectus muscle belly and carried through the subcutaneous fat. **B.** A cruciate incision is made in the anterior rectus sheath to expose the underlying rectus muscle. The rectus muscle is split bluntly along the direction of its fibers to expose the posterior sheath and peritoneum. *(continued)*

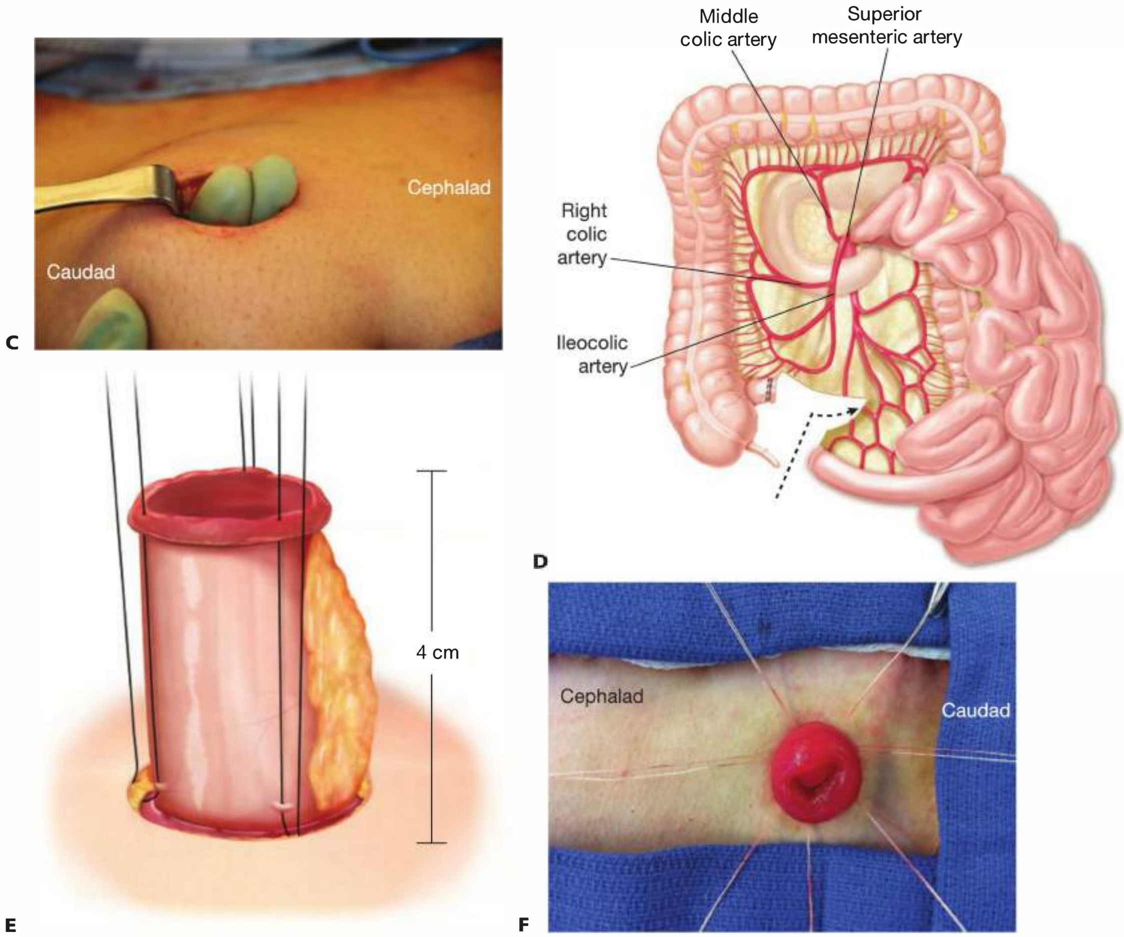


FIG 2 ● *(continued)* **C.** The peritoneum is incised longitudinally and the incision is widened by stretching it with two digits to obtain the desired aperture. **D.** The vascular end arcade and the mesentery are preserved on the ileal segment that is to be used for the end ileostomy *(dotted arrow)*. **E.** The ileum is advanced through the abdominal wall stoma aperture so that it protrudes for about 4 cm beyond the skin level. Following removal of the staple line, three-point sutures are placed through the end of the ileum (full thickness), the seromuscular layer at the base of the stoma 4 cm from the end of the ileum, and the dermis, respectively. No epidermis should be included in stitch. **F.** The sutures are placed circumferentially. They are only tied after all of them have been placed, everting the ileum to create a 2-cm–high ileostomy.

- Both edges of the rectal stump (or other potentially remaining distal bowel segment) are tagged with polypropylene suture to facilitate identification of the distal intestinal segment for potential ileostomy reversal.
- To prevent wound contamination, the surgical abdominal incision is closed next and then covered with a protective wound dressing prior to maturing the stoma.

Stoma Maturation

- The staple line is removed from the ileum.
- 3-0 absorbable (e.g., Vicryl®) interrupted stitches are placed (but not immediately tied), with the stitches running through the following three points (**FIG 2E**):
  - end of the ileum (full-thickness)
  - skin-level base of the stoma (4 cm from the end of the ileum) (seromuscular layer)
  - Dermis (large bites of the subcuticular layer should be avoided to prevent "buttonholing" and mucosal islands).
- One stitch is placed in each quadrant followed by one stitch between each quadrant stitch for a total of seven to eight stitches. Ensure that one stitch is on each side of, and adjacent to, the mesentery (but not through the mesentery).
- To allow for more precise placement, each stitch should be individually tagged and tied only when all stitches have been placed. The subcutaneous and mesenteric fat can be tucked in as each suture is tied. The goal is to create a stoma with a spout that protrudes about 2 cm beyond the skin level when completed (**FIG 2F**).
- The ileostomy appliance is placed over the stoma. Waterproof, nonallergenic tape can be used to further secure the edge of the appliance to the skin.

CREATION OF A LOOP ILEOSTOMY

Stoma Site Skin Incision and Abdominal Wall Aperture Creation

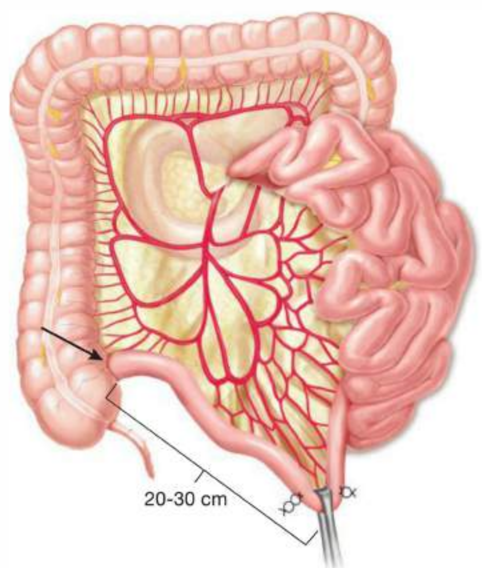
- The skin incision for a loop ileostomy is similar to the incision for an end ileostomy, except that it can be made slightly longer and slightly oblong. In obese patients, some of the subcutaneous tissues may have to be excised down to the fascia in the shape of a cone (apex at skin level) so as to not constrict the afferent and efferent limbs of the loop ileostomy.

Ileal Limb Preparation and Placement

- An ileal segment 20 to 30 cm proximal to the ileocecal valve is identified. The segment is selected so as to maximize mesenteric pedicle length and to avoid compromising the ileocecal valve. The segment's mesentery and vasculature are preserved (**FIG 3A**).
- Two different orienting sutures are placed on the antimesenteric side of the ileum to mark the afferent and efferent side of the ileal segment (e.g., by using sutures of different colors, or sutures with one knot for the afferent segment and two knots for the efferent segment) (**FIG 3B**).
- An umbilical tape is passed behind the ileum at the ileal-mesenteric interface. The ileal loop is advanced through the abdominal wall using the umbilical tape as a guide, taking care to maintain proper orientation and to avoid torsion.
- The afferent (productive) limb of the loop ileostomy is placed inferiorly so that its spout will be located on the caudal aspect of the stoma. This requires a partial (about 90 degrees) twist for correct orientation. Alternatively, the afferent limb can be placed on the medial or superior side of the stoma site, depending on surgeon preference and amount of tension on the ileostomy.
- Optionally, sutures may be placed between the ileal mesentery and peritoneum to maintain the appropriate rotation specially in obese patients.
- The umbilical tape is removed and may optionally be replaced with a supporting rod or a 6-cm segment of red rubber catheter (which may be looped and sutured to itself above the loop ileostomy or secured to the skin).
- To prevent contamination of the laparotomy incision, the surgical abdominal incision (midline or left paramedian) is closed next and a protective wound dressing is placed prior to stoma maturation.

Stoma Maturation

- It is important to create an adequate spout on the afferent bowel limb.
- First, the efferent (distal) limb of the ileum is transversely incised 1 cm above the skin surface for approximately 75% of the circumference of the ileum to allow for appropriate stoma eversion (**FIG 3C**). This allows for a large "hood" and for the os on the afferent productive limb to be larger (encompassing 80% to 90% of the ileostomy) than the os of the efferent limb.



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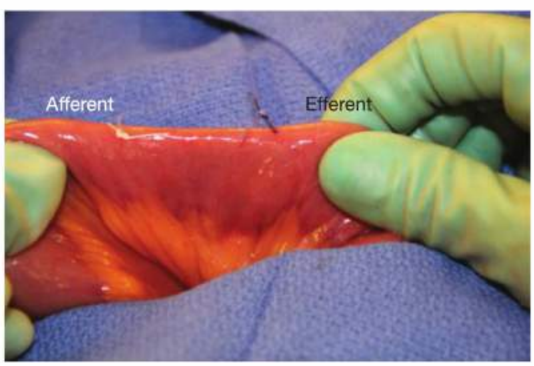


B

FIG 3 ● Creation of a loop ileostomy. **A.** An ileal segment that is 20 to 30 cm proximal to the ileocecal junction *(arrow)* is identified. The segment's mesentery and vasculature are preserved. **B.** Marking sutures (e.g., sutures of different colors or with differing numbers of knots) are placed on the afferent and efferent limbs. The ileum is advanced through the abdominal wall stoma aperture so that it protrudes for about 3 to 4 cm beyond the skin level. *(continued)*

TECHNIQUES

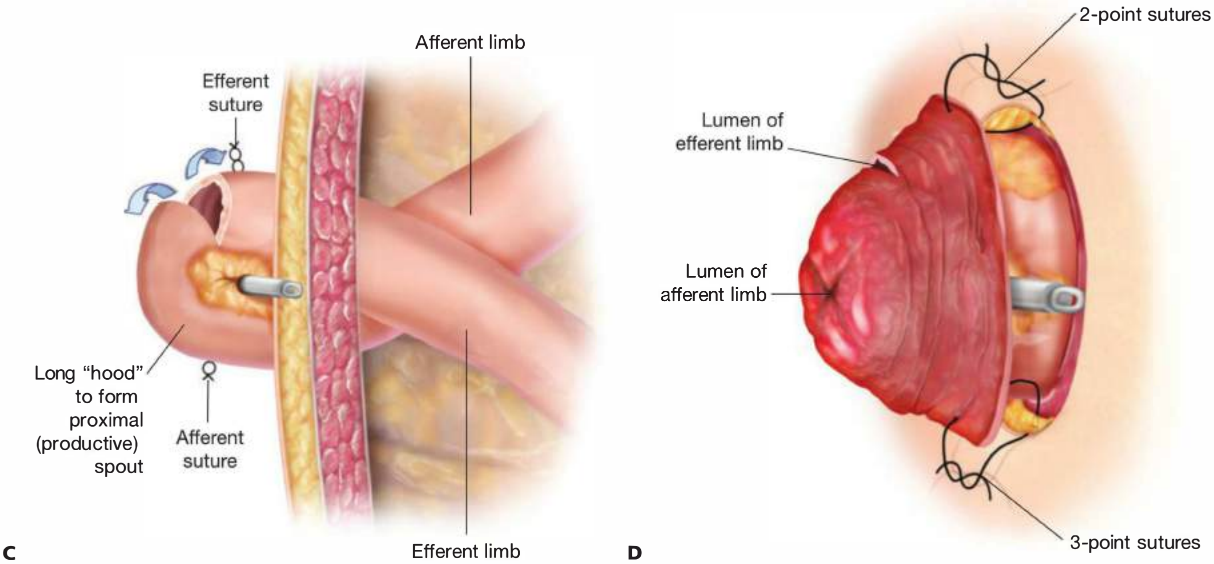


FIG 3 ● *(continued)* **C.** The ileum is incised 1 cm above the skin level on the efferent limb side for 75% of the circumference to create a large afferent spout. **D.** The loop ileostomy is matured by placing two-point sutures (full thickness through the end of the ileum and the dermis) on the efferent limb and three-point sutures (full thickness through the end of ileum, the seromuscular layer at the base of stoma, and the dermis) on the afferent limb to evert the ileum.

- The stoma is created and matured with 3-0 absorbable suture (e.g., Vicryl®). First, the efferent stoma is sewn flush with the dermis by using a two-point suturing technique, with each stitch taking a full-thickness bite through the cut edge of ileum and then through the dermis. Next, the afferent stoma is matured with a three-point suturing technique as already described in principle for the end ileostomy (**FIG 3D**). The main difference with an end ileostomy is that for a loop ileostomy, the seromuscular stitches at the base of the afferent stoma are closer to the stoma's os (about 3 to 4 cm) and the stoma spout may thus not protrude quite as much as with an end ileostomy. Also, sutures cannot be placed on the posterior bridge of ileum that joins the afferent and efferent limbs.
- Optionally, as the sutures are tied, the spout can be formed over a supporting rod (or catheter), which is left in place for 3 to 5 days postoperatively.
- The edge of the aperture in the ileostomy faceplate is placed beneath the rod or catheter.

CREATION OF A DIVIDED LOOP ILEOSTOMY

- A divided (or separated) loop ileostomy is an alternative technique for creating a protecting loop ileostomy; it may result in a more complete fecal diversion.

Stoma Site Skin Incision and Abdominal Wall Aperture Creation

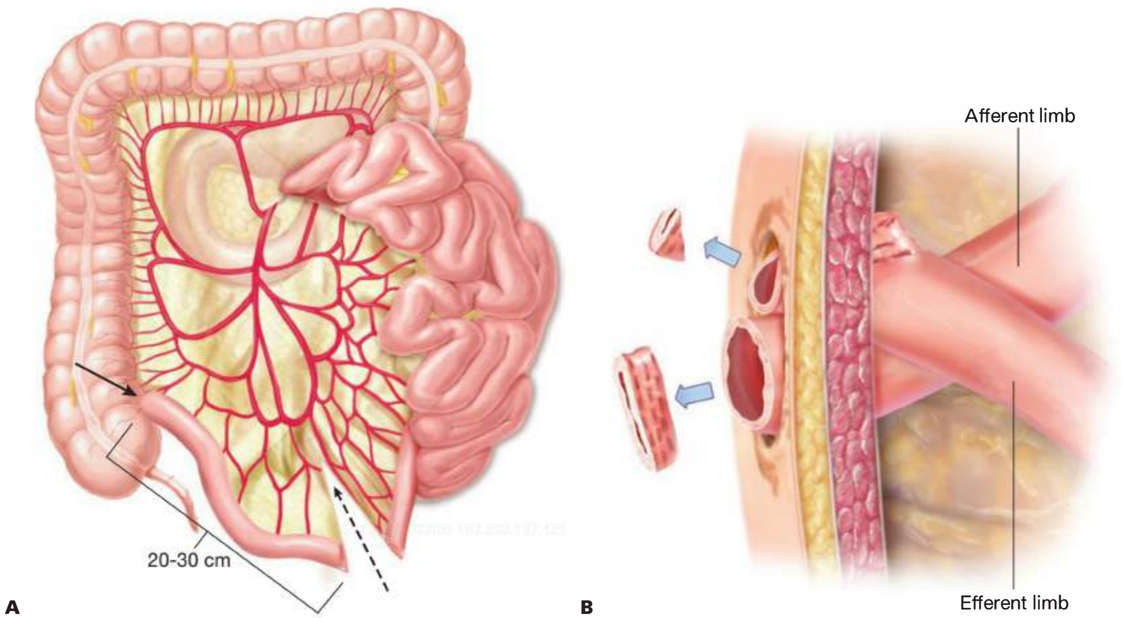
- The skin incision and abdominal wall aperture are created as for a loop ileostomy.

Ileal Limb Preparation and Placement

- The ileum is divided with a linear cutting stapler 20 to 30 cm proximal to the ileocecal valve. The mesentery and vasculature are only minimally divided (**FIG 4A**).
- The stapled afferent limb is advanced through the abdominal wall aperture so that it protrudes 4 cm beyond the skin and the staple line is removed. Only the antimesenteric corner of the efferent limb is externalized, thus minimizing the need for division of the mesentery (**FIG 4B**).

Stoma Maturation

- Afferent limb—The stoma is constructed in the same manner as described for an end ileostomy, using a three-stitch technique (**FIG 4C**).
- Efferent limb—The antimesenteric corner is excised to decompress the distal bowel if desired. A two-stitch technique is then used, placing sutures that encompass the full-thickness edge of the ileum and the dermis. Alternatively, the efferent limb can remain stapled closed if complete fecal diversion is desired.



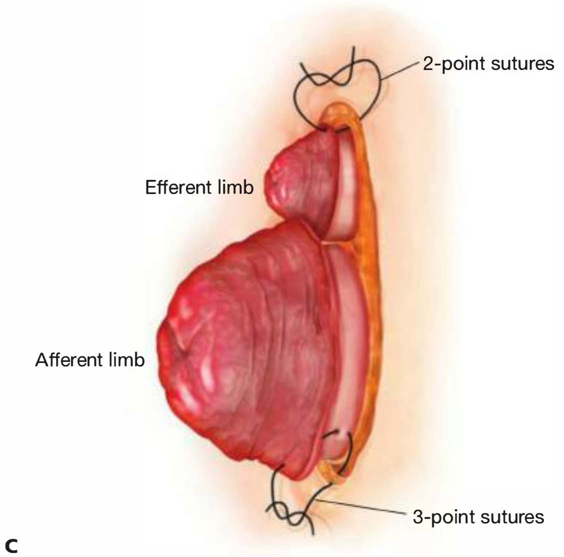


FIG 4 ● Creation of a divided loop ileostomy. **A.** The ileum is divided using a linear cutting stapler, 20 to 30 cm proximal to the ileocecal valve *(solid arrow)*. The mesentery and vasculature are only minimally divided *(dotted arrow)*. **B.** The stapled afferent limb is advanced through the abdominal wall aperture so that it protrudes for about 4 cm beyond the skin level, and the entire staple line is then cut off. Optionally, if distal decompression is desired for the efferent limb, only the antimesenteric corner is externalized, excised, and matured. The staple line may also be left intact on the efferent limb for total diversion. **C.** The afferent limb of the ileostomy is matured with three-point sutures. The efferent limb can be matured with two-point sutures.

CREATION OF AN END-LOOP ILEOSTOMY

- An end-loop (or loop-end) ileostomy is functionally not different from an end ileostomy, but the stoma maturation is akin to the technique for a loop ileostomy. An end-loop ileostomy allows for preservation of an adequate mesenteric blood supply when the mesentery would otherwise be too short for adequate advancement through the abdominal wall (e.g., in case of a shortened mesentery or a thickened abdominal wall). This technique is often used in obese patients and those with prior operations.

Stoma Site Skin Incision and Abdominal Wall Aperture Creation

- The skin and stoma site are prepared as described for a loop ileostomy.

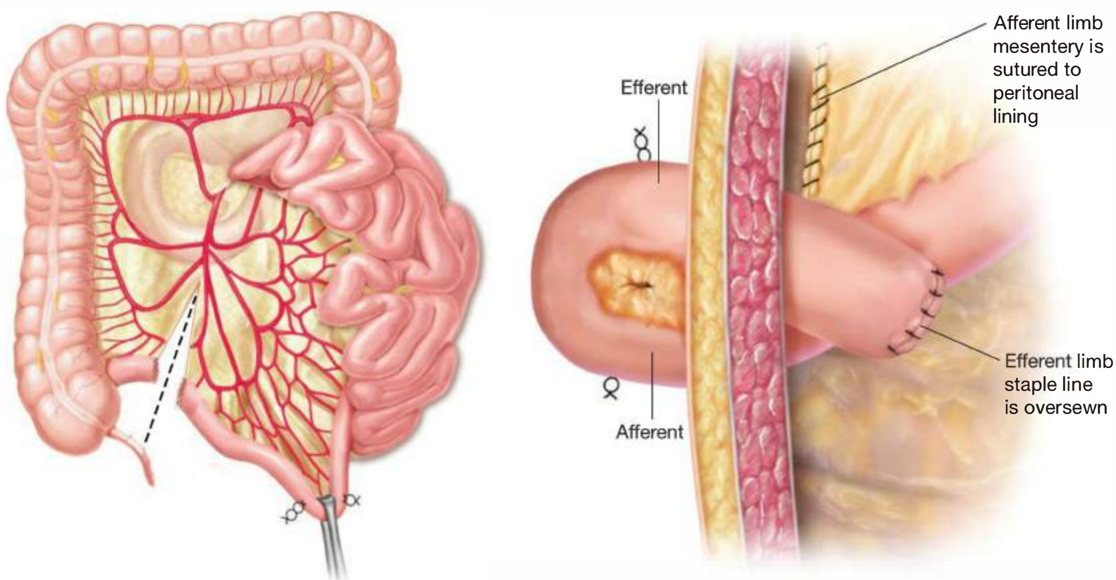
Ileal Limb Preparation and Placement

- The mesentery and vasculature are divided to obtain as much length as possible (FIG 5A).
- Following the distal intestinal resection or division, the staple line at the end of the ileum is oversewn.

- The segment of ileum to be used for the stoma creation is typically located about 10 cm proximal to the oversewn ileal staple line. The segment must have adequate mobility to reach the proposed stoma site without tension. Within the abdominal cavity, the afferent limb is oriented inferiorly and the efferent limb superiorly. The segment of ileum to be used for the stoma is then advanced through the abdominal wall as for a loop ileostomy (**FIG 5B**).
- Optionally, a supporting rod or catheter can be passed behind the ileum at the ileal-mesenteric interface.
- Optionally, the intraabdominal ileal mesentery may be sutured to the peritoneum.

Stoma Maturation

- The end-loop ileostomy is matured as described for a loop ileostomy (**FIG 3C,D**).



A **B**

FIG 5 ● Creation of an end-loop ileostomy. **A.** The mesentery and vasculature are divided proximally to obtain as much length as possible. **B.** Marking sutures are placed on the afferent and efferent limbs. The staple line closing off the ileum is oversewn with Lembert sutures and remains in the abdomen. A more proximal segment of ileum to be used for the ileostomy, approximately 10 cm proximal to the oversewn ileal staple line, is externalized so that the afferent limb is in the inferior position on the abdominal wall. The mesentery may be affixed to the abdominal wall to prevent stoma prolapse, torsion, or an internal hernia.

LAPAROSCOPIC CREATION OF AN ILEOSTOMY

- The laparoscopic approach can be used for temporary and permanent end ileostomies, loop ileostomies, divided loop ileostomies, and end-loop ileostomies.
- The entire abdominal cavity can be visualized and inspected, which can be beneficial as it allows for assessment of the underlying disease and the extent of adhesions. Additionally, laparoscopy allows for precise identification of the ileal segment to be used for the stoma and can help to ensure its proper orientation.
- The laparoscopic approach may not be feasible if the patient has extensive adhesions from prior operations or an insufficient intraabdominal domain due to intestinal dilatation.
- Laparoscopic ileostomy creation may result in shorter total incision length, shorter operative time, decreased pain, fewer wound complications, more rapid return of bowel function, and shorter hospital stay.

Stoma Site Skin Incision and Port Placement

- The 2-cm skin incision for the stoma site can be made prior to insufflation at the time of port site creation or after diagnostic laparoscopy and selection of the ileal segment to be externalized (see "Abdominal Wall Aperture Creation for the Stoma").
- A 5-mm or 10-mm port is placed through the upper midline for the camera.
- A 10-mm port is placed through the intended ileostomy site.
- A 5-mm port is placed in the left lower quadrant for bowel manipulation and adhesiolysis as necessary.
- An additional 5-mm port may be placed in the left suprapubic region if needed.

Ileal Limb Preparation and Placement

- The most distal segment of ileum that can reach the intended stoma site without tension is identified laparoscopically.
- For loop ileostomies, sutures or clips are placed to mark the afferent and efferent ileum prior to externalization.
- A laparoscopic bowel clamp is placed through the 10-mm port at the stoma site to grasp the ileum.
- The pneumoperitoneum is released.
- To facilitate the passage of the loop of ileum, the anterior rectus sheath can be further stretched or incised with a cruciate incision.
- The ileum, bowel clamp, and 10-mm port are pulled out of the abdomen.

Laparoscopic Confirmation of Proper Stoma Orientation

- Adequate stoma loop orientation and hemostasis are confirmed after reestablishing pneumoperitoneum.
- All ports are removed and the skin incisions are closed with reabsorbable suture.

Stoma Maturation

- The stoma is matured as described for the open technique.

PLACEMENT OF THE ILEOSTOMY APPLIANCE

- Most appliances are disposable and available as one-piece or two-piece products. A basic appliance consists of an adhesive faceplate with a central opening and a collection bag. When cutting out the definitive stoma aperture in the appliance faceplate, the stoma aperture is cut offset (i.e., medially in relation to the precut stoma aperture) so as to shift the entire appliance laterally on the patient. As a result, the portion of the appliance directly over any midline incision can be minimized. The edges of the cut-out area of the appliance should be 1 to 2 mm away from the edges of the ileostomy to avoid appliance trauma to, and leakage from, the ileostomy (**FIG 6**).

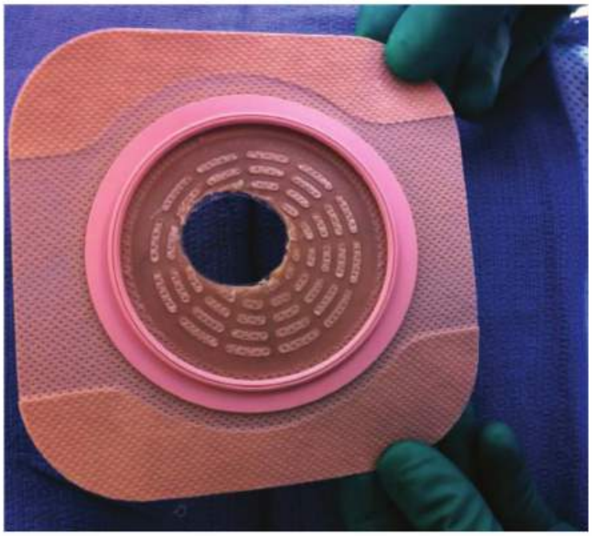


FIG 6 ● Ileostomy appliance. The faceplate stoma aperture is cut off-center in a medial direction to minimize the portion of the faceplate that lays directly over a midline incision (allows for a shift laterally off of the midline if an incision if present).

END AND DIVERTING LOOP ILEOSTOMIES: REVERSAL

DEFINITION

- Ileostomy reversal (synonyms: ileostomy takedown or closure) is a procedure that reestablishes intestinal continuity in a patient with an ileostomy.

PATIENT HISTORY AND PHYSICAL FINDINGS

- Reversal of a temporary ileostomy is usually performed at the earliest 2 to 3 months after ileostomy creation in order to allow for optimal healing of the area from which the enteric contents were diverted (e.g., distal anastomosis, bowel repair) or to allow for the distal inflammation to subside. An end ileostomy following subtotal colectomy may be reversed if the rectal and anal complex are healthy and without disease or malfunction.
- Modifiable risk factors (e.g., malnutrition) must be optimized and any chemotherapy and radiation should be completed.
- Reversal may be necessary at an earlier date for selected patients in the presence of an ileostomy complication such as prolapse or recurrent serious fluid and electrolyte abnormalities.
- Ileostomy reversal can be associated with considerable morbidity.
- Up to 30% of patients with potentially reversible ileostomies never have their ileostomies reversed due to underlying health issues, underlying disease prognosis, or patient preference.

PREOPERATIVE IMAGING AND OTHER DIAGNOSTIC STUDIES

- The indications for preoperative imaging and diagnostic (e.g., functional) studies must be individualized for each patient.
- The routine use of contrast studies prior to ileostomy takedown to assess the distal bowel or anastomosis for stricture, obstruction, leak, recurrence of disease, or to assess pouch anatomy is controversial. If a study is performed, the contrast can be instilled through the efferent limb of a loop ileostomy or per anum, depending on the location of the area to be studied.
- An examination under anesthesia and an endoscopic assessment may be performed to ascertain that a J-pouch is intact, to ensure that a distal anastomosis or repair has healed, and to ensure that a malignancy has not recurred.

- If the anal sphincter was involved in the disease or repair, an anal manometry or endoscopic ultrasonography may be helpful to evaluate the sphincter.

SURGICAL MANAGEMENT

Preoperative Planning

- Ileostomy reversal is not a minor operation and sometimes requires a full laparotomy.
- A loop ileostomy often facilitates subsequent ileostomy reversal by potentially obviating the need for a full laparotomy.
- The groundwork for successful ileostomy reversal is laid at the time of the construction of the ileostomy. To facilitate the ileostomy takedown procedure, an adhesion barrier should be placed at the time of ileostomy creation.
- Bowel preparation for the proximal intestine consists of 24 hours of clear liquids.
- Bowel preparation distal to the ileostomy is optional but is strongly recommended if no formal bowel preparation was performed prior to creation of ileostomy (e.g., in case of an emergency operation). Bowel preparation can be achieved under those circumstances as follows:
  - Patients with an end ileostomy and a rectal stump: transanal enema
  - Patients with a loop ileostomy: irrigation through the efferent limb or transanal retrograde enema, depending on the location of disease, repair, or anastomosis.
  - The radiologist can be asked to irrigate the diverted segment (efferent limb or colon) with saline solution at the completion of a contrast study.
  - Ureteral stents should be strongly considered if the patient has had significant pelvic inflammation.

Positioning

- The patient is placed in lithotomy position if an endoscopic assessment or exam under anesthesia is required, if the rectal vault requires irrigation and evacuation of inspissated mucus secretions, or if an ileorectal or ileoanal anastomosis is to be created.
- Supine position is adequate if no access to the anus or rectum is required.

TECHNIQUES

END ILEOSTOMY REVERSAL

Stoma Closure

- The stoma is closed with a running 0-silk suture.

Mobilization and Resection of Ileostomy

- A circumferential skin incision is made sharply around the closed ileostomy just peripheral to the mucocutaneous junction.
- Sharp dissection is used next to the bowel wall, with judicious use of electrocautery, to release the stoma from the subcutaneous fat, rectus muscle, and rectus sheath (**FIG 7**). Caution is used to avoid an injury to the bowel wall or mesentery. Eastman or Army-Navy retractors can facilitate exposure and visualization.
- Any adhesions to the abdominal wall adjacent to the internal aspect of the ileostomy site are lysed circumferentially to clear the peritoneal surface for safe subsequent reapproximation and closure of the abdominal wall defect. A wound protector is placed to minimize wound contamination.
- The ileostomy is excised with its fibrofatty tissue and a viable segment of ileum with intact serosa and adequate blood supply is prepared for the anastomosis. If a stapled anastomosis is planned, the anvil from the circular stapler is placed and secured in the ileum.

FIG 7 ● Skin incision and stoma mobilization for reversal of an end or loop ileostomy. A circumferential skin incision is made directly adjacent to the closed ileostomy. The incision is deepened across all abdominal wall layers down to the level of the abdominal cavity. The ileostomy and adherent fibrofatty tissues are resected.

Preparation of the Distal Bowel Segment

- Typically through a laparotomy, the distal bowel segment to which the ileum is to be anastomosed (usually the rectum) is carefully mobilized and prepared for anastomosis. The intestinal segment must be viable and of adequate length.

Anastomosis after Takedown of the End Ileostomy

- A standard ileorectal (or ileoanal or ileocolic) anastomosis can be created with a stapler (e.g., by using a circular end-to-end anastomosis [EEA] stapler) or a hand-sewn technique (**FIG 8**).
- A leak test is performed. Water is poured into the pelvis until the anastomosis is submerged. The bowel is occluded proximal to the anastomosis. Air is insufflated per anum with a proctoscope.
  - Small leaks can be oversewn and the leak test is repeated. If the leak test remains positive, the anastomosis can be redone with a low threshold for the placement of a proximal diverting loop ileostomy and a pelvic drain.
  - Small leaks low in the pelvis or large leaks should be repaired or the anastomosis should be redone.

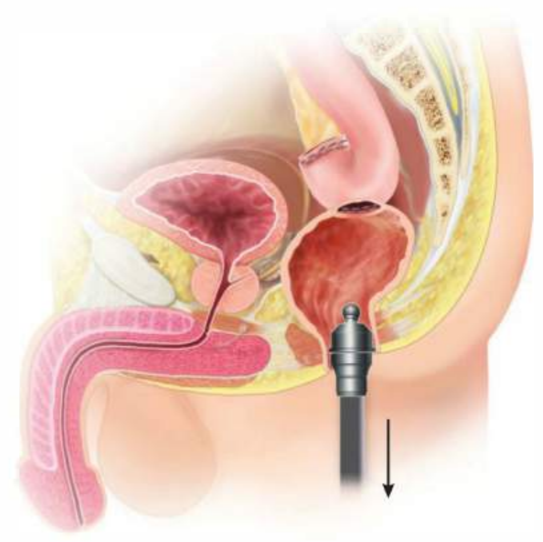


FIG 8 ● Reversal of an end ileostomy. Intestinal continuity is restored with a circular cutting stapler (e.g., by creating an ileorectal anastomosis).

Creation of a proximal diverting loop ileostomy and insertion of a pelvic drain should be strongly considered under those circumstances. The omentum should be wrapped around the anastomosis.

- Alternatively, the anastomosis can be visualized endoscopically (with or without injection of intravenous fluorescein to assess the intestinal blood supply).

Fascial Closure

- The abdominal wall stoma defect is closed without tension in two layers with running or interrupted 1-polydioxanone (PDS) suture. Omentum is placed between the anastomosis and the fascial closure, if available.
- If the fascia is of poor quality, a biologic mesh can be used for reinforcement.

Stoma Site Skin Closure

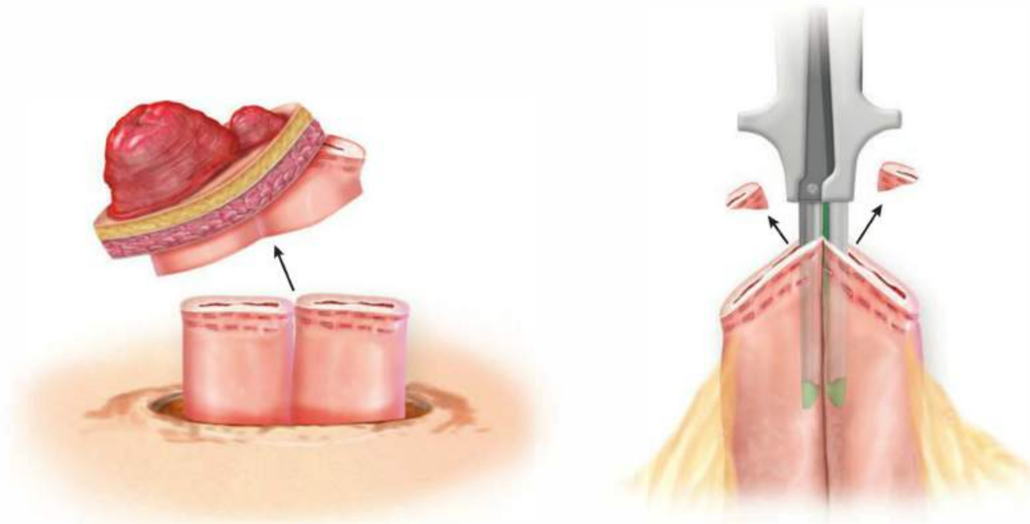
- The skin can be closed with numerous different techniques, but in principle, the closure should not be watertight. Options include the following:
  - Primary skin closure
    - Loose skin closure with interrupted 2-0 nylon sutures or staples. Wound fluid drainage should be facilitated, for instance, by application of wicks made of Kendall Telfa® dressing pads (the wicks should be removed on postoperative day 2 or 3).
    - Delayed primary closure (performed on postoperative day 2 or 3).
    - Purse-string closure. Loose circular (purse-string) skin closure with 2-0 running, subcuticular polypropylene. The approximately 1 to 1.5 cm remaining central opening is packed with moist gauze that is first removed on postoperative day 2 and then exchanged daily. The suture is removed on postoperative day 21. The purse-string closure may be associated with a lower surgical site infection rate than a primary closure.
- Wound healing by secondary intention. The wound is left open and wet-to-dry dressing changes are initiated.

REVERSAL LOOP ILEOSTOMY

- The ileostomy closure can usually be performed through the ileostomy site, without requiring a complete laparotomy.
- The steps leading up to the anastomosis are the same as for the reversal of the end ileostomy discussed earlier.
- A wound protector is placed to minimize wound contamination.

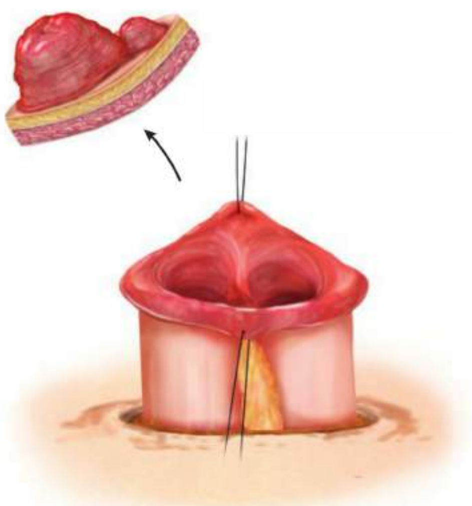
Anastomosis after Takedown of Loop Ileostomy

- The anastomosis between the proximal (afferent) and distal (efferent) ileal limbs can be either hand-sewn or stapled.
- The stoma and fibrofatty tissues are resected with a linear cutting stapler to a level where there are two distinct ileal limbs (FIG 9A).
  - For a stapled side-to-side anastomosis, the antimesenteric corner of each ileal end is cut and removed.
  - A side-to-side, functional end-to-end anastomosis is created with a linear cutting stapler (FIG 9B). The enteric defect is closed with a linear stapler or a hand-sewn technique.
  - The anastomosis can also be constructed with a circular stapler or hand-sewn.
- Alternatively, a direct transverse closure of the enteric defect at the stoma site can be performed. With this technique, the stoma and fibrofatty tissues are resected sparingly so that the connecting bridge of intestinal wall on the posterior (mesenteric) aspect of the loop stoma remains intact (FIG 10A).
  - The antimesenteric defect can then be closed either by a hand-sewn technique (double layer technique consisting of 3-0 absorbable full-thickness sutures [e.g., Vicryl®], followed by 3-0 nonabsorbable Lembert seromuscular sutures [e.g., silk]) (FIG 10B) or stapled technique (with a linear stapler) with optional oversewing of the staple line (FIG 10C).



A B

FIG 9 ● Reversal of a loop ileostomy: option 1 (results in larger anastomotic cross section). **A.** The ileum is mobilized from the abdominal wall. The stoma itself (including the staples in case of a divided loop ileostomy) and adjacent fibrofatty tissues are resected with a linear cutting stapler to a level where both limbs are completely separated. **B.** A side-to-side (functional end-to-end) stapled anastomosis is created with a linear cutting stapler inserted into the antimesenteric aspect of each ileal limb. The remaining ileal opening is closed off with a linear stapler application or by using a hand-sewn technique.



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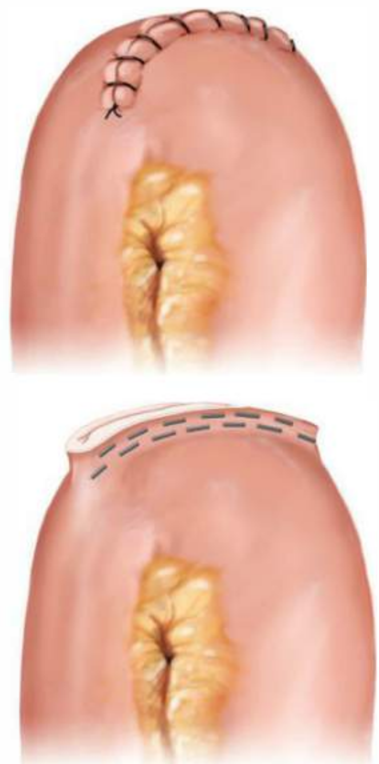

B

C

FIG 10 ● Reversal of a loop ileostomy: option 2. **A.** The ileum is mobilized from the abdominal wall. The stoma itself and adjacent fibrofatty tissues are resected sparingly so that the connecting bridge of ileum on the posterior/mesenteric aspect of the loop ileostomy is left intact. **B.** The ileal defect is closed with a transverse two-layer hand-sewn technique or **(C)** with a linear stapler.

PEARLS AND PITFALLS

Ileostomy Creation	
Indications	■ A diverting ileostomy may prevent morbidity by preventing a distal anastomotic disruption in high-risk patients.
Preoperative education	■ Stoma education is crucial to familiarize the patient with the impending stoma and to minimize potential complications.
Stoma placement	■ Preoperative ileostomy site determination and marking is critical. The stoma must be placed away from bony prominences, panni, and scars to create a viable, tension-free ileostomy with a reliable appliance seal.
Orientation of loop ileostomy	■ Use marking sutures on afferent and efferent limbs. Avoid torsion and mesenteric vascular compromise during stoma creation.
Stoma maturation	■ Creation of a 2-cm Brooke ileostomy (end or diverting loop) minimizes the morbidity that stems from the ileostomy effluent.
Follow-up	■ Close follow-up and the use of ileostomy care pathways are critical to recognize and address stoma-site problems and to minimize readmissions for dehydration and electrolyte abnormalities.
Ileostomy Reversal	
History and physical	■ Ileostomy reversal is usually an elective procedure. Allow the patient to attain an optimal health status before undertaking reversal.
Diagnostic tests	■ Consider diagnostic studies to assess the distal bowel or anastomosis prior to closure. These studies may prevent morbidity and improve outcome.
Preparation of the ileum for takedown	■ Dissect the ileum to viable, healthy ileum with adequate blood supply. Avoid tension on the anastomosis.
Skin closure	■ Healing by secondary intention predictably prevents wound infections and typically has similar cosmetic outcomes compared to primary closure. "Purse string" closure is an increasingly used as skin closure option.
Follow-up	■ Patients undergoing ileostomy reversal are at risk for major morbidity and mortality and must be followed closely postoperatively.

POSTOPERATIVE CARE

For Ileostomy Creation Patients

- Creation of an ileostomy results in the loss of the ileocecal valve and of the colonic water reabsorption, leading to dehydration and electrolyte abnormalities. Postoperatively, the newly created ileostomy begins to function within 72 hours, often with high output (>1 L) per day. Within weeks, the proximal small bowel adapts at least partially as water absorption increases and the effluent thickens. Ideal daily effluent volume after adaptation is 500 to 1000 mL.
- Appropriate hydration and electrolyte levels (sodium, potassium, magnesium, and calcium) must be maintained, using electrolyte solutions (e.g., Pedialyte®) and oral or intravenous sodium chloride. After discharge, the patient must contact his or her medical provider if the ileostomy output is greater than 1 L per day for 2 consecutive days.
- Psyllium (e.g., Metamucil®) can be used to thicken the enteric contents.
- Anticholinergic agents, opioid receptor agonists (e.g., loperamide), bile acid binders (e.g., cholestyramine), and narcotic agents (e.g., tincture of opium, codeine) can be used to decrease ileostomy output.
- Vitamin B_{12} is administered subcutaneously as needed.
- Support belts may be helpful for securing poorly fitting appliances, especially in obese patients.
- Maintaining a healthy skin around the stoma is paramount. Allergic reactions to the appliance can occur and may be managed by changing appliance type or manufacturer.
- Pooling of ileal effluent must be avoided by frequent appliance changes or bag emptying. The appliance should be changed immediately postoperatively if the patient experiences leakage or peristomal skin problems.

For Ileostomy Reversal Patients

- The patients must be followed closely postoperatively to identify problems and complications after ileostomy takedown. This is especially important in high-risk patients.
- Dehydration and electrolyte abnormalities may persist after ileostomy takedown.

OUTCOMES

- Dietary indiscretion (e.g., high glucose, high fat) and alcoholic beverages may result in diarrhea and dehydration. Dehydration contributes to readmission rates that can be as high as 20%.
- An "ileostomy care pathway," including a standardized set of perioperative patient education tools, direct patient engagement with stoma care, strict monitoring of stoma output postdischarge, and visiting nurse involvement, may all positively impact overall readmission rates (e.g., 35% prepathway implementation vs. 21% postpathway implementation)

and may decrease or even eliminate readmissions for dehydration (e.g., 15.5% prepathway implementation vs. 0% postpathway implementation).[1]

- The use of a sodium hyaluronate and carboxymethylcellulose-based bioabsorbable membrane can significantly decrease adhesion formation around a loop ileostomy as identified at the time of ileostomy reversal (e.g., no Seprafilm® vs. Seprafilm® around stoma, 30.6% vs. 14.1%).[2]
- In patients requiring a diverting loop ileostomy, a bridge (rod) does not significantly impact retraction or leakages.[3]
- Laparoscopic creation of an ileostomy is safe and effective and should be considered for patients.[4]
- Over 10% of patients require ileostomy-related reoperations. Obesity is an independent risk factor for ileostomy complications and, along with smoking history, is associated with a lower likelihood of subsequent ileostomy reversal.[5]
- Handsewn vs. stapled ileo-ileostomy anastomoses for ileostomy closure have similar major complications such as bowel obstruction (in about 15% of cases) and anastomotic leak (in about 2% of cases), with stapled anastomoses resulting in shorter operation times.[6]

COMPLICATIONS

Ileostomy Creation Patients

- Over 80% of patients experience one or more stoma-related complications. Common problems include skin irritation (in up to 60%), fixation problems (in up to 50%), and peristomal leakage (in up to 40%). Superficial necrosis, bleeding, and retraction can occur in up to 20%, 15%, and 10% of patients, respectively. Stoma-related complications are even more common for stomas in suboptimal locations.
- Parastomal hernia
- Parastomal fistula
- High-output ileostomies may result in dehydration, electrolyte abnormalities, and fat/fat-soluble vitamin malabsorption.

Ileostomy Reversal Patients

- An analysis of the National Surgical Quality Improvement Program (NSQIP) demonstrated that following elective ileostomy closure, 9.3% of patients had major complications (e.g., mortality, sepsis, return to the operating room, renal failure, major cardiac, neurologic, or respiratory episode) and 8.4% had minor complications (e.g., wound infection or urinary tract infection within 30 days). Mortality was 0.6%. Independent predictors of major complications were American Society of Anesthesiologists (ASA) physical status classification system score, functional status, history of chronic obstructive pulmonary disease (COPD), dialysis, disseminated cancer, and prolonged operative time.
- Hand-sewn ileo-ileostomy and stapled ileo-ileostomy anastomoses for ileostomy closure have similar major complication rates e.g., bowel obstruction in about 15% of cases and anastomotic leak in about 2% of cases.
- Wound infections following ileostomy reversal are significantly lower in patients undergoing delayed versus primary closure (0% vs. 24%) with similar cosmetic outcomes.

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Chapter 5

Jejunostomy Tube

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DEFINITION

- A jejunostomy feeding tube is a tube placed into the proximal jejunum and brought out through the skin to allow for feeding distal to the stomach. Jejunostomy tubes are indicated in patients who are unable to maintain adequate nutrition orally and who are unable to be fed via the stomach. Examples of conditions that may require a jejunostomy tube include, but are not limited to, gastric outlet obstruction, esophageal perforation, gastroparesis, or recurrent aspiration. Jejunostomy tubes may be placed via a nasojejunal or percutaneous route; the latter can be approached via interventional radiology, via laparoscopic or open surgery, or via endoscopy, as an extension through a percutaneous gastrostomy tube.

PATIENT HISTORY AND PHYSICAL FINDINGS

- A complete surgical history should be elicited, focusing on prior abdominal operations.
- A complete abdominal examination should be performed, noting prior incisions and hernias.
- Because malnutrition may be an indication for placement of a jejunostomy tube, a complete nutritional history should be obtained including recent weight loss.
- Physical examination should be focused on signs of severe malnutrition such as loss of subcutaneous fat, muscle wasting, and/or presence of edema and ascites.
- The Subjective Global Assessment Score combines the history and physical examination to provide a rating from A (*well nourished*) to C (*severely malnourished*).

IMAGING AND OTHER DIAGNOSTIC STUDIES

- A nutritional assessment should be performed. Severe malnutrition may be a reason for placement of a jejunostomy tube, such as prior to major elective surgery. Indicators of preoperative malnutrition include weight loss greater than 10% to 15% over the previous 6 months, body mass index less than 18.5 kg/m^2, Subjective Global Assessment Grade C, and/or serum albumin less than 3 g/dL.[1]
- Electrolytes should be checked and replaced prior to surgery. An electrocardiogram should also be checked in order to rule out cardiac abnormalities and arrhythmias.
- Additional studies and radiologic imaging should be based on the primary diagnosis. In patients with underlying malignancy, staging studies should be recent enough to ensure that there are no changes in the cancer status that may affect the operative plan.

SURGICAL MANAGEMENT

Preoperative Planning

- Although enteral feeding is preferred to the parenteral route, the surgeon should ensure that there are no contraindications to enteral nutrition such as distal obstruction, ileus, high-output enterocutaneous fistula, or shock.
- Alternatives to jejunostomy tubes include temporary nasally inserted feeding tubes and gastrostomy tubes. Temporary feeding access can be achieved using a nasogastric or a nasojejunal feeding tube; the latter can be placed with the assistance of fluoroscopy or endoscopy. Smaller diameter feeding tubes may be more comfortable for the patient but also may be more prone to clogging. Gastrostomy tubes for longer term feeding access can be placed endoscopically, radiologically, or surgically.
- If enteral access is not the primary indication for surgery, then the complete operative plan should be considered. The anticipated duration of inability to take in oral nutrition or of inadequate nutrition (<60% of caloric requirement) should be taken in consideration when deciding whether or not to place a feeding jejunostomy tube as well as in deciding the route of placement (nasojejunal vs. surgical).[1] In cancer patients, whether the goal of surgery is curative or palliative should be considered. A temporary feeding jejunostomy tube may be indicated after resection of cancer of the esophagus, stomach, or pancreas to allow continued distal enteral nutrition in the event of an anastomotic leak.
- Palliative care may include placement of a surgical jejunostomy tube. Cancer patients who are not candidates for curative treatment should be assessed for their preferences, quality of life, and resources. The risks of surgical intervention should be weighed against the potential benefits of enteral nutrition. A candid discussion should be held with the patient regarding advanced directives and end-of-life care.
- When enteral access is the primary indication for surgery, the surgeon should discuss the planned operative approach with the patient. When a laparoscopic jejunostomy tube is planned, the surgeon should discuss the possibility of conversion to open. If the jejunostomy tube is palliative, the surgeon should discuss the possibility of aborting the procedure when the risks outweigh the benefits (i.e., in the setting of carcinomatosis and inability to safely dissect the proximal jejunum).
- Although no randomized trials exist regarding antibiotic prophylaxis prior to jejunostomy tube placement, there is high-quality evidence that antibiotic prophylaxis reduces surgical site infections across procedures and baseline risks.[2] In addition, a meta-analysis of randomized controlled trials of antibiotic prophylaxis to prevent peristomal infection after percutaneous endoscopic gastrostomy demonstrated a significant risk reduction with cephalosporin and penicillin-based prophylaxis.[3]

Positioning

- The patient should be positioned in the supine position. This is required for both laparoscopic and open techniques. For the laparoscopic approach, it is important to secure the patient to the bed with straps or tapes to allow for safe manipulation of the operating table.

OPEN JEJUNOSTOMY FEEDING TUBE PLACEMENT

First Step—Placement of Skin Incision

- A limited midline incision, approximately 5 cm in length, is made above the umbilicus. This allows for identification of the ligament of Treitz. A larger incision may be needed if the patient has had multiple prior operations requiring adhesiolysis.
- Once the abdomen is entered, the omentum can be followed to the transverse colon, which is retracted cephalad. The ligament of Treitz is located at the base of the transverse mesocolon to the left of the fourth portion of the duodenum (**FIG 1**) and is identified by visualization and palpation. A segment of jejunum distal to the ligament of Treitz is identified. A distance of 15 to 20 cm from the ligament of Treitz will allow the jejunum to reach the abdominal wall without tension, while also providing for enough length for a proximal revision of the jejunal segment, should one be necessary in the future.
- An exit site is identified in the skin of the left upper quadrant, several centimeters lateral from the midline. A stab incision is made at this level, and tonsil clamps are used to deliver the jejunostomy tube into the abdominal cavity.

Second Step—Choice of Tubes

- The type of jejunostomy tube used can be as simple as a 10- or 12-French red rubber catheter or a silicone jejunostomy tube similar to those used in laparoscopic cases. Silicone tubes may have more longevity.[4] Avoid using balloon-tipped catheters (i.e., Foley catheters) or, alternatively, ensure that the ability to inflate the balloon has been disabled to prevent future attempts at insufflating the balloon that could lead to subsequent bowel obstruction.
- If using a red rubber catheter, the tip may be cut off, which allows for exchange over a wire should the tube become clogged. Additional side holes may also be cut at the distal end of the tube in order to improve flow through the catheter.

Third Step—Suturing Tube into the Bowel

- The previously chosen site of proximal jejunum is delivered into the wound. The site of entry of the tube should be on the antimesenteric side of the jejunum. Once this is identified, a 3-0 silk is used to create a diamond-shaped purse-string suture. A small opening is made inside the purse-string suture with cautery, only large enough to allow for the tube to be inserted into the bowel.
- The tube is placed into the bowel and advanced into the distal portion of the jejunum. The length of advancement into the jejunum should be long enough to prevent backflow of feeds into the proximal small intestine.
- The purse-string suture is secured, and the tube is placed along the proximal bowel wall. The Witzel technique is then used to prevent extravasations of enteric feeds at the jejunostomy tube entrance site. In this technique, 3-0 silk seromuscular sutures are placed perpendicularly on the antimesenteric border of the bowel on both sides of the feeding tube (Lembert sutures) in order to imbricate the bowel wall over the feeding tube, creating a serosal tunnel (**FIG 2**). This should be approximately 2 to 3 cm in length and care should be taken to not narrow the lumen

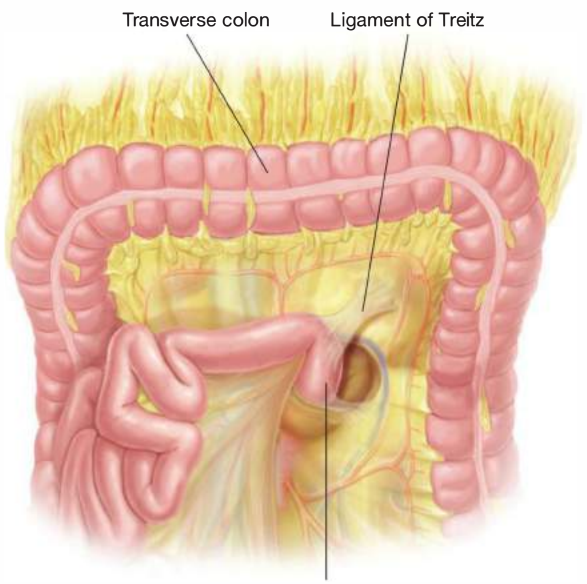

FIG 1 ● Identification of the ligament of Treitz. With the transverse colon retracted superiorly, the ligament of Treitz can be easily identified at the base of the transverse mesocolon and to the left of the fourth portion of the duodenum.

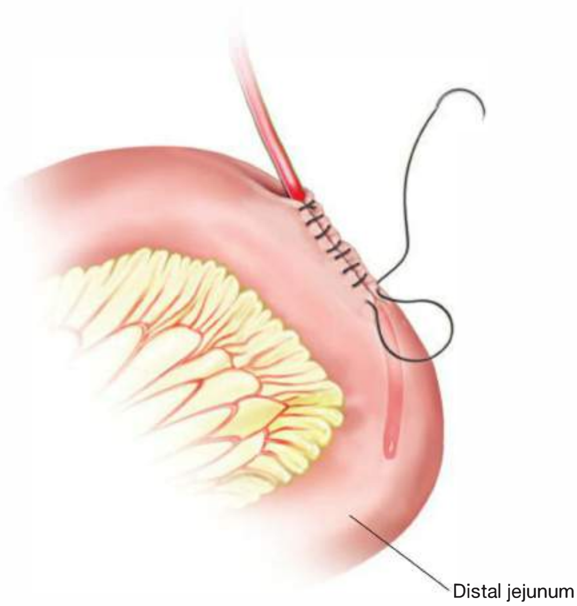

FIG 2 ● The open Witzel technique. 3-0 silk seromuscular sutures are placed perpendicularly on the antimesenteric border of the bowel on both sides of the feeding tube (Lembert sutures) in order to imbricate the bowel wall over the feeding tube, creating a serosal tunnel.

of the bowel or tube with these sutures. Care should also be taken to avoid perforating the feeding tube during the placement of these sutures, as this could lead to extravasation of the enteric feeds into the abdominal cavity.

Fourth Step—Suturing the Tube to the Abdominal Wall

- The tube should then be secured with 3-0 silk seromuscular sutures to the abdominal wall parietal peritoneum in four quadrants around the exit point of the tube just proximal to the last Witzel suture. Care should be taken to avoid perforating the feeding tube during the placement of these sutures, as this could lead to extravasation of the enteric feeds into the abdominal cavity. One additional suture can be used to tack the jejunum to the abdominal wall distal to the tube entrance site to prevent kinking or volvulus of the jejunum around the tube site.

LAPAROSCOPIC JEJUNOSTOMY FEEDING TUBE PLACEMENT

First Step—Laparoscopic Port Placement

- The abdomen may be entered either by a cut-down technique, by use of an insufflation needle followed by entry with an optical access trocar, or with an optical access trocar alone. One 5-mm port should be placed periumbilically and two additional 5-mm ports should be placed in a triangulated fashion to allow for manipulation of the jejunum; these should be placed under direct visualization to prevent bowel injury. These are traditionally placed in the right upper and left lower quadrants.

Second Step—Identification of the Ligament of Treitz

- The patient is placed in a Trendelenburg position and is rotated to the right side in order to facilitate identification of the ligament of Treitz.
- The transverse colon is elevated with an atraumatic grasper to identify the ligament of Treitz, located at the base of the transverse mesocolon and to the left of the fourth portion of the duodenum (**FIG 1**). A segment of jejunum approximately 15 to 20 cm distal from the ligament that will easily allow the jejunum to reach the abdominal wall without tension is identified.

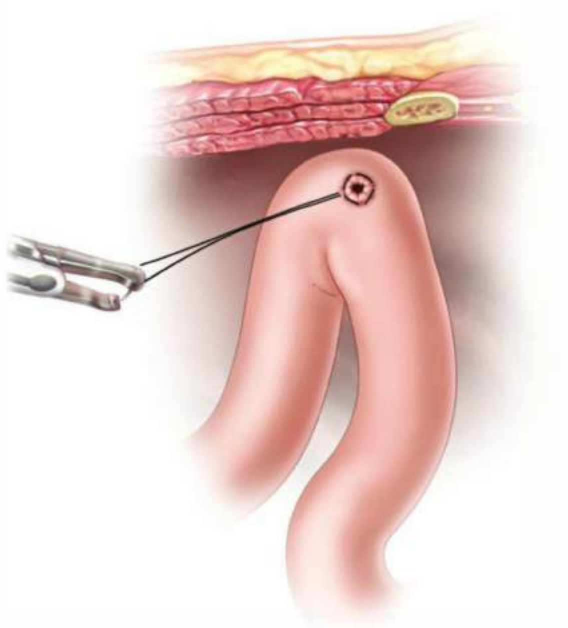

FIG 3 ● A purse-string suture of 3-0 silk is placed with an endoscopic sewing device in a circular manner at the site where the feeding tube will be inserted.

Third Step—Placing the Tube in the Jejunum

- A purse-string suture of 3-0 silk can be placed with a laparoscopic needle driver or with an endoscopic sewing device in a circular manner, in the same fashion as performed in open cases (**FIG 3**). Using electrocautery, make an opening in the small bowel and deliver the feeding tube through the opening and into the distal jejunum. The purse-string suture is tied intracorporeally.
- Lembert sutures are placed to create a Witzel serosal tunnel around the feeding tube. The jejunostomy tube is then tacked to the anterior abdominal wall with a four-quadrant suture placed intracorporeally proximally to the Witzel tunnel.
- If using a laparoscopic jejunostomy tube kit that provides T-fasteners, the jejunum is grasped with two atraumatic graspers and the percutaneous T-fastener is placed through the skin and into the bowel just proximal to where the tube will enter the jejunum. Care should be taken not to place the needle through and through the bowel (back-wall perforation) that would lead to leakage of tube feeds and enteric contents into the abdominal cavity postoperatively. Once the needle is inside the bowel, the T-fastener is released by pushing in the stylet (**FIG 4**). The needle is then removed, and a hemostat is used to pull up on the suture in order to pull the jejunum up flushed to the abdominal wall. Additional T-fasteners are placed in a diamond shape around the planned insertion site.
- The jejunum is then accessed with a needle, and a guidewire is threaded into the bowel (**FIG 5**). The wire is followed laparoscopically to ensure it is going down the distal jejunal limb. A skin incision is made at the guidewire exit site and the dilator is placed over the wire and into the jejunum. The dilator is exchanged for the peel-away sheath. The wire is removed and the tube is placed through the peel-away sheath. The sheath is then peeled away from the catheter (**FIG 6**).
- Confirmation that the tube is in the bowel lumen can be achieved by injecting air into the tube and observing the bowel distend.

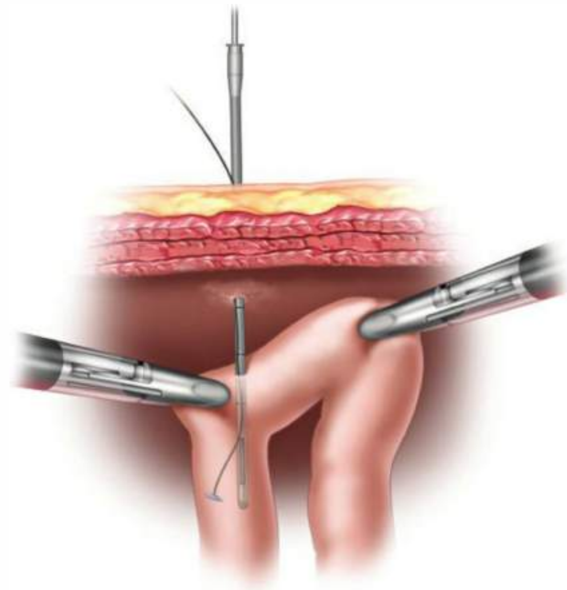

FIG 4 ● Laparoscopic jejunostomy kit technique. Once the needle is inserted inside the bowel, pushing in the stylet deploys the T-fastener.

Fourth Step—Securing the Jejunum to the Abdominal Wall

- The bowel can be fastened to the abdominal wall in four corners with 3-0 silks using laparoscopic needle drivers (**FIG 3**). An alternative method is to place sutures on all four quadrants around the purse-string site and deliver them through the abdominal wall with a suture passer.
- If T-fasteners are used, they are then secured by crimping the metal fasteners above the bolsters with a straight hemostat, thus approximating the jejunum to the abdominal wall. An additional T-fastener can be used to tack the jejunum to the abdominal wall distal to the tube insertion site to prevent volvulus (**FIG 7**).
- Inject a small amount of saline or air into the tube after it has been secured to the abdominal wall to ensure there is no leak and that the tube is patent.

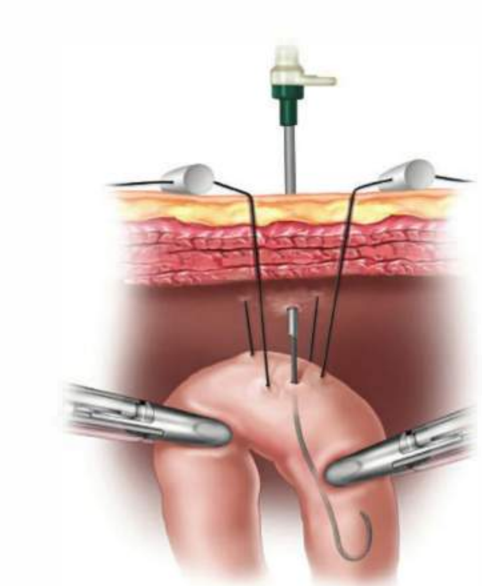

FIG 5 ● Laparoscopic jejunostomy kit technique. The jejunum is then accessed with a needle and a guidewire is threaded into the bowel.

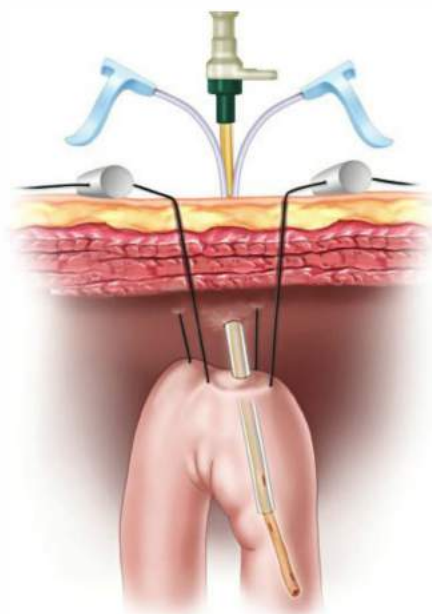

FIG 6 ● Laparoscopic jejunostomy kit technique. The jejunostomy tube is placed through the peel-away sheath and into the distal jejunal limb.

FIG 7 ● Laparoscopic jejunostomy kit technique. **A.** The T-fasteners have been secured by crimping the metal fasteners above the bolsters, thus approximating the jejunum to the abdominal wall at the jejunostomy site. **B.** An additional T-fastener was placed to tack the jejunum to the abdominal wall distal to the tube insertion site to prevent volvulus.

PEARLS AND PITFALLS

Technique	
Open jejunostomy tube placement	
Creating the serosal tunnel	■ When creating the Witzel tunnel, it is possible to cause narrowing of the proximal bowel. The sutures should be carefully placed close to the feeding tube to avoid this problem.
Laparoscopic jejunostomy tube placement	
Using T-fasteners	■ Care should be taken not to place the needle through and through the bowel (avoid back-wall perforation of the bowel). ■ When crimping the T-fasteners, ensure that the jejunum is flush to the abdominal wall. However, do not indent the skin significantly, which can cause necrosis of the skin and cause the patient significant pain. ■ Fasteners should be carefully planned as kits only carry five fasteners and once through the skin and fascia, the fastener is not reusable.
Wire placement	■ Ensure that the wire is traveling distally when placed. ■ Ensure that the wire is freely mobile in the bowel and has not dissected into the layers of the intestinal wall.
Confirmation of tube placement	■ Ensure that the dilator and tube are visualized laparoscopically while entering into the distal aspect of the jejunum. ■ Inject a small amount of saline or air into the tube after it has been secured to the abdominal wall to ensure there is no leak and that the tube is patent.

POSTOPERATIVE CARE

- Postoperatively, the patient's jejunostomy tube can be used immediately.
- The jejunostomy tube should be flushed daily, before and after administration of medications, and after stopping tube feeds to prevent clogging and to ensure patency.
- If a laparoscopic jejunostomy kit was used, the T-fasteners can be cut at the skin level 2 weeks after tube placement.
- Nutritional consultation should be considered in order to determine the patient's caloric needs. Nutritionists may also assist in the choice of enteral formula. There is data from meta-analyses of randomized trials suggesting a benefit to using immunonutrition in perioperative head/neck and gastrointestinal cancer patients.[5,6]
- In malnourished patients who are at high risk for refeeding syndrome, nutritional support should be started slowly.[7] Fluid and electrolyte imbalances should be corrected. In addition, high-risk patients should be monitored closely in terms of their vital signs, electrolytes, weight, and neurologic signs and symptoms. Patients should be monitored for hypophosphatemia, hypokalemia, hypomagnesemia, hyperglycemia, and hyponatremia upon initiation of feeds. Because of the risk of arrhythmias, telemetry may be indicated in severe cases.
- Diarrhea is a common side effect of enteral nutrition. High-quality data on preventive interventions are lacking.[8]

Persistent diarrhea (>72 hours) should trigger evaluation for *Clostridium difficile* infection, rectal examination to rule out fecal impaction, cessation of laxatives, and restoration of fluid and electrolyte balance. Addition of soluble fiber or modification of the composition of the enteral formula may reduce diarrhea.[8]

- Nonocclusive bowel necrosis is a rare but devastating complication of enteral feeding. Tube feed tolerance should be monitored closely, particularly among patients with preexisting impaired gastrointestinal function. Signs of intolerance may be nonspecific such as nausea, diarrhea, bloating, and abdominal pain. Mechanisms that may contribute to nonocclusive bowel necrosis include mesenteric hypoperfusion, bacterial contamination, and hyperosmolarity of the tube feeds. Unfortunately, due to the rarity of nonocclusive bowel necrosis, specific risk factors cannot be identified.[9] Therefore, a low threshold for diagnosis should be maintained and early reexploration performed when suspected.

OUTCOMES

- Outcomes after jejunostomy tube placement are dependent on the primary diagnosis.
- In cancer patients undergoing curative treatment, enteral nutrition improves the tolerance and response to therapy.[10,11] In cancer patients undergoing palliative treatment, enteral nutrition may improve symptoms and quality of life while reducing loss of autonomy.[10]

COMPLICATIONS

- Diarrhea
- Dermatitis
- Infection
- Tube leakage (peristomal or intraperitoneal)
- Small bowel perforation
- Displacement of the jejunostomy tube
- Enterocutaneous fistula
- Refeeding syndrome
- Mechanical small bowel obstruction at the jejunostomy tube site
- Volvulus around the jejunostomy tube site
- Nonocclusive bowel necrosis

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Chapter 6

Appendectomy: Open Technique

James Suliburk David Berger

DEFINITION

- Open appendectomy is defined as removal of the appendix via an incision in the abdominal wall without use of a camera. Prior to laparoscopy, it was the most commonly performed emergency general surgery operation in the United States.
- Open appendectomy has been replaced in frequency by laparoscopic appendectomy as the most common emergency general surgery operation performed.
- Laparoscopic appendectomy is not always possible, and an open approach may be preferred in patients who have had extensive abdominal or pelvic surgery. Additionally, it may be necessary to convert to an open technique from an initial laparoscopic approach due to technical or anatomic reasons. Open appendectomy can also be the preferred approach in patients who are pregnant in which the gravid uterus precludes laparoscopy.

DIFFERENTIAL DIAGNOSIS

- Patients presenting with appendicitis may have any number of conditions mimicking the classic right lower quadrant (RLQ) pain of appendicitis. Conditions that have to be considered in the differential diagnosis of acute appendicitis can be broken down in categories, including the following:
  - Gastrointestinal: gastroenteritis, mesenteric lymphadenitis, Meckel's diverticulum, intussusception, cholecystitis, inflammatory bowel disease, diverticulitis, perforated cancers, and perforated peptic ulcers
  - Gynecologic: ectopic pregnancy, salpingitis, endometriosis, ovarian torsion, tuboovarian abscess
  - Urologic: urinary tract infection, nephrolithiasis

PATIENT HISTORY AND PHYSICAL FINDINGS

- Patients most commonly present with appendicitis between the ages of 10 and 40 years. Approximately 75% of patients will present with pain of less than 24 hours duration. Classically, the pain is described as starting at the umbilicus and then migrating over several hours' time to the RLQ as the stimulus changes from the visceral to somatic nerves. However, this classic migration is not always present, and nearly 40% of patients will have atypical pain, with only vague abdominal pain or even flank pain.
- Atypical pain can frequently be caused by subtle variation in the appendix location with right upper quadrant pain being caused by an anteriorly located appendix on a high-riding cecum, tenesmus triggered by an inflamed appendix tip in the pelvis, and flank pain triggered by a retrocecal appendix.
- Nausea, vomiting, and anorexia are classically associated with appendicitis but are variably present. Of these, the sequence of having anorexia and/or abdominal pain preceding vomiting is more consistent with appendicitis. When vomiting is the first symptom elicited, the diagnosis of appendicitis is questionable. Diarrhea is fairly nonspecific.
- Physical exam findings consistent with appendicitis are dependent on the location of the appendix. Because the appendix may be located anywhere on the cecum, signs are extremely variable. Classic RLQ point tenderness at McBurney point is present in the normal anterior location of the appendix. Rovsing's sign (RLQ pain when left lower quadrant is pressed) may also be present.
- When the appendix is located in a retrocecal position, a positive psoas sign (pain with extension of the right thigh with the patient lying on the left side) can be elicited.
- When the inflamed appendix is in the pelvis, the classic obturator sign (pain with internal rotation of the flexed thigh in the supine position) may be positive.
- Additional tests for subtle peritoneal irritation, including gently shaking the hospital stretcher or having the patient walk, cough, or jump to determine if this exacerbates pain, are nonspecific for appendicitis and simply indicate peritoneal irritation.
- Diffuse peritonitis is consistent with ruptured appendicitis and intraabdominal sepsis. These patients usually present with temperature greater than 39°C and tachycardia.

IMAGING AND OTHER DIAGNOSTIC STUDIES

- Laboratory studies and radiologic studies can be complementary to history and physical exam in establishing the diagnosis. A mild leukocytosis is generally present. Occasionally, a "left shift" with normal leukocyte count is seen. Fewer than 5% of patients presenting with acute appendicitis will have both a normal white blood cell (WBC) count and no shift.
- Urinary analysis may show a few white or red cells but should not reflect bacteriuria.
- Serum chemistry testing for amylase and lipase and liver function tests are useful in cases where the history of presentation and physical exam findings are not classic and there is an atypical presentation.
- Imaging studies have come to the forefront of appendicitis diagnosis in recent years. Computed tomography (CT) enhanced with intravenous (IV) and enteral contrast is the gold standard for evaluation of appendicitis. Case series differ slightly in their reports, but a reasonable estimation is that CT is 90% sensitive and 95% specific for detection of appendicitis.
- Widespread use of CT has been shown to reduce the incidence of negative appendectomy.[1] Furthermore, findings of phlegmon or abscess on CT may prompt the surgeon to undertake an alternate approach in treating complex cases of appendicitis with percutaneous drainage and IV antibiotic therapy as the first step of therapy in order to minimize morbidity to the patient.
- Ultrasound remains an imaging modality that is operator dependent. In skilled centers, it can be especially helpful in pediatric patients and in early pregnancy.

- Plain abdominal radiographs should not be considered routine or mandatory in the specific evaluation of appendicitis but can be used as an initial test in patients presenting with diffuse peritonitis and signs of intraabdominal sepsis.

SURGICAL MANAGEMENT

- The bulk of surgical treatment should be discussed in the "Techniques" section. Here, consider indications and other more general concerns, such as discussed in the following sections.

Preoperative Planning

- Patients should receive adequate preoperative fluid resuscitation prior to operation in order to restore urine output. This is especially important for patients who show systemic signs of inflammation (systemic inflammatory response syndrome [SIRS]: fever, tachycardia, increased respiratory rate, WBC count $\geq$12,000/mm^3 or $\leq$4,000/mm^3, or >10% bands).
- Evidence-based studies clearly indicate that as soon as the decision to operate on the patient is made, IV antibiotics covering facultative, gram-negative, and anaerobic flora should be promptly administered in an effort to reduce surgical site infection (SSI).[2] If simple (nonruptured) appendicitis is encountered at operation, there is no benefit in administration of postoperative antibiotics.

Positioning

- The patient is positioned on a supine position with the arms extended or tucked depending on surgeon preference. A Foley catheter can be inserted at the surgeon's discretion.

TECHNIQUES

OPEN APPENDECTOMY FOR PRIMARY TREATMENT OF APPENDICITIS

First Step—Skin Incision

- A McBurney (oblique) or Rocky Davis (transverse) incision is made in the RLQ, slightly superior to the point of maximal tenderness found during preoperative exam, and centered on the midclavicular line (**FIG 1**).

Second Step—Abdominal Wall

- There are three muscle layers in the lateral abdominal wall. As these are encountered when entering the abdomen, these are the external oblique, the internal oblique, and the transversus abdominis muscles.
- Each muscle aponeurosis is cut in the direction of the muscle fibers.
- A muscle-splitting technique is used to spread apart each muscle layer along the orientation of the muscle fibers (**FIG 2**) until the peritoneum is reached.
- The peritoneum is then grasped with forceps in order to assure no bowel is adherent and is incised with scissors to enter the abdominal cavity (**FIG 3**).
- An appropriate retractor is placed to enhance operative exposure. This can be either a Balfour or a Bookwalter retractor.

Third Step—Exposure of the Appendix

- After the peritoneum is entered, the cecum is identified. Sponge sticks can be helpful to sweep the small bowel in a lateral to medial direction in order to expose the cecum.

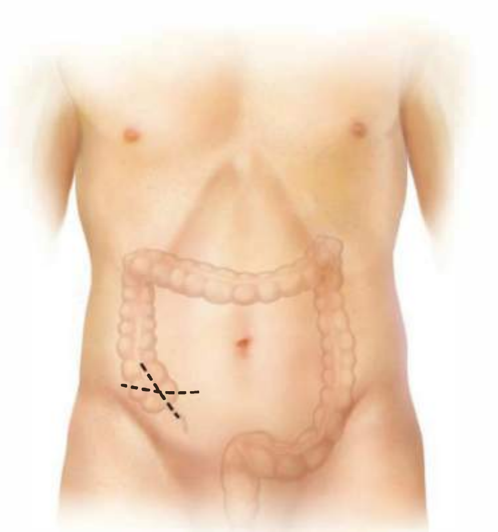

FIG 1 ● Incision placement. A Rocky Davis (transverse) or McBurney (oblique) incision is used. The midpoint of the incision should be centered over the maximal point of tenderness.

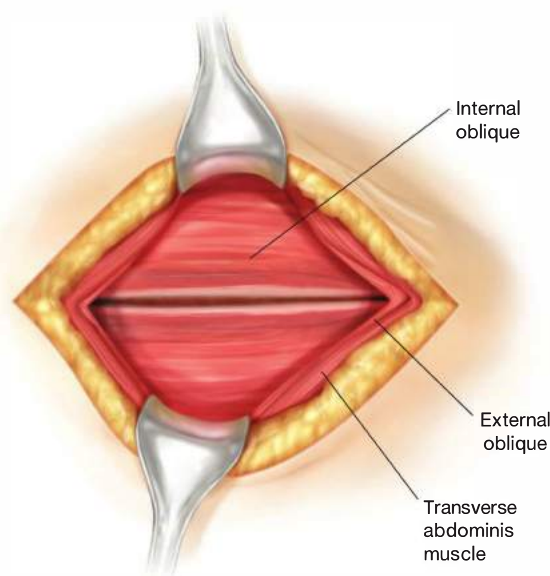

FIG 2 ● Abdominal wall opening. A muscle-splitting technique is used to spread apart each muscle layer along the orientation of the muscle fibers.

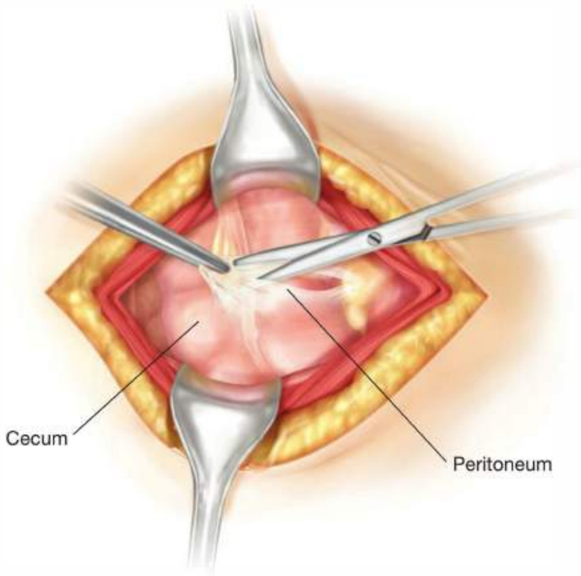

FIG 3 ● Abdominal wall opening. The peritoneum is then grasped with forceps in order to assure no bowel is adherent and is incised with scissors to enter the abdominal cavity.

- Once the cecum is identified, the anterior taenia is identified. The cecum is then mobilized, following the anterior taenia to its confluence with the appendiceal base (**FIG 4**).
- The convergence of all three teniae coli allows for the correct identification of the base of the appendix. This is critical to ensure that the entire appendix is removed.
- Failure to remove the base of the appendix may cause a closed loop obstruction between a persistent fecalith at the base of the appendix and the stump staple line. This may lead to an appendiceal stump blowout postoperatively.
- In cases of retrocecal appendicitis, the cecum will need to be fully mobilized in a lateral to medial fashion so that it is completely reflected from the retroperitoneum in order to find the appendix.

Fourth Step—Ligation and Resection

- The appendix and cecum are gently pulled into the wound. The mesoappendix is transected and ligated between clamps (**FIG 5**).
- Absorbable suture ties are placed at the appendiceal base, and the appendix is then transected (**FIG 6**). There is no supporting data for electrocautery ablation of the appendiceal mucosa at the ligated stump, and this common practice clearly puts at risk the security of the suture used to ligate the appendiceal stump.
- Inversion of the appendiceal stump may be performed if the surgeon desires. Commonly, a "Z-stitch" is used for this purpose (**FIG 7**).
- In the Z-stitch, the upper bite is placed as a Lembert suture and then brought below the base of the appendiceal stump and a second seromuscular stitch is placed. The base of the appendix is then inverted using forceps and the ends of the suture tied down over the inverted stump (**FIG 7**).
  - In cases of severe appendiceal stump edema and inflammation, a gastrointestinal stapler may be used to transect the base of the appendix, even including a segment of healthy cecal base in the resection; be careful to avoid impingement of the ileocecal valve when firing the stapler (**FIG 8**).

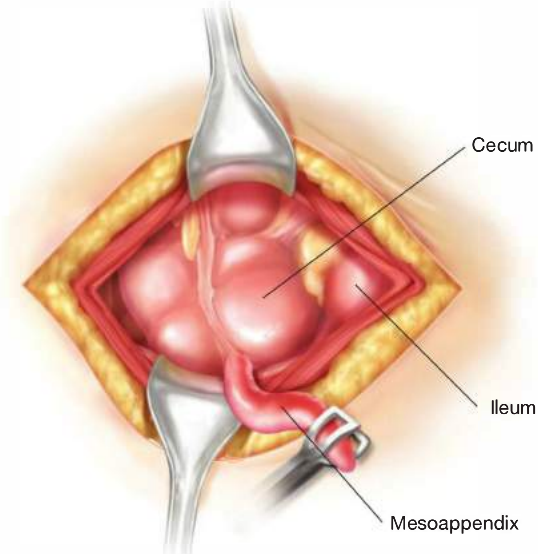

FIG 4 ● Delivery of the appendix into the wound. Once the cecum is identified, the anterior teniae coli is identified. The cecum is then mobilized following the anterior taenia to its confluence with the appendiceal base.

FIG 5 ● Clamping and ligation of the mesoappendix. The appendix and cecum are gently pulled into the wound. The mesoappendix is transected and ligated between clamps.

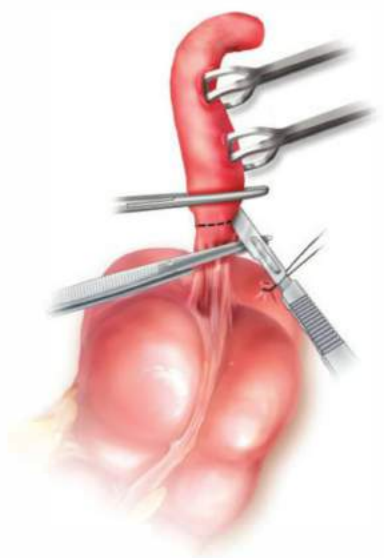

FIG 6 ● Ligation of the appendiceal base. Absorbable suture ties are placed at the appendiceal base, and the appendix is then transected.

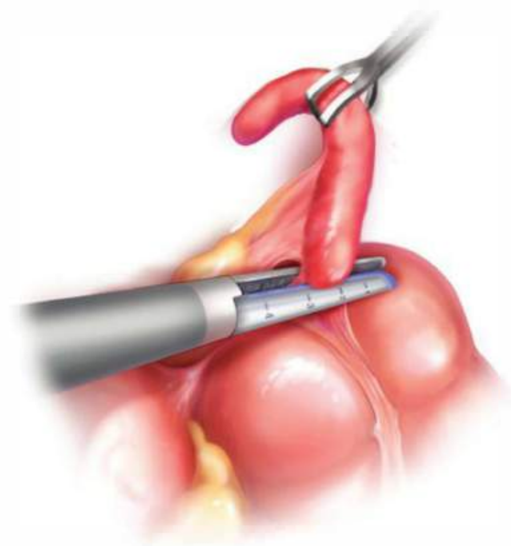

FIG 8 ● Use of gastrointestinal stapler to transect the appendiceal base.

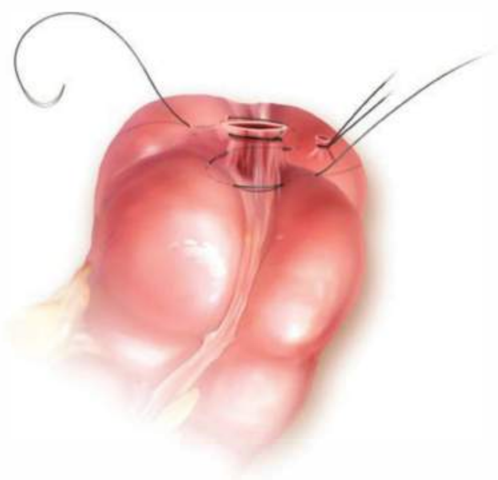

FIG 7 ● Inversion of the appendiceal stump. The appendiceal stump is inverted into the cecum with the placement of a Z-stitch.

- Irrigation of the surgical field is of unclear benefit. There are limited data in adults. A randomized prospective study in children failed to show any change in intraabdominal abscess whether irrigation was used or not used.[3]

Fifth Step—Closure

- All three muscle layers are closed separately with running absorbable suture.
- The skin can be closed, left open, or loosely approximated, depending on the severity of contamination encountered during the case.
- For gangrenous or perforated appendicitis, considered delayed primary closure or placement of a negative pressure wound therapy device to minimize superficial surgical site infection.
- No drain is indicated in simple appendicitis. Drain placement in cases of complicated appendicitis is also not supported by clinical trials.

OPEN APPENDECTOMY FOR APPENDICEAL NEOPLASMS

- Occasionally, the surgeon may encounter an appendiceal neoplasm as the cause of the suspected appendicitis. Overall, this happens in approximately 1% of cases of suspected appendicitis.
    - Appendiceal tumors encountered may include carcinoid tumor, mucinous neoplasm, or appendiceal/cecal adenocarcinoma. In these cases, it is essential to understand what operation needs to be done for the patient. **FIG 9** is shown as a quick reference guide.
    - For carcinoid tumors less than 1 cm in size, a simple appendectomy is sufficient.
    - For carcinoid tumors between 1 and 2 cm in size, surgical treatment will depend on the tumor location. If the carcinoid tumor is at the base of the appendix or if the tumor invades the mesoappendix, then a right hemicolectomy is indicated to obtain an

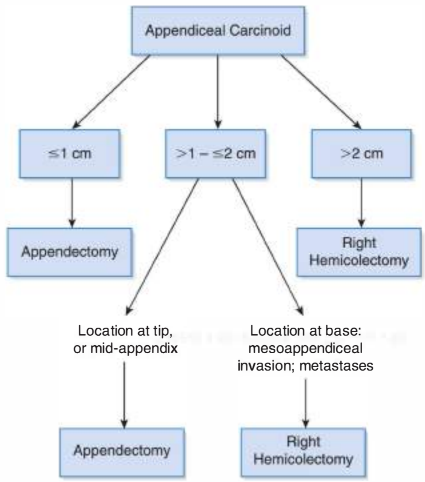

FIG 9 ● Management of appendiceal carcinoid.

adequate lymphadenectomy. Otherwise, a simple appendectomy is sufficient.

- For carcinoid tumors greater than 2 cm in size, a right hemicolectomy with a high ileocolic lymphovascular pedicle transection is indicated due to the higher incidence of metastatic disease observed in the nodal basin in these patients.[4]
- In cases where right hemicolectomy is indicated, it is prudent to close the RLQ incision and convert to a midline laparotomy.
- For mucinous appendiceal neoplasms, the extent of resection will be dictated by the degree of invasion. Intraoperatively, special attention should be given to not rupturing an intact mucinous neoplasm.
- If rupture of a mucinous neoplasm has occurred, then the surgeon should examine if mucin coats peritoneal surfaces. If mucin is diffusely coating the abdomen, then right hemicolectomy is indicated. If there is no mucin contamination, appendectomy with clear margins will suffice. Pathology must then be followed up to determine if the lesion was malignant or not.
- If malignancy is identified, refer to a specialty center for consideration of right hemicolectomy (if not originally performed). Debulking and intraperitoneal chemotherapy is also indicated in cases of diffuse mucin coating of the abdominal surfaces.[5]
- Nonmucinous appendiceal adenocarcinoma warrants a right hemicolectomy with a high ileocolic lymphovascular transection in order to perform an adequate lymphadenectomy.
- For the technical description on how to perform an open right hemicolectomy, please refer to the description of this technique elsewhere in this textbook.

CONVERSION TO OPEN APPENDECTOMY AFTER FAILED ATTEMPT AT LAPAROSCOPIC APPENDECTOMY

First Step—Skin Incision

- When converting to an open procedure from laparoscopy, a lower midline laparotomy incision is preferred. The incision may be extended above the umbilicus if additional exposure is required.

Second Step—Abdominal Wall

- It is essential to stay in the midline, along the linea alba, during the fascial incision in order to facilitate optimal closure and to prevent ventral incisional hernia formation. Care should be taken not to extend the incision too far inferiorly as the bladder is at risk of injury (especially in cases where no Foley catheter is present).

Third Step—Appendiceal Resection

- Once the peritoneum is entered, any adhesions are lysed sharply and an appropriate retractor is placed to enhance operative exposure. This can be either a Balfour or a Bookwalter retractor.
- At this point, the cecum is mobilized and the appendix is exposed. The mesoappendix is then divided and tied between clamps.
- The base of the appendix, identified by the convergence of the teniae coli at the base of the cecum, is ligated with sequential absorbable suture ties as described.
- If the base is easily identified at the beginning of the case, it may be helpful to perform a "retrograde" dissection of the appendix. In this technique, the appendiceal base is transected first. The mesoappendix is then sequentially transected from the appendiceal base to its tip (**FIG 10**). This technique can be useful when the mesoappendix is severely adhered to the cecum.
- If inflammation is severe, an ileocecectomy may be required or even partial colectomy. If inflammation is so severe as to preclude mobilization of the cecum and terminal lieum, a cecostomy maybe created. Please refer to the description of this technique described elsewhere in this textbook.

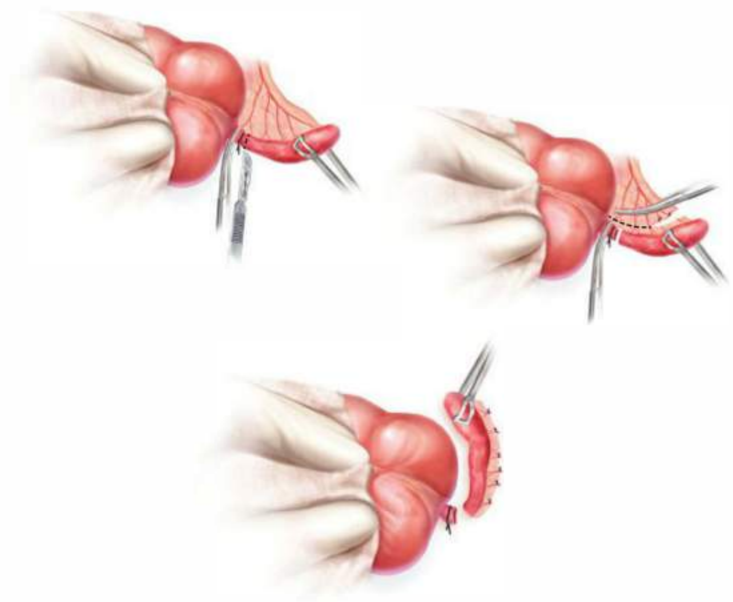

FIG 10 ● "Retrograde dissection" of the appendix. In this technique, the appendiceal base is transected first. The mesoappendix is then sequentially transected from the appendiceal base to its tip. This technique can be useful when the mesoappendix is severely adhered to the cecum.

PEARLS AND PITFALLS

Indications	■ Beware of atypical pathology in the atypical patient clinical presentation.
Placement of incision	■ Midline incision is preferred when converting from laparoscopic to open surgery. ■ For primary open RLQ incision approach, place the incision slightly higher than the maximal point of tenderness.
Exposure	■ Use sponge sticks to sweep the bowel out of the way and to expose the cecum. ■ *Gently* use Babcocks to pull the cecum and appendix into the wound.
Resection	■ Proper identification of the appendiceal base by the convergence of the teniae coli at the base of the cecum is critical to prevent incomplete resection and possible appendiceal stump blowout postoperatively. ■ If the base of the appendix is severely inflamed, use a gastrointestinal anastomosis (GIA) stapler to transect, including a segment of healthy cecal base in the resection (be careful to avoid impingement of the ileocecal valve). ■ Consider performing a retrograde appendectomy in cases where the appendix is densely adhered to the cecum.
Closure	■ For gangrenous or perforated appendicitis, considered delayed primary closure or placement of a negative pressure wound therapy device to minimize superficial surgical site infection.

POSTOPERATIVE CARE

- For cases of simple appendicitis, antibiotics should be stopped within 24 hours of surgery. There is no evidence supporting improved outcomes with additional antibiotics beyond 24 hours of surgery end time.
- In cases of gangrenous or perforated appendicitis, empiric antibiotic therapy should be continued with coverage for facultative, gram-negative, and anaerobic bacteria. Endpoints of duration of IV antibiotic coverage include WBC count less than 12,000/mm^3, less than 10% bands, return of bowel function, and temperature lower than 38°C. If these criteria are not reached by postoperative day 6, then a CT scan of the abdomen and pelvis with contrast is obtained to evaluate for potential intraabdominal and/or pelvic abscess.

COMPLICATIONS

- Appendectomy for simple appendicitis is performed with very low complication rate. Patients may be discharged home within 24 to 48 hours with no additional antibiotics needed.

- Appendectomy for complicated appendicitis carries significantly increased morbidity and mortality rates as compared to simple appendectomy.
  - Postoperative ileus is common, and diet should be initiated when clinical signs of return of bowel function exist.
  - SSI is also a common complication. SSI is lower in children than adults, and as such, primary closure after perforated open appendectomy is indicated in this setting.
  - Primary wound closure in adults should be done with caution as wound infection rates can approach 30%.[6]
- Intraabdominal abscess is treated with image-guided drainage and culture and IV antibiotic therapy tailored toward microbiology of the abscess. If the abscess is not accessible via percutaneous approach, a surgical drainage of significant collections via a laparoscopic or open approach is indicated.
- Append the seal stop blowout: Oftentimes, this is associated with incomplete resection of the appendix and may lead to severe peritonitis, necessitating repeat exploratory laparotomy. In these cases, an ileocecectomy and a possible performance of a temporary ileostomy should be considered. If inflammation is so severe as to preclude mobilization of the cecum and terminal lieum, a cecostomy tube maybe placed through the hole where the base of the appendix connected to the cecum in order to created a controlled fistula that may be treated at a later date.
- Incisional hernia: Incidence is higher with midline incisions.
- Postoperative small bowel obstruction

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Chapter 7

Appendectomy: Laparoscopic Technique

Roosevelt Fajardo

DEFINITION

- Acute appendicitis is the most frequent cause of acute surgical abdominal pain seen in the emergency services around the world. Close to 7% of the total world population will suffer from appendicitis at some point in their lives. Although it may occur at any age, its incidence is higher in childhood, with a peak incidence between 10 and 30 years of age. It is more frequent in men, with a male-to-female ratio of 1.4:1. Advances in laparoscopic surgery around the world have made laparoscopic appendectomy a safe and simple procedure.

DIFFERENTIAL DIAGNOSIS

- Urinary tract infection
- Intestinal obstruction
- Acute cholecystitis
- Mesenteric adenitis
- Meckel's diverticulitis
- Colonic diverticulitis
- Right ureteric colic
- Ectopic pregnancy
- Salpingitis, pelvic inflammatory disease
- Ruptured ovarian follicle
- Gastroenteritis
- Terminal ileitis

PATIENT HISTORY AND PHYSICAL FINDINGS

- Despite advances in diagnostic imaging, diagnosis of acute appendicitis continues to be predominantly clinical. A good clinical history and a thorough physical examination should provide the surgeon with a high degree of suspicion. The characteristic clinical picture is one of abdominal pain that exacerbates with movement, starting in the periumbilical region and then migrating to the right lower quadrant. Fever, anorexia, nausea, and vomiting are frequent.
- The Alvarado score, a clinical scoring system used in the diagnosis of appendicitis, assigns points to six clinical items and two laboratory measurements with a maximum possible total of 10 points. With scores greater than 5, the probability of acute appendicitis increases.
- A popular mnemonic used to remember the Alvarado score factors is **MANTRELS**: **M**igration to the right iliac fossa, **A**norexia, **N**ausea/Vomiting, **T**enderness in the right iliac fossa, **R**ebound pain, **E**levated temperature (fever), **L**eukocytosis, and **S**hift of leukocytes to the left. Due to the popularity of this mnemonic, the Alvarado score is sometimes referred to as the MANTRELS score.
- The location of the appendix may change the clinical presentation. With the appendix in a retrocecal location, patients may present with right flank pain. With an appendix in a pelvic location, patients typically present with urinary symptoms and diarrhea.

IMAGING AND OTHER DIAGNOSTIC STUDIES

- The hemogram typically shows a leukocytosis, with a left-sided shift. Female patients in fertile age should have a pregnancy test prior to surgery.
- Ultrasound (**FIG 1**) has shown to have 86% sensitivity and 81% specificity for the diagnosis of acute appendicitis and has the benefit of not being invasive, but it is operator dependent.
- Computerized axial tomography (CAT; **FIG 2**) scan, with a 94% sensitivity and a 95% specificity, has been shown to be the most accurate imaging study for the diagnosis of acute appendicitis but is expensive and may delay surgical intervention.
- Magnetic resonance imaging (MRI) is reserved for patients who cannot be exposed to radiation, such as pregnant women suspected of having appendicitis.

SURGICAL MANAGEMENT

Indications

- Same indications than for open appendectomy
- Any patient with diagnosis of appendicitis who can tolerate pneumoperitoneum and general anesthesia, provided that trained staff and the necessary equipment for a safe procedure are available

Preoperative Planning

- Appropriate prophylactic antibiotic should be administered 30 minutes before surgery.
- Decompression of the bladder by voiding before surgery or by using a Foley catheter may avoid injury of the bladder during trocar placement.

Patient and Team Positioning

- The patient is secured to the table with the arms padded and tucked to the side.
- The surgeon and the camera operator stand on the patient's left side (**FIG 3**).
- The monitor is placed in front of the surgeon (at eye level) on the patient's right side.

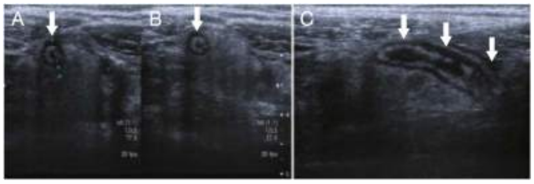

FIG 1 ● Ultrasound imaging in appendicitis. *Arrows* show a distended appendix with a thickened wall. **A** and **B** show transverse views of the appendix. **C** shows a longitudinal view of the appendix.

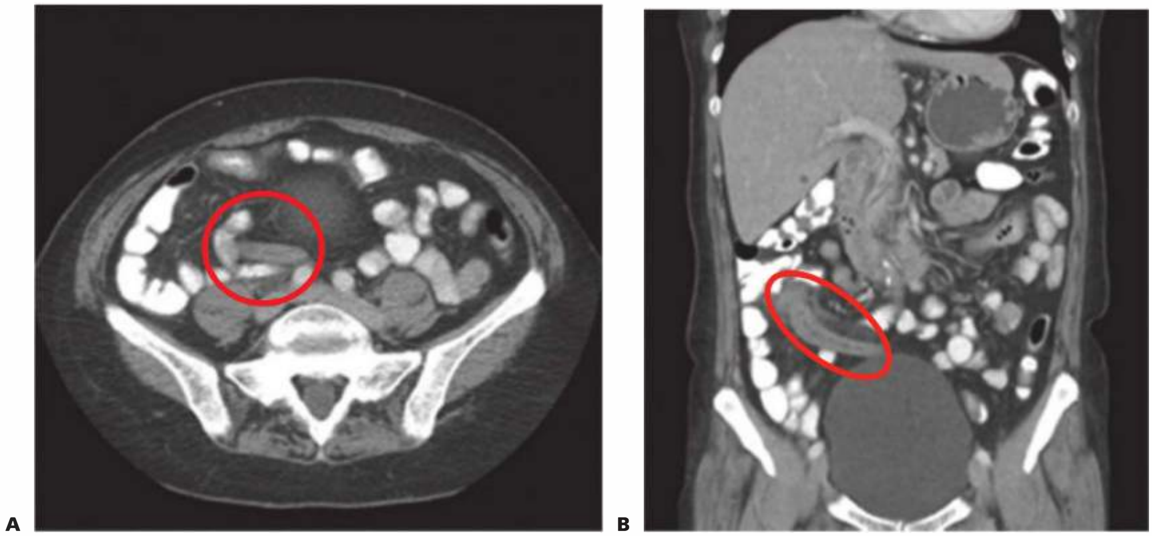

FIG 2 ● CAT scan imaging in appendicitis. **A:** Axial view. **B:** Coronal view. Red circles show acute appendicitis with periappendiceal inflammation.

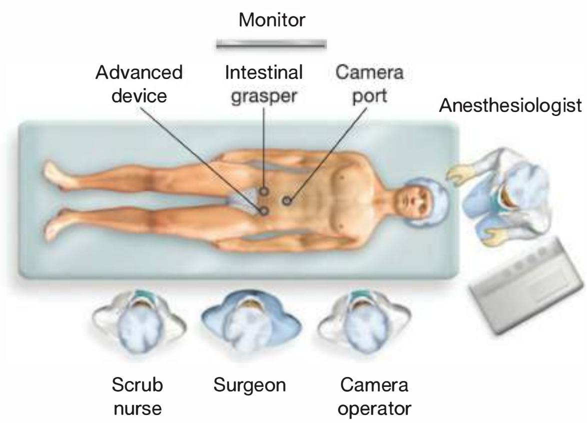

FIG 3 ● Patient, port, team, and operating room setup.

Port Placement

- A traditional laparoscopic appendectomy is performed using a three-port system (**FIGS 3** and **4**). The surgeon should be able to work two-handed.
- The ports are triangulated to enhance maneuverability and exposure.
- A 10-mm Hasson trocar is inserted in the umbilicus. This trocar will be used for CO_2 insufflation and also as a camera port.
- A 12-mm trocar is inserted in the left lower quadrant. In addition to being the main dissection port, this port will be used for the stapler and also as an extraction site. If a good quality 5-mm camera is available, then a 5-mm port can be inserted in this location; in this alternative setup, the specimen would be retrieved through the umbilical port site.
- A 5-mm trocar is inserted in the right lower quadrant. This trocar will be used to help retract and expose. Placement of a urinary catheter may be required before introducing the lower abdominal trocars in order to reduce the risk of bladder perforation during this step of the procedure.

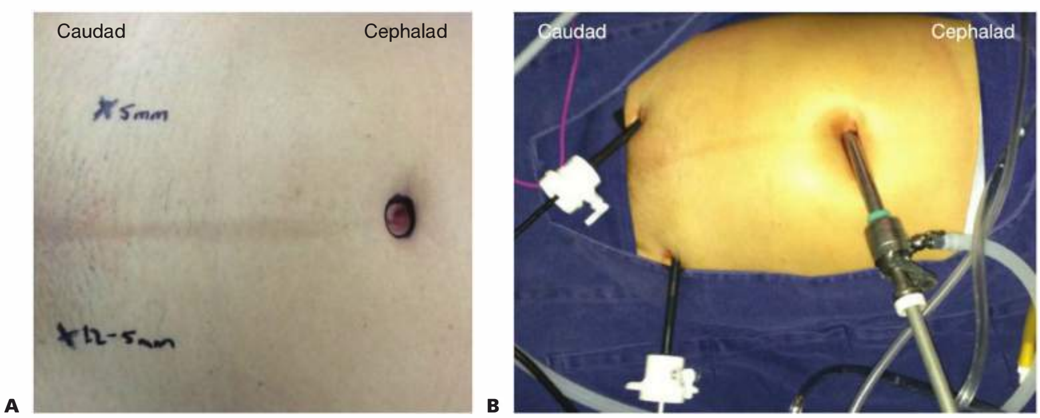

FIG 4 ● **A,B.** Port placement. The three ports are triangulated to enhance maneuverability and visualization.

STEP 1. EXPOSURE OF THE APPENDIX AND IDENTIFICATION OF THE APPENDICEAL BASE

- The patient is placed in a Trendelenburg position and rotated with the right side up to help mobilize the small bowel out of the field of view and to enhance operative exposure.
- The fold of Treves (an antimesenteric fat fold also known as the sail sign) allows for identification of the terminal ileum (**FIG 5**). Following the terminal ileum distally to the ileocecal junction facilitates identification of the cecum. The appendix can usually be seen at the base of the cecum.
- In retrocecal appendicitis cases, the cecum may have to be mobilized medially by transecting its lateral peritoneal attachments in order to expose the appendix.
- The base of the inflamed appendix is localized by identifying the convergence of the three teniae coli at the base of the cecum (**FIG 5**).

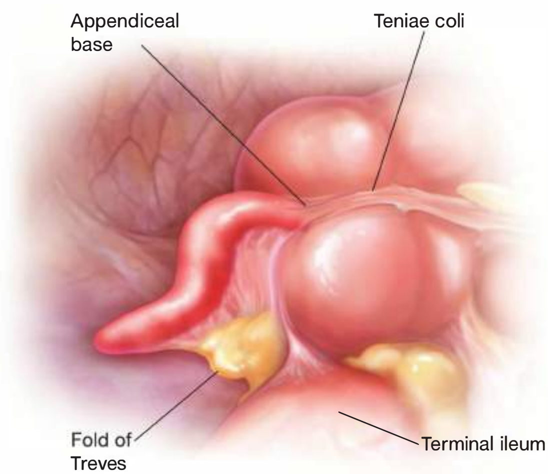

FIG 5 ● The appendiceal base can be identified by the convergence of the teniae coli at the base of the cecum. Identifying the ileocecal junction, with the fold of Treves in the antimesenteric aspect of the terminal ileum, facilitates identification of the cecum and the appendix in patients with severe inflammation.

STEP 2. DIVISION OF THE MESOAPPENDIX

- Once identified, the tip of the appendix is pulled up with a grasper introduced through the right lower quadrant port site. This allows for the exposure of the triangular-shaped space between the appendix, the cecum, and terminal ileum, where the mesoappendix can be readily identified (**FIG 6**).
- The mesoappendix can then be sequentially transected with an advance energy device (LigaSure or a Harmonic) (**FIG 7**) very close to the appendix. Transection of the mesoappendix is carried down to the base of the appendix (**FIG 8**). Alternatively, the mesoappendix may be transected with a linear vascular load stapler.

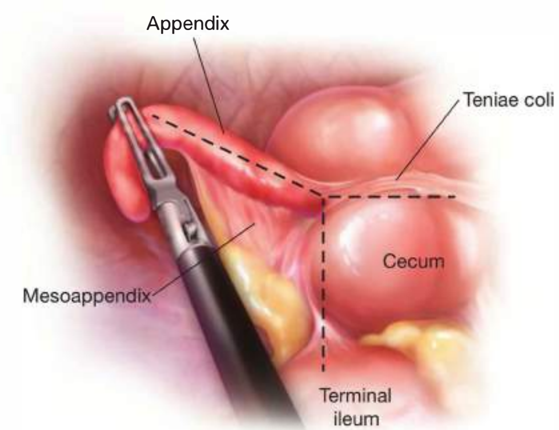

FIG 6 ● Exposure of the mesoappendix. Pulling up on the tip of the appendix exposes the triangular space between the appendix, the cecum, and terminal ileum, where the mesoappendix can be readily identified.

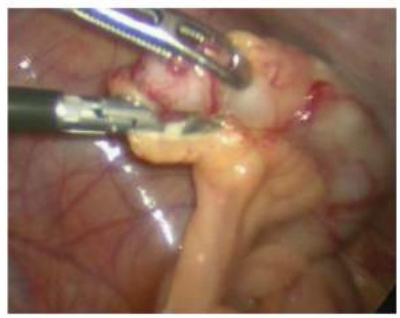

FIG 7 ● Transection of the mesoappendix with an energy device.

FIG 8 ● The appendix has been completely skeletonized by transecting the mesoappendix down to the level of the appendiceal base. The appendix is now ready for transection.

STEP 3. TRANSECTION OF THE APPENDIX

- The appendix is transected at its base, flush to the cecal wall.
- This is critical to avoid, potentially leaving a fecalith impacted in a retained, long appendiceal stump. In this situation, a dead space will be left between the stapled transected end of the appendix and the persistent luminal obstruction produced by the fecalith at the base of the appendix. Progressive fluid and gas accumulation in this dead space could lead to a "blown" appendiceal stump and the development of severe peritonitis postoperatively.
- If the base of the appendix is sufficiently narrow, it may be ligated with 8- to 10-mm Hem-o-Lok clips (**FIG 9**) or with a pretied Roeder's endoloop. In cases where the appendix is thicker and inflamed, a linear 30- or 45-mm stapling device (introduced through the right lower quadrant port site) may be used to transect the appendix at its base (**FIG 10**).

A

B

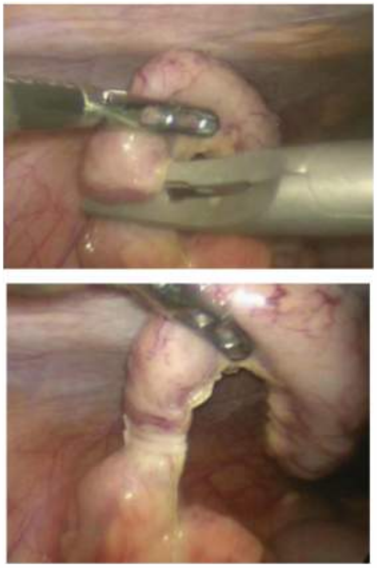

FIG 9 ● **A,B.** Ligation of the appendiceal base with Hem-O-Lock clips. This is only possible when the appendiceal base is sufficiently narrow.

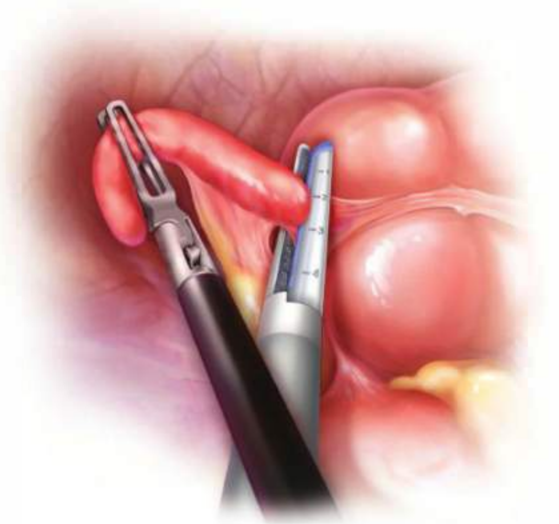

FIG 10 ● In cases with a thick appendix with severe inflammation, the appendix is transected at its base with a linear stapler device.

STEP 4. RETRIEVAL OF THE SPECIMEN

- With the appendix transected, the appendiceal stump staple line is checked for integrity and hemostasis (**FIG 11**).
- The appendix may be then retrieved through the 12-mm trocar site using an endoretrieval bag (**FIG 12**).

FIG 11 ● With the appendix transected, the appendiceal stump staple line is checked for integrity and hemostasis.

FIG 12 ● The appendix may be then retrieved through the 12-mm trocar site using an endoretrieval bag.

STEP 5. CLOSURE

- The operative site is irrigated with sterile normal saline solution.
- A drain is placed by the appendiceal stump only in cases of perforated appendicitis.
- The pneumoperitoneum is evacuated.
- All ports are removed.
- The skin incisions are closed with reabsorbable subcuticular sutures.

PEARLS AND PITFALLS

Localization on the appendix	■ By identifying the cecum and following the teniae coli distally or using the terminal ileum as a guide to reach the ileocecal valve
Transection of the mesoappendix	■ Stay close to the appendix; this will minimize cumbersome bleeding and will facilitate the extraction of the specimen from the abdominal cavity.
Transection of the base of the appendix	■ It is imperative to transect the base of the appendix to prevent a potential blown appendiceal stump syndrome. ■ If the base of the appendix is too thick, use a linear stapling device.
Extraction from the abdominal cavity	■ Use an endoretrieval bag to protect the wound. You may need to expand the 12-mm trocar site if the appendix is bulky.
Use of drainage	■ Only leave a closed drainage in cases of perforation of the appendix.

POSTOPERATIVE CARE

- This procedure, done through laparoscopy, is less painful, and it may be done as an outpatient procedure in most cases of uncomplicated appendicitis. The patient can resume oral feeding within a few hours of the surgery and go back to routine activities sooner than with traditional open surgery.
  - Patients with perforated or complicated appendicitis are generally admitted for intravenous (IV) antibiotics until they are afebrile with a normal white blood cell count. Antibiotics are usually targeted toward gram-negative and anaerobic organisms. As with patients with simple appendicitis, discharge criteria include ability to tolerate oral intake and appropriate pain control. If patients continue to have abdominal pain, develop leukocytosis, or become febrile after undergoing appendectomy for perforated or complicated appendicitis, their symptoms may be signs of an intraabdominal abscess. Image-guided percutaneous drainage may be needed for resolution.

OUTCOMES

- Laparoscopic appendectomy has been shown to have multiple advantages over the open procedure, including a lower rate of wound site infection, although there are reports in the literature of an increased rate of residual abscesses when compared with open appendectomy.

COMPLICATIONS

- Complications of acute appendectomy are relatively rare, and they are more frequently associated with the disease status or the presence of perforation.
- In nonperforated appendicitis, reported mortality is 0.8 per 1,000, and it increases to 5.1 per 1,000 in cases of perforation.
- Wound infection may vary from 5% to 50% in cases of perforated appendicitis.

- Surgical site infection is directly related to the status of the disease, and it increases by up to 20% in cases of perforated appendicitis. With the advent of laparoscopic appendectomy, this rate of infection has dropped dramatically.
- Hematoma
- Appendiceal stump leak/blowout
- Port site hernia

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Chapter 8

Appendectomy: Single-Incision Laparoscopic Surgery Technique

Reshma Brahmbhatt   Mike K. Liang

DEFINITION

- Single-incision laparoscopic surgery (SILS) appendectomy is defined as laparoscopic removal of the appendix using a single skin incision. The entire procedure, including an intracorporeal appendectomy, is performed laparoscopically. This is in contrast to other methods of single-incision appendectomy, which use a single port/incision for dissection but then proceed to pull the appendix out of the incision and essentially perform an open appendectomy. The addition of an additional port distant from the single incision (usually the suprapubic region) is called a SILS plus one (SILS +1) appendectomy.

DIFFERENTIAL DIAGNOSIS

- The differential diagnosis for acute appendicitis in the healthy adult patient includes gastroenteritis, colitis, cystitis/pyelonephritis, inflammatory bowel disease, and diverticulitis.
- Female patients have an expanded differential diagnosis, which can include pelvic inflammatory disease, ovarian pathology, ectopic pregnancy, endometriosis, and mittelschmerz.
- Pediatric patients can have acute mesenteric adenitis, especially following an upper respiratory tract illness, that can mimic acute appendicitis.
- Immunosuppressed patients may have opportunistic infections that present in a similar fashion to acute appendicitis, and consideration should be given to a full infectious workup.

PATIENT HISTORY AND PHYSICAL FINDINGS

- For patients to undergo SILS appendectomy, they must be candidates for traditional laparoscopic appendectomy. Patients with previous midline abdominal surgery or large ventral hernias may present a relative contraindication to SILS appendectomy due to adhesions and potential difficulty with abdominal entry.
- A thorough history and physical examination is necessary to carefully select patients for SILS appendectomy. Pediatric, elderly, and pregnant patients are appropriate for SILS appendectomy.[1] Absolute and relative contraindications to SILS appendectomy are listed in Table 1.

Table 1: Absolute and Relative Contraindications to Single-Incision Laparoscopic Surgery Appendectomy

Absolute contraindications	• Hemodynamic instability • Inability to undergo general anesthesia • Inability to tolerate abdominal insufflation
Relative contraindications	• Generalized peritonitis • History of midline laparotomy or umbilical hernia repair with prosthetic material • Large midline ventral hernia • Surgeon inexperienced with single-incision laparoscopic procedures

- A thorough history should be performed, including location and duration of symptoms, previous history of similar episodes, and detailed past medical and surgical history. A short (1 to 2 days) history of nausea/vomiting, anorexia, fevers, and periumbilical or right lower quadrant pain in a previously healthy patient is suspicious for acute appendicitis. A longer (5 to 7 days) history of nausea/vomiting, malaise, fevers, and right lower quadrant pain may be consistent with perforated appendicitis and abscess formation.
- A complete physical examination should be performed. Particular attention should be paid to the patient's vital signs and abdominal examination. The patient will often be ill appearing and prefer to lie still.
- Classic abdominal findings of appendicitis include tenderness in the right lower quadrant with localized guarding and rebound. The abdomen is often soft with minimal to no distention.
- Female patients of childbearing age should undergo a bimanual vaginal examination to evaluate for gynecologic conditions, such as pelvic inflammatory disease or adnexal abnormalities, which may mimic appendicitis.
- Atypical presentations of acute appendicitis can include suprapubic pain, right flank pain, and right upper quadrant pain, depending on where the appendix may be located.
- Anatomic variations may cause pain in the right flank (retrocecal appendix) or even the absence of abdominal pain (pelvic-lying appendix). Right-sided pain on rectal examination may point toward an appendix hanging in the pelvis.
- It is also important to note that with very early appendicitis, the patient will often have mild (or even absent) signs and symptoms. These clinical variations should be kept in mind while evaluating the patient for acute appendicitis.

IMAGING AND OTHER DIAGNOSTIC STUDIES

- Standard laboratory studies ordered in the evaluation of acute appendicitis include a complete blood count, basic metabolic panel or electrolytes, and urinalysis and urine pregnancy test.
- An elevated white blood cell count suggests an inflammatory response such as appendicitis.
- Electrolyte derangements due to dehydration or vomiting should be corrected prior to surgical management.
- A urinalysis may show a urinary tract infection or cystitis to be the source of the patient's symptoms rather than appendicitis; however, identifying leukocytes in the urine is not uncommon with acute appendicitis.
- A positive urine pregnancy test should prompt further evaluation of another diagnosis (such as ruptured ectopic pregnancy) and will affect the medications and anesthesia used during the procedure.
- Clinical scoring systems, such as the Alvarado score or the appendicitis inflammatory response score use various laboratory and clinical findings to assess a patient's likelihood of having acute appendicitis.[2–3]

- Computed tomography (CT) is the most ordered radiologic study in the evaluation of acute appendicitis. The scan should be ordered as a CT abdomen/pelvis with intravenous (IV) and oral or rectal contrast.
- CT findings consistent with appendicitis include appendiceal dilation, failure of appendiceal opacification with oral or rectal contrast, presence of a fecalith, periappendiceal fat stranding and enhancement, and pelvic free fluid. CT is excellent in visualizing perforated appendicitis with an abscess and should be considered in any patient where the diagnosis of complicated appendicitis is entertained. Additionally, CT can provide information on other intraabdominal and pelvic structures/pathology (**FIG 1**).
- Transabdominal ultrasonography can be used to evaluate for appendicitis as a nonradiating alternative to CT scans. Findings consistent with appendicitis include a thickened appendiceal wall, appendiceal dilation, identification of a fecalith, periappendiceal fluid, and a "target sign." Limitations to ultrasonography include operator dependence and difficulty in appendiceal visualization in patients with higher body mass index (BMI) (**FIG 2**). Ultrasonography is most often used in children and pregnant patients.
- Focused magnetic resonance imaging (MRI) has been used in specific cases as an alternative to CT scan and ultrasound. Pregnant women and children may benefit from this nonradiating imaging modality, but MRI may not be as readily available as ultrasound and CT scan in all centers. The need for MRI should be evaluated on a case-by-case basis.
- Women of childbearing age may require evaluation of their adnexal structures via CT scan or transvaginal/transabdominal ultrasonography to rule out differential diagnoses.
- In adult male patients with a classic presentation of appendicitis, radiologic studies are not necessarily indicated and are used only at the discretion of the surgeon.

FIG 1 ● CT scan demonstrating acute appendicitis. The appendix is dilated, thick-walled, and enhances with IV contrast *(arrow)*, suggesting inflammation. There is also stranding/thickening around the adjacent cecal wall.

FIG 2 ● Ultrasound examination demonstrating acute appendicitis. The appendix is noncompressible and contains a visible fecalith *(arrow)*.

SURGICAL MANAGEMENT

Preoperative Planning

- Preoperative antibiotics, with gram-negative and anaerobic coverage, should be administered before the incision is made.
- A Foley catheter should be placed to ensure bladder decompression.
- Patients with large midline laparotomy scars or periumbilical hernia repairs may have significant adhesions or prosthetic material at the level of the umbilicus, making safe abdominal entry potentially difficult. The surgeon should use his or her discretion at proceeding with a SILS appendectomy in these particular patients and should have a low threshold for adding additional ports (SILS +1 appendectomy) for improved exposure and visualization.

Positioning

- SILS appendectomy is performed from the left side of the patient, similar to traditional laparoscopic appendectomy. The patient should be positioned in a supine position, with the left arm tucked to provide adequate space for the surgeon and the assistant (**FIG 3**).

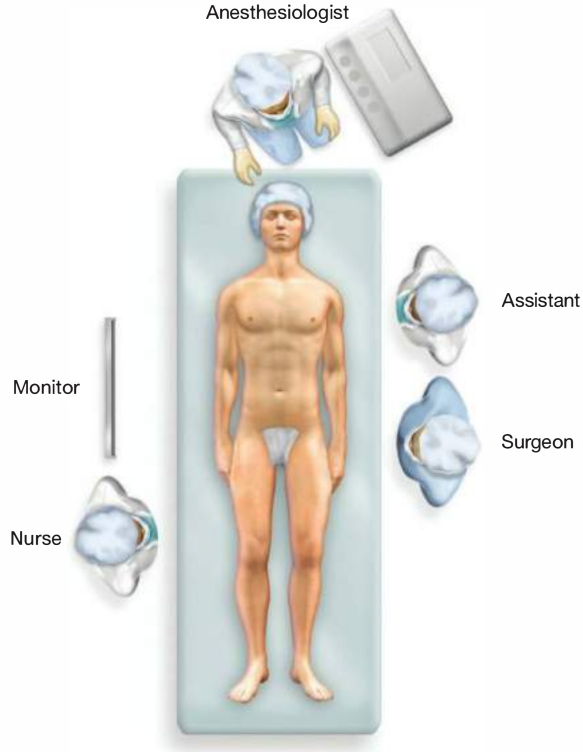


FIG 3 ● Patient, team, and operating room setup. The surgical team stands at the patient's left side. The patient is positioned in a supine position, with the left arm tucked to provide adequate space for the surgeon and assistant. The laparoscopic monitor should be positioned at the right side of the patient.

- The patient's abdomen should be prepped and draped from the xiphoid to the pubis, allowing for possible conversion to a traditional laparoscopic or open appendectomy if indicated.
- The laparoscopic monitors should be positioned at the right side of the patient or at foot of the operating table (**FIG 3**).

SKIN INCISION AND PORT PLACEMENT

- A 12- to 20-mm incision should be made adjacent to or through the umbilicus, with consideration for the potential need to extend the incision if conversion to an open appendectomy is needed (**FIG 4**). In patients with previous periumbilical or midline laparotomy scars, the surgeon should consider alternative methods of abdominal entry

FIG 4 ● Placement of the incision. A 12- to 20-mm incision should be made adjacent to or through the umbilicus, with consideration for the potential need to extend the incision if conversion to an open appendectomy is needed.

(Veress needle insufflation through the left upper quadrant, trocar insertion in left upper quadrant, etc.) or alternate placement of the SILS port (supraumbilical, left lateral abdomen). Although these methods may result in a SILS +1 appendectomy or in a more challenging closure of the incision, they may allow safer entry into the peritoneal cavity.

- The umbilical skin incision should be taken down through the subcutaneous tissues. The midline fascia close to the umbilicus (umbilical stalk) should be incised in a longitudinal manner.
- Once safe access into the peritoneal cavity is confirmed, the port should be placed through the incision following the port manufacturer's instructions.
- There are many types of SILS ports currently available; the type of SILS port used is left to the discretion of the surgeon (**FIG 5**). An alternative to the placement of a SILS port is to insert multiple standard ports through a single skin incision.
- Prior to port placement, a surgical sponge may be introduced into the abdominal cavity to facilitate retraction later in the procedure.
- Port placement varies depending on the single-port device used. Once the port is placed, pneumoperitoneum is created and the laparoscopic camera and instruments are introduced. It is advisable to triangulate the ports to minimize instrument conflict.

FIG 5 ● SILS port placed via umbilical incision.

- A 30-degree camera and traditional straight laparoscopic instruments are used. Alternatively, articulated instruments may be employed.
- In order to afford maximal operative reach and to avoid internal and external instrument conflict, bariatric and standard length instruments may be used simultaneously. Moreover, a right-angle light cord adaptor may be used to further decrease conflict.
- The patient is placed in a Trendelenburg position with the left side down to help move the small bowel into the left upper quadrant, enhancing exposure of the cecum and the appendix.

APPENDICEAL IDENTIFICATION

- The right lower quadrant should be examined closely (**FIG 6**). Significant fluid or abscess collections should be carefully aspirated to allow for visualization of the right lower quadrant.
- The presence of significant adhesions may require additional port placement or conversion to traditional laparoscopic appendectomy (or open procedure) to allow for appropriate visualization and/or adhesiolysis.
- The appendiceal base should be identified using the convergence of the teniae coli at the base of the cecum as a landmark.
- The surgeon's right-hand instrument should grasp and elevate the appendix. The left-hand instrument should bluntly dissect any adhesions, allowing for full visualization of the appendix, from tip to base.
- If the appendix appears to be completely normal, the right lower quadrant should be closely investigated for other potential sources of the patient's symptoms. Any diagnosis other than appendicitis should prompt appropriate management by the surgeon and may require conversion to a traditional laparoscopic or open procedure. Appendectomy may be performed at the same time, as per the surgeon's discretion.

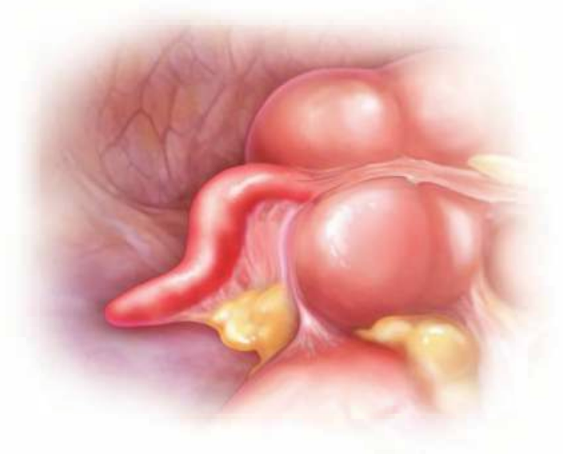
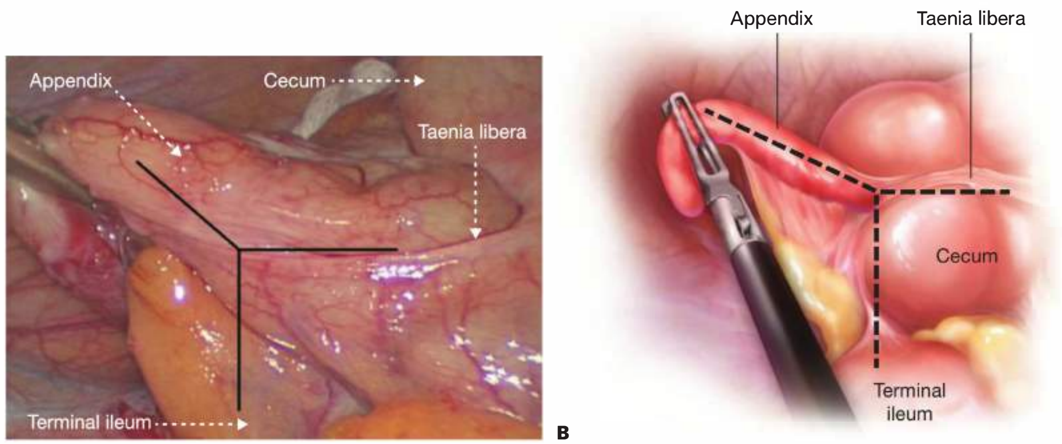


FIG 6 ● Examination of right lower quadrant showing inflamed appendix.

APPENDICEAL CRITICAL VIEW[4]

- The appendix should be retracted to the 10 o'clock position, the terminal ileum should be placed in the 6 o'clock position, and the taenia libera (anterior band of the teniae coli) should be positioned in the 3 o'clock position (**FIG 7**). This allows for clear identification of the appendiceal base and associated anatomy prior to appendiceal transection.
- If the critical view cannot be obtained, or the appendiceal base is not easily identified, a suprapubic port can be placed to allow for further dissection/retraction (SILS +1 appendectomy). If the anatomy still remains unclear, the procedure can be converted to a traditional laparoscopic appendectomy or to an open appendectomy, as per the surgeon's discretion.

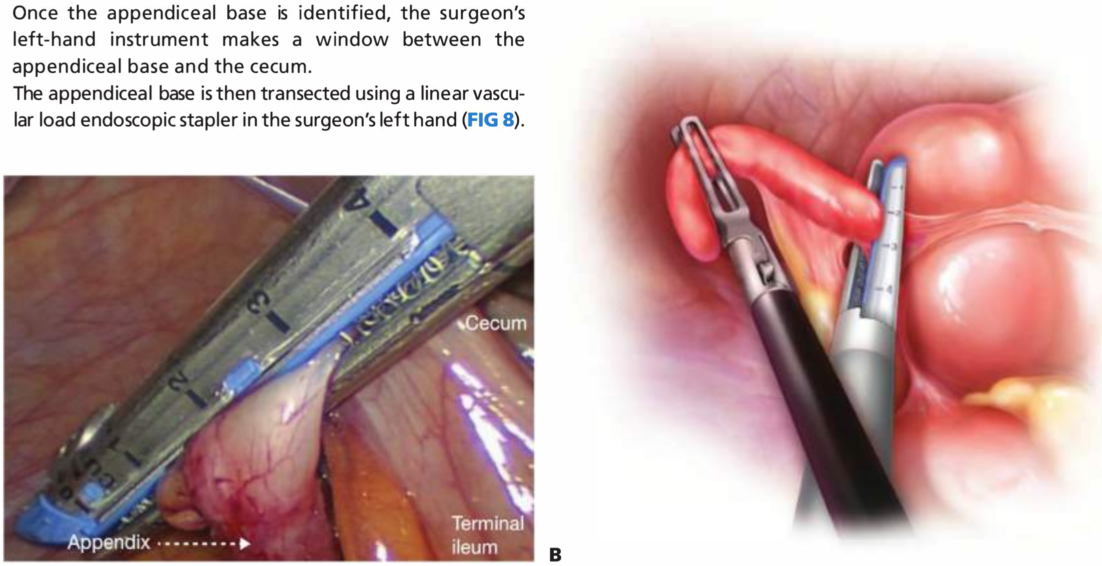


A B

FIG 7 ● **A.** The appendiceal critical view. The appendix is retracted to the 10 o'clock position, the terminal ileum is placed in the 6 o'clock position, and the taenia libera (anterior band of the teniae coli) is positioned in the 3 o'clock position. The terminal ileum can be identified by the fold of Treves (fatty fold in the antimesenteric border of the terminal ileum), also known as the "sail sign." **B.** Illustration of this step.

APPENDICEAL TRANSECTION

- Once the appendiceal base is identified, the surgeon's left-hand instrument makes a window between the appendiceal base and the cecum.
- The appendiceal base is then transected using a linear vascular load endoscopic stapler in the surgeon's left hand (**FIG 8**).



A B

FIG 8 ● **A.** Appendiceal base transection by an endoscopic stapler. **B.** Illustration of this step.

- The appendiceal mesentery is similarly transected using a linear vascular load endoscopic stapler.
- Alternatively, similar to traditional laparoscopic appendectomy, energy devices and endoloops may be used as per the surgeon's discretion.
- The appendix is then placed in a retrieval bag, if desired, and removed via the port site. The specimen should be sent for pathologic evaluation and assessment. A proportion of appendectomies (up to 1%) have associated tumors or malignancies.

PORT SITE CLOSURE

- Once the appendix has been removed from the abdominal cavity, operative field is examined for hemostasis. Minor bleeding from the mesenteric staple line can be controlled with electrocautery. The appendiceal stump should be examined to ensure a complete staple line (**FIG 9**). Any blood or purulent material should be aspirated out of the abdominal cavity. Drains should not be placed under routine circumstances.

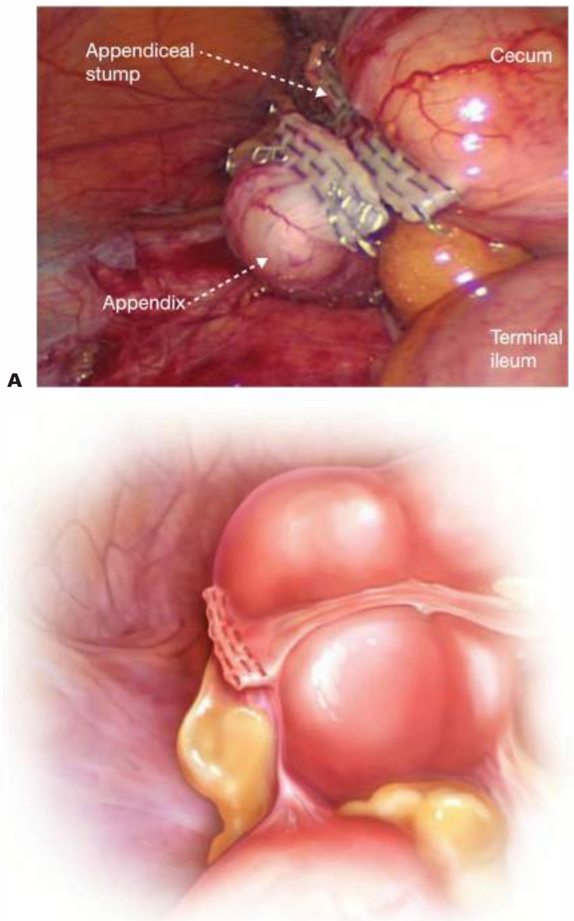


FIG 9 ● **A.** After transection, the operative field is inspected to ensure adequate hemostasis and an intact appendiceal stump staple line. **B.** Illustration of this step.

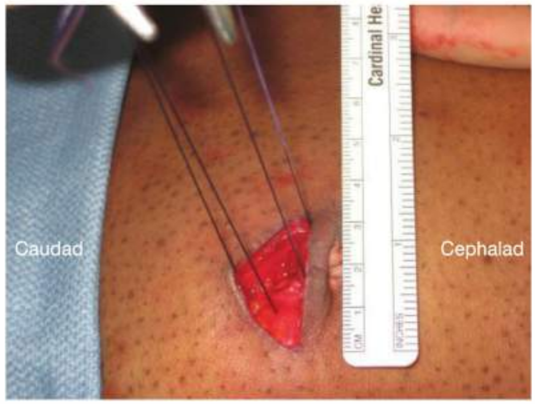


FIG 10 ● The fascial defect is closed with interrupted absorbable figure-of-eight sutures.

- Any additional ports are removed under direct visualization and the abdomen is desufflated. The SILS port is removed according to the port manufacturer's instructions.
- The fascial defect is closed with interrupted absorbable figure-of-eight sutures (**FIG 10**). The subcutaneous tissues are irrigated and the skin is closed with a subcuticular stitch (**FIG 11**).
- If the incision was made through the umbilicus, care should be taken to sew the umbilicus down to the fascia and to reapproximate the umbilical skin well to allow for an aesthetically pleasing closure and to prevent seroma formation.

FIG 11 ● The subcutaneous tissues are irrigated and the skin is closed with a subcuticular stitch.

PEARLS AND PITFALLS

Indications	■ A complete history and physical examination and review of available imaging should take place to confirm the diagnosis of appendicitis and to assure the patient is a suitable candidate for SILS appendectomy.
Abdominal entry	■ If a safe periumbilical entry is questionable, alternate port site placement, or additional ports, may be placed to assist in SILS port placement.
Critical view	■ The appendix should be retracted to the 10 o'clock position, the terminal ileum should be placed in the 6 o'clock position, and the taenia libera (anterior band of the teniae coli) should be positioned in the 3 o'clock position. ■ Complete visualization of the appendiceal base is mandatory prior to transection. If this is not possible, conversion to a SILS +1 or to a traditional laparoscopic appendectomy may be required.
Closure	■ If the incision was transumbilical, the umbilicus should be tacked back down to the fascia.

POSTOPERATIVE CARE

- Patients with simple or uncomplicated appendicitis are usually discharged home after a 23-hour observation period, during which the patient is confirmed to tolerate oral intake and to have appropriate pain control.[5,6]
- Recent studies advocate for same-day discharge for this patient population; discharge timing remains up to the discretion of the surgeon.
- Patients with perforated or complicated appendicitis are generally admitted for IV antibiotics for 3 to 7 days or until they are afebrile and with a normal white blood cell count. Antibiotics are usually targeted toward gram-negative and anaerobic organisms.
- As with patients with simple appendicitis, discharge criteria include ability to tolerate oral intake and appropriate pain control.
- If patients continue to have abdominal pain, develop leukocytosis, or become febrile after undergoing appendectomy for perforated or complicated appendicitis, their symptoms may be signs of an intraabdominal abscess. Image-guided percutaneous drainage is usually needed for resolution.
- Pathology results should be concordant with the diagnosis of acute appendicitis. A negative appendectomy should prompt further workup as required.
- A pathologic diagnosis of appendiceal tumor or malignancy is present in 1% of specimens removed for acute appendicitis.

OUTCOMES

- Although long-term studies evaluating SILS appendectomy are not currently available due to the new nature of the approach, reviews and pooled analyses show no difference in complications and outcomes compared to traditional laparoscopic appendectomy.[7–11]
- A recent prospective randomized controlled trial comparing SILS appendectomy to traditional laparoscopic appendectomy showed no difference in complications, outcomes, or cosmetic and pain results between the two approaches (follow-up of 14 days).[12]
- Further research, ideally as prospective randomized trials, will allow a better comparison of outcomes to traditional laparoscopic appendectomy.
- Although recent studies on SILS procedures show a possible increase in incisional hernias after the SILS procedure, currently available studies show no significant benefit or drawback for the SILS technique for appendectomy.[13,14]

COMPLICATIONS

- Surgical site infection: superficial, deep, organ/space
- Hematoma
- Stump appendicitis/incomplete appendectomy
- Appendiceal stump leak/blowout
- Port site hernia
- Ileus and small bowel obstruction

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Chapter 9

Right Hemicolectomy: Open Technique

Somala Mohammed Kathleen R. Liscum Eric J. Silberfein

DEFINITION

- Right hemicolectomy refers to the removal of the cecum, the ascending colon, the hepatic flexure, the proximal portion of the transverse colon, and part of the terminal ileum (**FIG 1**). It is the standard surgical treatment for malignant neoplasms of the right colon and involves ligation of the ileocolic, right colic, and right branch of the middle colic vessels.

DIFFERENTIAL DIAGNOSIS

- Various benign and malignant conditions require right hemicolectomy. The most common indication is a mass in the right colon. Other indications include neoplasms of the cecum or appendix. Benign conditions for which right hemicolectomy is performed include adenomatous polyps that cannot be removed endoscopically, cecal volvulus, inflammatory bowel disease, and right-sided diverticulitis, among others.

PATIENT HISTORY AND PHYSICAL FINDINGS

- A thorough history and physical examination is mandatory.
- Findings such as ascites or diffuse adenopathy may result in additional diagnostic workup to rule out metastatic disease and this may alter the overall care plan for the patient.
- A baseline nutritional and functional status should also be ascertained in the preoperative setting.
- Previous abdominal surgeries should be noted.
- A thorough family history, including history of colonic polyps and cancers, should be obtained.

IMAGING AND OTHER DIAGNOSTIC STUDIES

- A full colonoscopy should be obtained to examine the remainder of the colon, which has up to a 5% chance of synchronous disease. Colonoscopy can also allow for India ink tattooing of the lesion to facilitate accurate intraoperative localization (**FIG 2**).
- Preoperative imaging also includes high-quality dual phase computed tomography (CT) imaging of the abdomen and pelvis to not only assess for metastatic disease but also to evaluate the primary tumor's relationship to nearby structures such as the kidney, ureter, duodenum, and nearby vessels such as the vena cava, superior mesenteric vessels, and middle colic vessels. Tumors that involve adjacent organs require additional preoperative planning and consultation with ancillary services may be necessary. Attempts at en bloc resection should be made in cases where the tumor involves adjacent organs or structures.
- Additional workup includes a CT of the chest, complete blood cell count, and comprehensive metabolic panel. A baseline carcinoembryonic antigen (CEA) level should be obtained to assist with postoperative surveillance for recurrence. Positron emission tomography (PET)-CT is not routinely indicated.

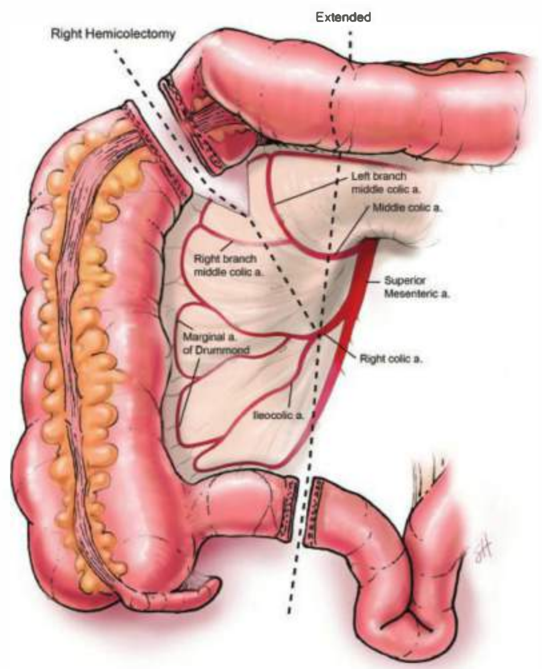


FIG 1 ● Vascular anatomy of a right hemicolectomy. (Printed with permission from Baylor College of Medicine.)

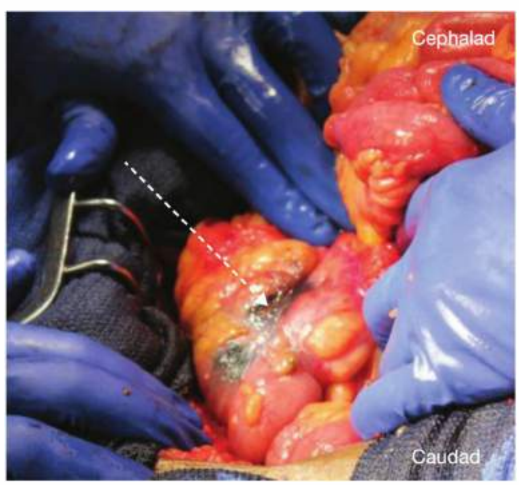


FIG 2 ● Tattooed lesion in the cecum.

SURGICAL MANAGEMENT

Preoperative Planning

- Preoperative bowel preparation is not mandatory but it may make manipulation of the colon more manageable. If intraoperative colonoscopy is required, a prepped colon would also be preferred.
- Preoperative antibiotic prophylaxis for skin and bowel flora is recommended. Intravenous broad-spectrum antibiotics that contain second- or third-generation cephalosporins (such as cefoxitin or ceftriaxone) or fluoroquinolones (such as ciprofloxacin) along with metronidazole will adequately cover gram-negative and anaerobic pathogens. Alternatively, ertapenem, a carbapenem with activity against gram-positive, gram-negative, and anaerobic flora, can be used. Prophylactic antibiotics should be at therapeutic bloodstream levels at the time of incision. Redosing the antibiotic should be considered when taking into account the length of the operation, the estimated blood loss, and the half-life of the antibiotic.
- Venous thromboembolic prophylaxis for patients undergoing right hemicolectomy includes both mechanical interventions, such as pneumatic compression devices, and pharmacologic interventions, such as low-molecular-weight heparin or unfractionated heparin. These agents should be delivered prior to induction of anesthesia as the dramatically decreased level of vascular tone associated with anesthesia results in venous stasis and risks thrombosis. Patients on preoperative warfarin should be transitioned to either low-molecular-weight or unfractionated heparin.
- Preoperative thoracic epidural placement for postoperative pain control should be offered to patients without contraindications to this form of analgesia. Epidural pain control reduces narcotic requirements postoperatively and decreases risk of postoperative ileus and pulmonary complications. Otherwise, patient-controlled analgesia is preferred. Intravenous nonsteroidal antiinflammatory drugs (NSAIDs) should also be considered in the perioperative period to decrease the use and side effects of narcotic analgesia.
- Ancillary surgical services may be required to assist in the patient's care for procedures such as preoperative placement of ureteral stents or assistance in resection or reconstruction of involved adjacent organs, such as the kidneys, ureters, or the duodenum.

ANESTHESIA AND PATIENT POSITIONING

- General endotracheal anesthesia is preferred for right hemicolectomy. However, spinal anesthesia alone is feasible if necessary.
- The patient is placed supine with or without the arms tucked.
- After induction of anesthesia, the bladder is catheterized and an orogastric tube is placed.
- The entire abdomen is prepped and draped.
- The surgeon stands on the patient's right and the first assistant on the left.

INCISION

- A midline laparotomy is made.
- Upon entering the abdominal cavity, inspect for evidence of metastatic disease. The liver should be palpated for masses and biopsied as needed, and the small bowel eviscerated and inspected from the ligament of Treitz to the ileocecal valve. The colon and rectum should be inspected and palpated. The omentum and peritoneum should be evaluated for tumor implants or carcinomatosis. In women, the ovaries should also be inspected for abnormalities.

RIGHT COLON MOBILIZATION

- Placement of self-retaining retractors, such as a Balfour, may be used to improve exposure. Otherwise, the abdominal wall is retracted with handheld instruments.
- The cecum and ascending colon are freed from the peritoneal reflection by incising along the white line of Toldt (**FIG 3**). The terminal ileum is also freed from the retroperitoneum and mobilized by incising the peritoneum along the root of the mesentery.
- As the colon and terminal ileum are reflected anteriorly and medially, the right gonadal vessels and right ureter should be identified in the retroperitoneum and not mobilized anteriorly so as to avoid injury.
- The lateral dissection is carried sharply up and around the hepatic flexure in the avascular, embryologic plane between the mesocolon and the duodenum. The second and third portions of the duodenum are identified near the hepatic flexure and injury to this structure must be avoided.
- The hepatocolic ligament is transected (**FIG 4**).
- The gastrocolic ligament, extending from the greater curvature of the stomach to the transverse colon, is divided from left to right to complete the mobilization of the hepatic flexure (**FIG 5**).

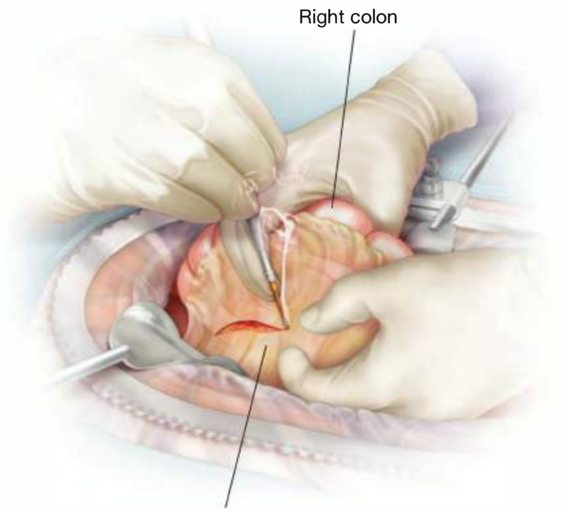


FIG 3 ● Ascending colon mobilization. The surgeon retracts the ascending colon medially. Dissection proceeds along the right paracolic gutter by transecting the white line of Toldt.

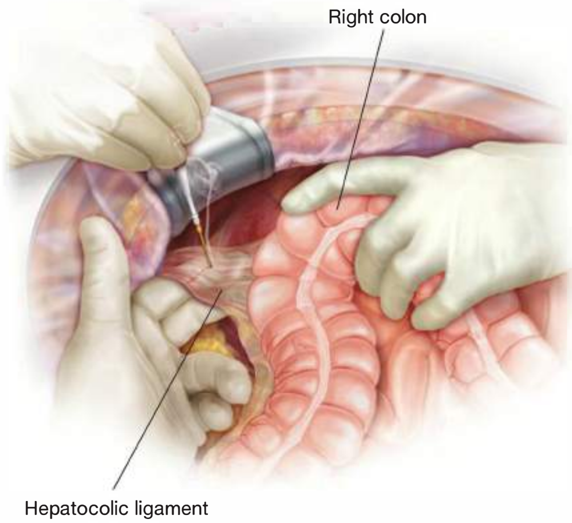


FIG 4 ● Hepatic flexure mobilization. Gentle traction on the hepatic flexure of the colon exposes the hepatocolic ligament, which is then transected with electrocautery.

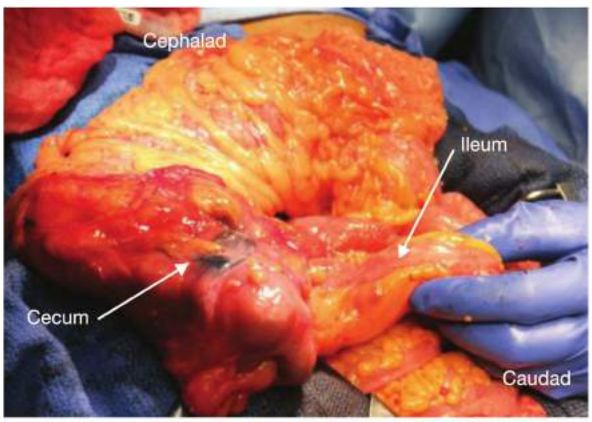


FIG 5 ● Fully mobilized terminal ileum and right colon. The tattooed area can be seen on the surface of the cecum.

VASCULAR PEDICLE TRANSECTION

- For a right hemicolectomy, the vascular arcades of interest include the ileocolic, the right colic, and the right branch of the middle colic vessels.
- An avascular window between the right branch of the middle colic and the right or ileocolic vessel arcade is made (**FIG 6**).
- The right branch of the middle colic is doubly clamped, divided, and tied while the left branch is spared.
- The right colic arcade, if present, is also taken at its origin to ensure adequate resection of lymphatics. This arcade, however, rarely branches directly off the superior mesenteric vessels. It is most often a branch of the ileocolic arcade.
- The ileocolic arcade is therefore ligated at its origin in the majority of circumstances (**FIG 7**).
- The lymphatic drainage pattern mirrors that of the vascular system. There are two possible paths of lymphatic spread: paraintestinal (along the intestine) and central (along the vessels). To reduce the risk of recurrence, an adequate lymph node harvest should be attempted by ligating the required mesenteric vessels at their origin. A minimum of 12 resected nodes is required for American Joint Committee on Cancer for adequate staging of colorectal cancer. Intramural spreading of cancer beyond 2 cm is rare, but an oncologic resection should aim for proximal and distal mucosal margins of at least 5 to 7 cm to ensure adequate harvest of paraintestinal and mesenteric nodes.

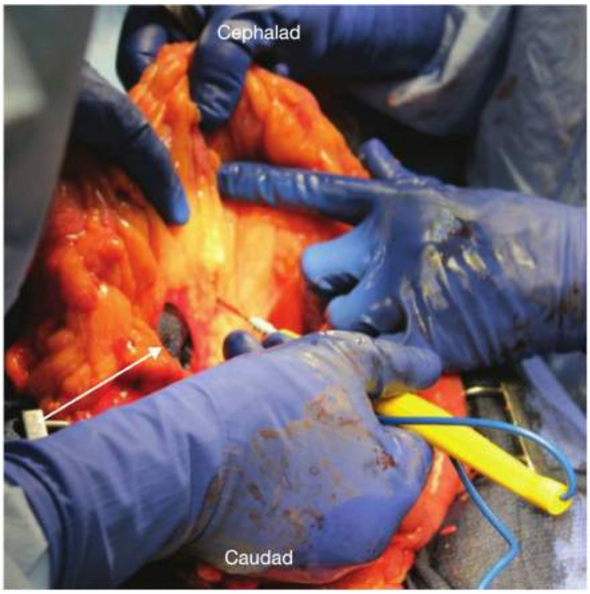
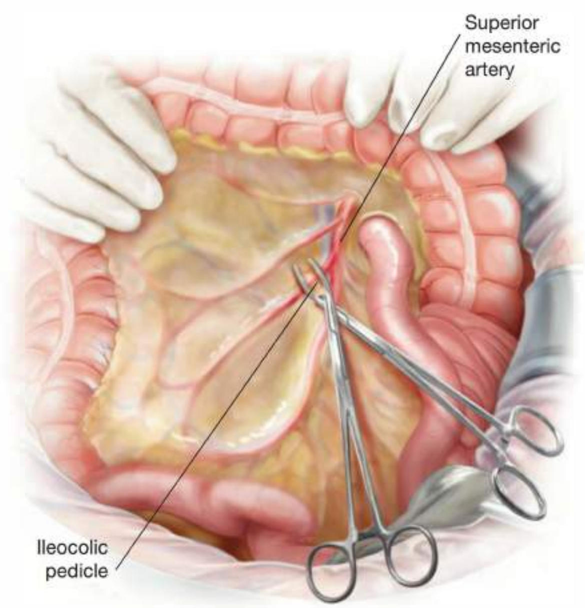


FIG 6 ● Avascular window adjacent to right branch of the middle colic vessels *(arrow)*.

- An extended right hemicolectomy may be performed for lesions located at the hepatic flexure or transverse colon. This procedure involves transection of the middle colic vessels at their origin and an anastomosis of the distal ileum with the distal transverse colon, relying on the margin artery of Drummond for blood supply. If the integrity of this blood vessel is questionable, the resection must be extended to include the splenic flexure and the distal ileum is anastomosed to the descending colon.
- For an extended right hemicolectomy, mobilization of the splenic flexure is required. In order to mobilize the splenic flexure, the splenocolic, phrenocolic, and gastrocolic ligaments must be divided (**FIG 8**). The splenic flexure is then carefully dissected of the tail of the pancreas. Care must be taken to avoid injury to the spleen and the ascending branch of the left colic artery.



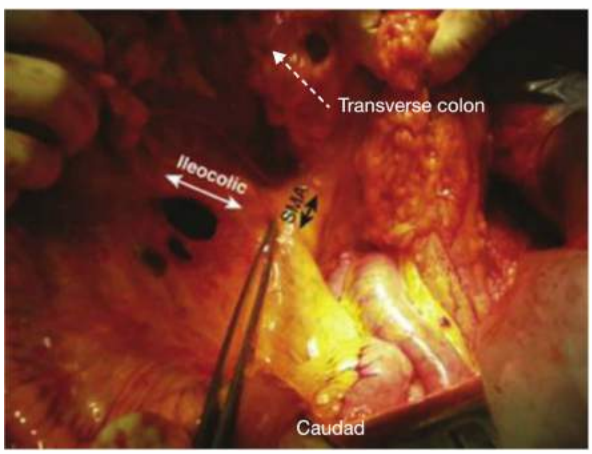


FIG 7 ● Transection of the ileocolic pedicle. The ileocolic vessels are transected at their origin of the superior mesenteric vessels. *SMA*, superior mesenteric artery.

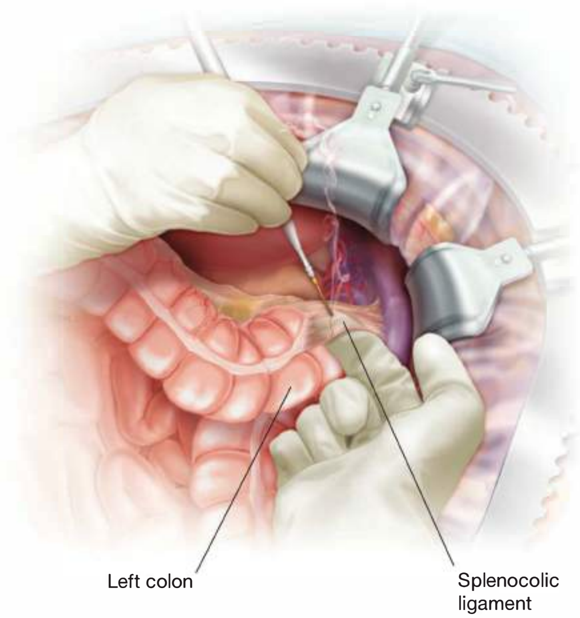


FIG 8 ● Splenic flexure mobilization (for extended right hemicolectomies). After medial and lateral mobilization of the splenic flexure attachments, the surgeon hooks his or her right index finger under the splenocolic ligament, providing good exposure and allowing for a safe transection of this ligament.

BOWEL TRANSECTION

- The colon is cleared of epiploic fat at the proposed site of anastomosis to allow the bowel wall to be visualized, thereby facilitating precise placement of sutures or staplers. The transverse colon is then transected to the right of the middle colic vessels with a linear 75-mm blue load stapler (**FIG 9**).
- The distal ileum is divided approximately 10 cm proximal to the ileocecal valve with a linear 75-mm blue load stapler (**FIG 10**).
- If adjacent organs are involved, every attempt at a complete en bloc resection must be made. The specimen should be assessed with the pathologist to ensure that the diseased segment is acquired and that adequate margins have been obtained. If there is any doubt about margin status, an intraoperative frozen section evaluation should be conducted.

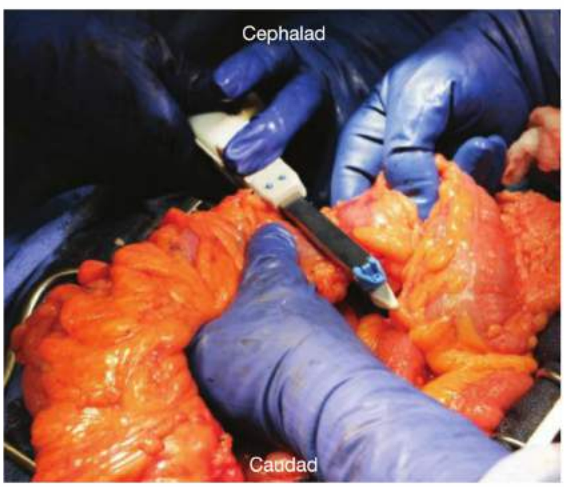


FIG 9 ● Colon transection. The colon is divided to the right side of the middle colic vessels with a linear stapler.

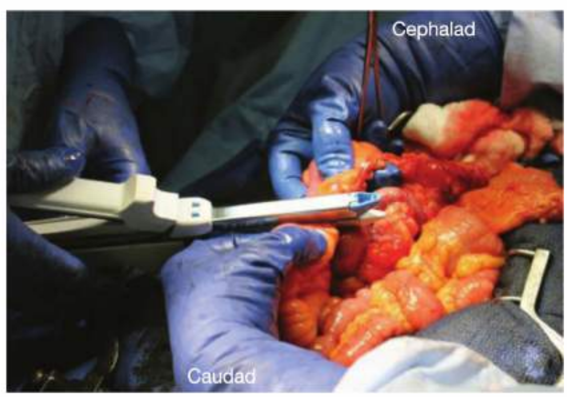


FIG 10 ● Ileal transection. The terminal ileum is divided with a linear stapler.

ILEOCOLONIC ANASTOMOSIS

- After resection, reconstruction proceeds with an anastomosis between the ileum and the transverse colon.
- A primary ileocolic anastomosis is almost always possible. Either a hand-sewn or a stapled anastomosis can be performed in an end-to-end, end-to-side, side-to-side, or side-to-end fashion. The viability of the proximal and distal segments of bowel should be assessed and further resection to well-perfused bowel should be performed if there is any question regarding the viability of the bowel.
- Atraumatic bowel clamps should be placed proximal and distal to the anastomotic site to prevent spillage of bowel contents. Gauze pads should also be placed in the abdomen to protect surrounding structures and the skin from contamination during the process of transecting the colon and creating the anastomosis.
- The ileal and transverse colon segments should be brought into apposition to allow a tension-free anastomosis.
- For the stapled technique, the antimesenteric borders of the bowel segments are approximated with interrupted 3-0 silk sutures. A small enterotomy is made on the antimesenteric border of both the ileum and the transverse colon (**FIG 11**) to allow insertion of a stapling device (**FIG 12**). The stapler is allowed to gently close, bringing together the ileum and transverse colon (**FIG 13**). Once it is assured that the mesentery is clear and the stapler is in good position, the stapling device is fired and then slowly removed.
- This fuses the two previous enterotomies into a single enterotomy. This new enterotomy can be closed either with a stapler, placed at a right angle to the previous staple line (**FIG 14**), or with sutures, in one or two layers (**FIGS 15** and **16**).

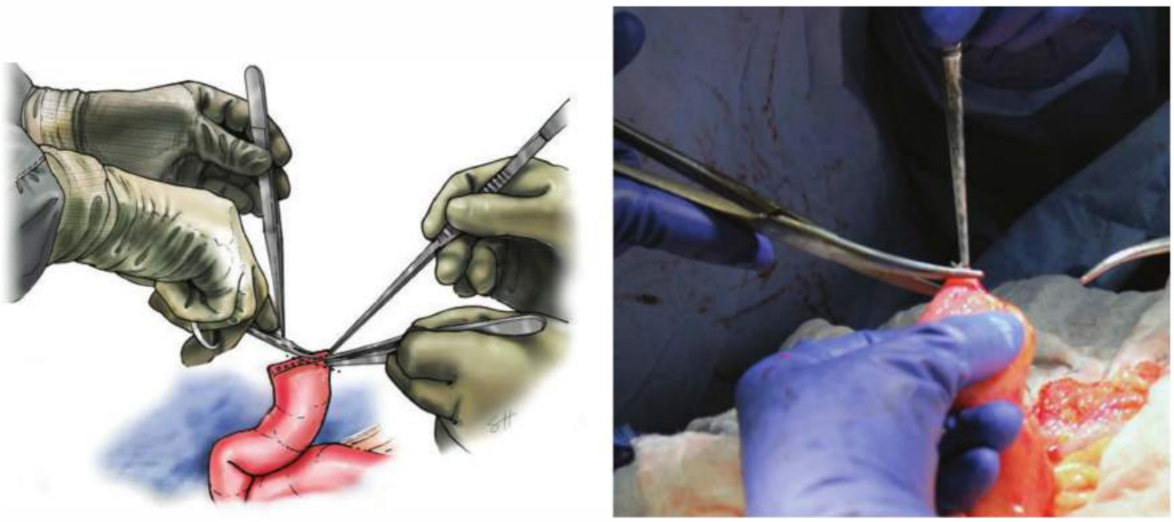


FIG 11 ● Stapled ileocolonic anastomosis. Scissors are used to make a small enterotomy on the antimesenteric border of the bowel. (Printed with permission from Baylor College of Medicine.)

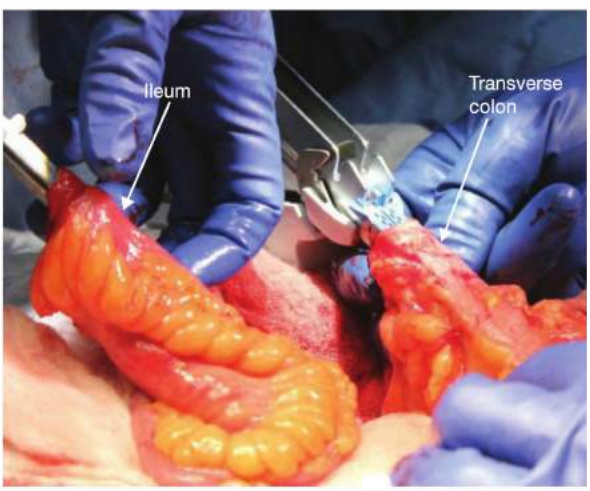


FIG 12 ● Stapled ileocolonic anastomosis: inserting the stapling device into the enterotomy.

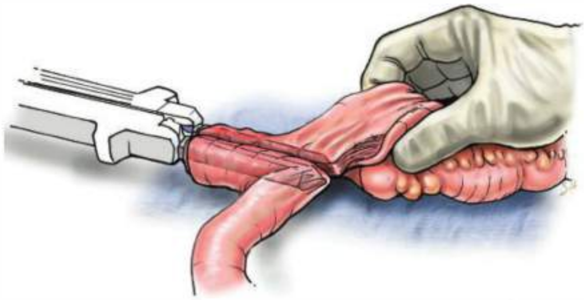


FIG 13 ● Stapled ileocolonic anastomosis. The stapler is inserted in the ileum and transverse colon and is then closed. (Printed with permission from Baylor College of Medicine.)

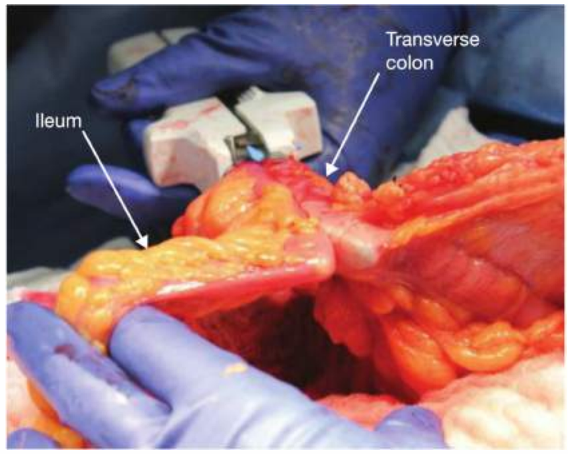


FIG 14 ● Stapled ileocolonic anastomosis: closing the common enterotomy with a stapler. (Printed with permission from Baylor College of Medicine.)

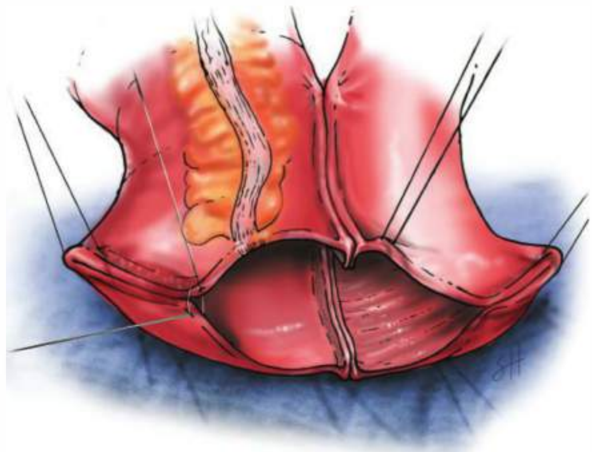


FIG 15 ● Stapled ileocolonic anastomosis: closing the inner layer of the common enterotomy with an absorbable running suture. (Printed with permission from Baylor College of Medicine.)

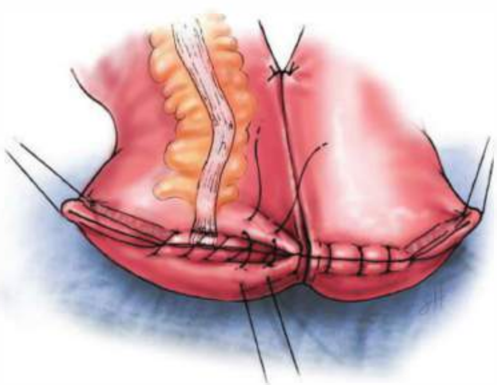
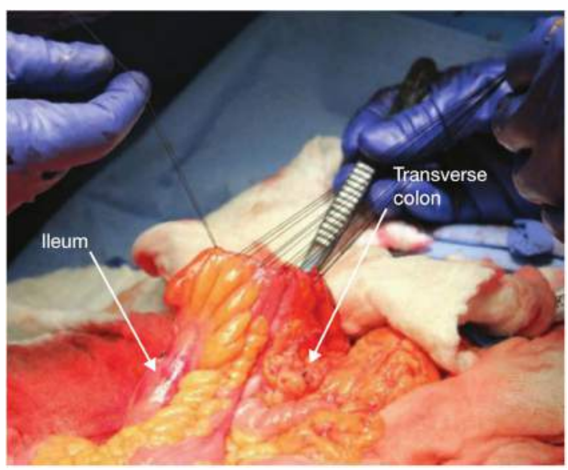


FIG 16 ● Stapled ileocolonic anastomosis: closing the outer layer of the common enterotomy with interrupted Lembert sutures. (Printed with permission from Baylor College of Medicine.)



- The completed anastomosis is visually inspected to ensure that it is well perfused and is palpated to check for patency (FIG 17).
- Alternatively, a hand-sewn anastomosis can be performed in either one or two layers. The type of suture (monofilament, braided, absorbable), type of stitch (interrupted, continuous, Lembert), or configuration used is probably not as important as are the principles of approximating well-perfused bowel without tension. The authors prefer a two-layer, side-to-side anastomosis using an outer layer of interrupted Lembert silk sutures and an inner continuous running layer of monofilament absorbable suture.
- Closure of the mesenteric defect is optional and is based on surgeon preference. Oftentimes, the omentum can be placed around the anastomosis.

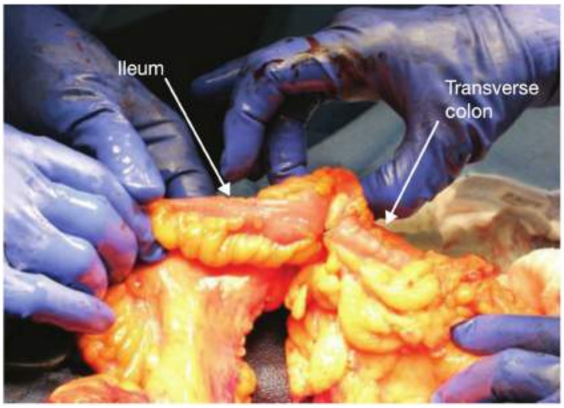


FIG 17 ● The completed ileotransverse colon side-by-side stapled anastomosis. Palpation of the anastomosis between the thumb and index finger shows that the anastomosis is patent. Notice that both the ileal and colonic segment are well perfused. Closure of the mesenteric defect is optional and is based on surgeon preference.

CLOSURE

- Once hemostasis is ensured and the abdomen is irrigated, the abdominal fascia and skin are closed in standard fashion. Drains are not routinely required, although in cases of infection or abscess, a drain may be placed.

PEARLS AND PITFALLS

Colon mobilization	■ The plane between the mesocolon and the retroperitoneum is an avascular embryologic plane that should be dissected sharply. Excess blood loss during this dissection alerts the surgeon that the incorrect plane was entered.
Vascular dissection	■ During dissection of the middle colic vessels, avulsion of the large collateral branch that connects the inferior pancreaticoduodenal vein with the middle colic vein and superior mesenteric vein can result in bleeding that is difficult to control because the vein retracts and cannot be isolated easily. ■ Avoiding excess upward and medial traction of the right colon while mobilizing the hepatic flexure best prevents this. ■ Transillumination of the mesocolon and the mesentery of the terminal ileum can help to identify vascular arcades to minimize iatrogenic injury in patients with thick mesentery and can assure good blood supply to the anastomosis.
Anastomosis	■ A well-vascularized, tension-free anastomosis minimizes the risk of anastomotic breakdown. ■ If there is any doubt regarding the integrity of the anastomosis, the bowel segments should be further resected to healthy, vascularized bowel. ■ Blood supply to the anastomosis can also be further assessed with Doppler ultrasound if necessary.

POSTOPERATIVE CARE

- In the absence of intraabdominal infection, antibiotic therapy does not need to be continued postoperatively.
- A nasogastric tube is not routinely placed.
- The patient should begin ambulating on postoperative day 1.
- The Foley catheter can usually be removed on postoperative day 1 or 2 unless an epidural remains in place.
- The patient can be started on a liquid diet. The diet can be advanced based on clinical progress.
- Deep venous thrombosis (DVT) prophylaxis should be continued until the time of discharge and can be considered as an outpatient in certain subsets of patients.
- The patient should be counseled about the initial changes in bowel habits including more frequent, loose stools and the possible appearance of blood clots in the first few bowel movements.

COMPLICATIONS

- Intraoperative complications include injury to the ureter, duodenum, nearby bowel or colon segments, nearby blood vessels such as the inferior pancreaticoduodenal vessels or the superior mesenteric vessels, or an anastomosis that is poorly vascularized or under tension.
- Early postoperative complications include wound infection, anastomotic leak, or intraabdominal abscess formation
- Late postoperative complications include development of colocutaneous fistulas, recurrence of cancer, anastomotic stricture, incisional or internal hernia, or ureteral stricture from ureteral devascularization.
- An extended right hemicolectomy adds the potential complication of splenic injury, as the splenic flexure must be mobilized to achieve a tension-free anastomosis. Because most of the proximal colon absorbs fecal water, an extended right hemicolectomy also predisposes to postoperative diarrhea.

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Chapter **10**

Laparoscopic Right Hemicolectomy

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DEFINITION

- Right hemicolectomy is defined as the resection of a portion of the terminal ileum, cecum, ascending colon, and portion of the transverse colon. When performed for neoplastic disease, it includes resection of the vascular pedicles including the ileocolic, right colic (when present), and sometimes right branch of the middle colic artery and their associated veins. An extended right hemicolectomy is one in which the middle colic vessels are ligated. Laparoscopic right hemicolectomy has been shown to be a preferred alternative technique in the resection of benign and malignant diseases of the colon and in experienced hands has been shown to have equivalent oncologic outcomes with improvements in speed of recovery when compared to open resection.[1–3]

INDICATIONS

- Right hemicolectomy may be performed for either benign or malignant indications, but the underlying principles of surgical resection apply to both open and laparoscopic approaches. A thorough preoperative workup to define the underlying disease plays a critical role in determining the nature of the operative intervention and optimizing the surgical treatment.
- Benign pathology (common etiologies)
  - Crohn's disease: most frequently occurs in the terminal ileum and may include the ascending colon with associated an associated inflammatory phlegmon or fistula. Right hemicolectomy for Crohn's is performed when the disease is refractory to medical therapy.
  - Right-sided diverticulitis: occurs uncommonly in the U.S. population and it is felt to arise as a congenital lesion occurring more commonly in Asian patients. It is commonly misdiagnosed as acute appendicitis.
  - Ischemic colitis: uncommonly affects the right colon in isolation owing to its collateral blood supply; however may present with abdominal pain, bloating due to stricture, or hematochezia.
  - Cecal volvulus: caused by a twist (typically clock-wise) of the terminal ileum and colonic mesentery around fixed retroperitoneal attachments, presents with acute abdominal pain and obstructive symptoms.
- Neoplastic pathology
  - Endoscopically unresectable polyps should be treated with colectomy. As they have potential to harbor malignant foci not detected on biopsy, they should be managed according to oncologic principles. Right-sided polyps include high-risk adenomas with high-grade dysplasia or villous components, large hyperplastic polyps, or sessile serrated adenoma/polyps (SSA/Ps).
  - Malignancy is the most common indication for laparoscopic right hemicolectomy. Equivalent outcomes to open resection have been demonstrated in large multi-center randomized controlled trials.[2–6] A bulky cancer or one that has invaded into adjacent organs should be resected en bloc with associated tissues and may be considered for open resection.
  - Adenocarcinoma: The location with respect to the anatomy of the blood supply determines the extent of bowel resection.
  - Carcinoid: Right colectomy is indicated for carcinoid tumors of the terminal ileum or appendix when 2 cm or greater. Colectomy is also indicated for adverse features such as goblet cell carcinoid histology or presence of lymphovascular or perineural invasion.

PATIENT HISTORY AND PHYSICAL FINDINGS

- Adenocarcinoma patients are commonly asymptomatic but can present with anemia, melena, altered stool patterns (diarrhea), pain, and weight loss.
- A thorough history and physical examination is essential for identifying candidates for laparoscopic surgery. Several patient factors that can affect the feasibility of laparoscopic resection are shown in Table 1. Patient characteristics or underlying disease issue may preclude safety of the laparoscopic approach or greatly increase the operative difficulty and time and these factors should be considered when making the decision to proceed with laparoscopy and during operative planning.
- Obesity poses unique challenges during laparoscopic hemicolectomy. The ease of finding the correct plane and the central vascular anatomy is greatly diminished in obese patients. Patient positioning may also be impacted by obesity as obese patients may not tolerate extreme Trendelenburg, reverse Trendelenburg, or side to side positioning. In addition, obesity has been associated with a higher risk for conversion to open surgery. Despite these challenges, patients who are obese have increased risk for morbidity such as wound infection when compared to nonobese patients and thus may derive significant benefit from laparoscopic surgery.
- Patients with decreased cardiac output may not tolerate increased intraabdominal pressures resulting in decreased venous return secondary to pneumoperitoneum.
- Intraabdominal adhesions caused by prior surgery may preclude laparoscopy. Laparoscopic lysis of adhesions may be

Table 1: Patient Factors that Can Affect the Feasibility of Laparoscopic Resection

Obesity
Prior abdominal surgery
Cardiac dysfunction
Pulmonary dysfunction
Large tumor burden
Potential local involvement of adjacent vital organs
Abnormal intraabdominal anatomy

performed, although surgeon experience and the extent of adhesions should be considered.

- Patients with nutritional deficiencies and impaired healing, such as those on high-dose steroids, recent immunomodulators, or systemic chemotherapy, are at higher risk for anastomotic failure. In those patients with ongoing life-threatening illnesses, ileocolonic anastomosis should be deferred in favor of end ileostomy. An ileocolostomy should not be performed in patients with hemodynamic instability.

DIAGNOSTIC STUDIES

- Colonoscopy: All tumors should be localized, biopsied, and tattooed prior to embarking on laparoscopic surgery. Tattooing allows for intraoperative localization of the tumor, although it may be faint when localized to the mesenteric border (**FIG 1**). The tattoo can also be on the retroperitoneal surface and not seen (**FIG 2**). Synchronous tumors (present in 3% to 5% of patients with colon cancer) and unresected polyps should be noted and considered in the treatment plan.[7] Colonoscopy may not be possible in patients with a complete obstruction. In these patients, intraoperative palpation of the entire colon should be performed to assess for secondary lesions. After recovery from surgery, a short interval completion colonoscopy should be performed.
- CT colonography/enterography: Can be useful in patients not amenable to colonoscopy. Use of CT enterography provides additional information of the small intestines in patients with Crohn's disease that may alter surgical strategy.
- CT scan of the abdomen and pelvis: In inflammatory bowel disease patients, CT scan provides information pertaining to the extent is of colitis, presence of a fistula, and/or abscess. In patients with malignancy, CT scans of the chest, abdomen, and pelvis should be performed to assess for pulmonary, hepatic, and lymphatic metastasis as well as infiltration of the primary tumor into adjacent structures.[8]

SURGICAL MANAGEMENT

Preoperative Planning

- Appropriate preoperative antibiotic coverage before incision has been shown to decrease the risk of surgical site infections, but courses of antibiotics greater than 24 hours are actually associated with worse outcomes.[9]
- The need for a pre-operative mechanical bowel preparation in patients undergoing right hemicolectomy is controversial.[10,11]

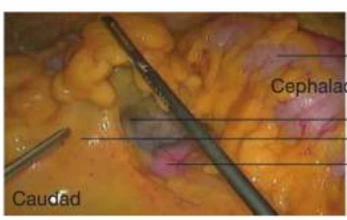

FIG 1 ● Tattooing the target. Tattoos placed within the colonic mesentery may not be visible upon initial inspection. As shown in this operative photograph, the distal ascending colon at the hepatic flexure has been anteriorly reflected to reveal the location of a previously placed intramesenteric tattoo.

FIG 2 ● Tattooing the target. In some instances, a tattoo placed within the mesentery is not visible until dissection into the retroperitoneum. Here, the dissection of Toldt's fascia (anterior) has been performed and the retroperitoneum exposed, revealing the location of the tattoo within the retroperitoneum of the ascending colon.

We use mechanical bowel preparation because it lightens the colon, thus facilitating laparoscopic manipulation of the colon.

Patient Positioning

- The patient is positioned supine and secured with Trendelenburg straps on the ankles (**FIG 3**). If an extended right hemicolectomy will be performed, the patient may be placed in a lithotomy position to facilitate the mobilization of the splenic flexure, if necessary.
- Gravity is the single greatest facilitator of exposure during colectomy. During the course of the case, the patient may be placed in steep Trendelenburg, reverse Trendelenburg and rotated right side up. For this reason, the patient must be secured to be operating table and a variety of devices have been used to secure the patient. We prefer to use ankle and chest straps, but commercially available foam pads placed under the patient to prevent slippage may also be used. We avoid using pads of beanbags placed above the shoulder that can cause brachial plexus injuries.
- Both arms should be padded and tucked at the patient's side. If the patient is too wide for the table, the right arm may

FIG 3 ● Securing the patient to the table. Velcro straps are secured to the patient's ankles, then attached to the operating room table to protect the patient's legs from sliding laterally off the table's sides with extreme left-right positioning and to assist in keeping the patient from slipping toward the head of the table when in placed in steep Trendelenburg position.

be left out so that the operative team standing together on the patient's left side still has sufficient working space. The patient's hands should be turned such that their palms face medially with the thumbs anterior and fingers should be positioned so that they are in a neutral position.

- Ensure that intravenous (IV) lines are working after positioning and prior to the start of the case. A second IV is recommended because the patient's arms will be inaccessible during the operation, thus making the establishment of another IV difficult.

PORT PLACEMENT

- A variety of methods may be employed for the entry into the abdomen during laparoscopic surgery. Two commonly used options are the use of a Veress needle or the authors' preferred technique of a direct fascial cutdown (Hassan technique). Pneumoperitoneum is established with carbon dioxide to 15 mmHg as tolerated.
- Standard port placement includes a 10- to 12-mm umbilical port (camera port), 5-mm working ports in the left upper quadrant, and either a 5-mm or 10- to 12-mm port in the left lower quadrant. A fourth port is used in either the suprapubic or right lower quadrant positions. An optional 5-mm port is placed in the patient's right upper quadrant to assist with the distal transverse colon or splenic flexure mobilization as needed for an extended right hemicolectomy (**FIG 4**).

FIG 4 ● Port placement. This diagram shows the standard and additional laparoscopic port sites for a laparoscopic right hemicolectomy. Standard placement includes a 10- to 12-mm umbilical port *(1)*, 5-mm left upper quadrant port *(2)*, and either a 5-mm or 10- to12-mm left lower quadrant port. A fourth port is used in the optional locations *(o)*, either suprapubic or right lower quadrant positions. An optional 5-mm port is placed in the patient's right upper quadrant to assist with the distal transverse colon or splenic flexure as needed for an extended right hemicolectomy.

VASCULAR TRANSECTION AND MEDIAL TO LATERAL MOBILIZATION OF THE ILEOCOLIC MESENTERY

- The abdomen should be thoroughly inspected to rule out metastatic sites or synchronous pathology with evaluation of the peritoneum, liver, retroperitoneum, and adnexal structures in women.
- The patient is positioned with the left side down and in slight Trendelenburg.
- The omentum is retracted cephalad over the transverse colon into the upper abdomen. In an obese patient with a bulky omentum, an assistant can hold retraction of the omentum through the left upper quadrant port.
- The small intestine is swept to the left lower quadrant, allowing for complete visualization of the mesenteric attachments to the right colon and the superior mesenteric artery (SMA). The ileocolic vessels (ICV) can be identified as they cross over the third portion of the duodenum. The fold of Treves is grasped and retracted laterally to demonstrate the course of the ICV and to identify their origin from the SMA and the confluence of the ileocolic vein into the superior mesenteric vein (SMV) (**FIG 5**).
- The peritoneal surface is scored on the dorsal surface of the ICV near the SMA (**FIG 6**). While ensuring that the lymph node-bearing tissue is dissected into the ileocolic mesentery (specimen side), the retroperitoneal attachments to the colonic mesentery are divided.

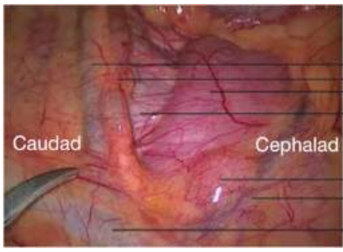

FIG 5 ● Exposure of the ileocolic pedicle. After the small bowel has been placed in the patient's left hemiabdomen exposing the right colon mesentery, the ileocolic pedicle is often seen pulsating within its mesentery. The duodenum is often seen through a thin layer of colon mesentery; the ICV can be identified as they cross the third portion of the duodenum. In this image, the SMV, inferior vena cava, and right colic artery and vein are seen. IVC, inferior vena cava; SMV, superior mesenteric vein.

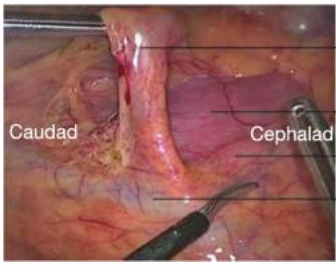

FIG 6 ● Dissection of the ICV. Scoring of the peritoneum along the inferior sulcus of the ICV allows for a posterior dissection to the ICV. Gentle lifting of the pedicle will allow for dissection of the tissue to the origin of the ICV at the SMA and SMV. ICV, ileocolic vessels; SMV, superior mesenteric vein.

- The correct, avascular plane can be developed with a combination of sharp and blunt dissection. The small retroperitoneal vessels can act as a guide and should be dissected downward, away from the colonic mesentery. If these are bluntly torn, minimal, yet bothersome bleeding can ensue. This careful medial to lateral dissection of the ileocolic mesentery is carried cephalad to the origin of the ICV, with care taken not to inadvertently injure the duodenum, and laterally releasing the colonic mesentery from retroperitoneal attachments without injury to the ureter or gonadal vessels. The dissection plane should be anterior to the duodenum and pancreatic head, taking care to avoid inadvertent duodenal mobilization or dissection between the duodenum and pancreas (**FIG 7**).
- The ICV can then be divided at the origin from the SMA/SMV with either an endoscopic GIA stapler with a vascular load (our preference; see **FIG 8**), with an energy device, or between endoclips. Node-bearing tissue should be kept with the specimen.
- Next the dissection is taken up along the SMA to identify the right colic artery and vein (when present) (**FIG 9**) as well as the middle colic vessels (MCV) and their bifurcation (**FIG 10**). This step is facilitated by anterior and cephalad traction on the transverse colon to tent the mesentery.
- By following the SMA from the point of ICV ligation, the variably present right colic artery is identified to arise from the SMA between the ICV and the MCV where it should be divided at its origin with an energy-sealing device.
- The venous drainage of the right colon is also highly variable and the right colic vein is missing in up to 50% of patients. It can be found joining the right gastroepiploic and superior pancreaticoduodenal veins at the gastrocolic trunk of Henle.
- In cases of more distal ascending colon or hepatic flexure tumors, transaction of either the right branch or the entire trunk of the middle colic artery (MCA) should be performed after exposing the origin of these vessels from the SMA. Tearing the vein at this level will result in rapid bleeding; therefore, it is important to carefully and completely identify the vascular anatomy of the right colon prior to dividing the mesentery.

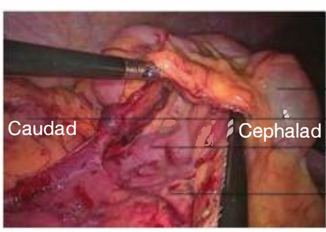

FIG 7 ● Medial to lateral dissection. The medial to lateral dissection of the ileocolic mesentery is continued both laterally and superiorly anterior to the duodenum and head of pancreas along the course of the SMA and SMV to the origin on the middle colic vessels.

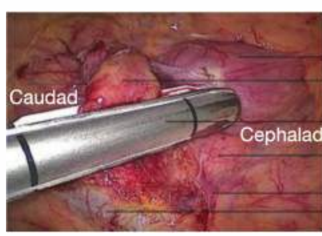

FIG 8 ● Transection of the ICV. Once the ileocolic artery and vein have been cleared of their surrounding fat and lymphatic tissue, they can be transected at their origins off the SMA and SMV. This can be performed with a 30mm stapler (as shown) or with an energy device as appropriate. The vessels can be separated and ligated either separately or together, as per surgeon preference.

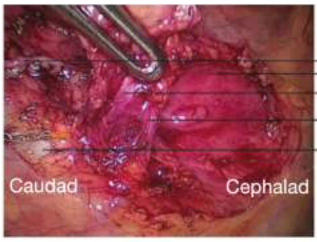

FIG 9 ● Transection of the right colic vessels. A right colic artery and vein are shown originating from the superior mesenteric artery and vein. This is often discovered only after transection of the ileocolic artery and vein has been completed. These vessels are typically smaller than the ileocolic artery and vein and may be ligated with staples, endoclips or an energy device. SMV, superior mesenteric vein.

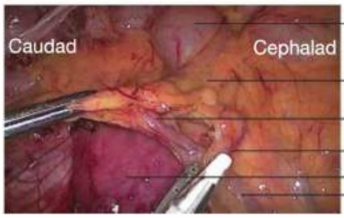

FIG 10 ● Exposure of the middle colic vessels. The colon mesentery is incised along the border of the superior mesenteric vessels to the bifurcation of the right and left branches of the middle colic artery and vein as shown here, ensuring that all lymphatic tissue within the distribution of the right and proximal transverse colon is removed with the specimen. This dissection is performed anteriorly to the duodenum and head of pancreas. The right branch of the middle colic artery and vein are typically small enough to transect with a sealing energy device.

LATERAL COLON MOBILIZATION

- Placing the patient in Trendelenburg position and retracting the small bowel out of the pelvis into the upper abdomen facilitates this step.
- The ascending colon is mobilized in an inferior to superior fashion by lifting the cecum away from the retroperitoneum and scoring the base of the cecal and terminal ileal mesenteries until the medial to lateral dissection is met (**FIG 11**). Care should be taken to avoid inadvertent dissection and injury of the ureter and gonadal vein.
- The lateral attachments along Toldt's fascia are then incised up to the level of the hepatic flexure. We prefer an inferior to superior approach as this minimizes the risk for kidney mobilization or duodenal Kocherization during bowel mobilization (**FIG 12**).
- After the ascending colon has been mobilized, the mobilization of the transverse colon and hepatic flexure is performed. With the patient in reverse Trendelenburg position, the lesser sac is opened by releasing the omentum from the transverse colon. At this level the omentum is frequently fused to the transverse mesocolon so care should be taken to avoid inadvertent mesenteric vascular injury.
- The proximal transverse colonic attachments along the hepatocolic ligament can then be divided with an energy device to meet the plane over the duodenum previously established during the medial to lateral dissection (**FIG 13**). The previous exposure of the duodenum minimizes the risk of inadvertent Kocherization and/or injury to the duodenum at this stage.

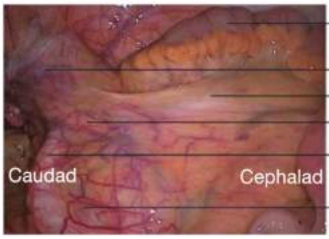

FIG 11 ● Exposure of the right pelvic inlet. With the patient positioned in steep Trendelenburg and the small intestine removed from the pelvis, the proximal lateral pelvic and abdominal attachments of the terminal ileum and cecum are identified. Important anatomy is appreciated in this photo: right common iliac artery and vein and the right ureter. These peritoneal attachments must be incised and freed to allow complete mobility of the small intestine.

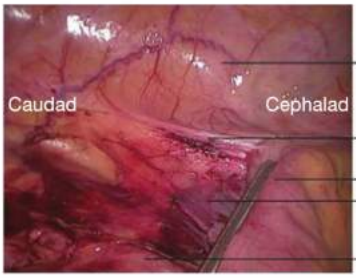

FIG 12 ● Lateral mobilization of the ascending colon. Once the lateral pelvic and initial abdominal attachments are incised, gentle traction on the cecum and ascending colon toward the patient's left upper quadrant will assist in the dissection of Toldt's fascia. The dark purple-appearing tissue toward the bottom of this operative photo reveals the retroperitoneum previously dissected during the initial medial to lateral dissection. The ureter maintains a close approximation to the dissection planes.

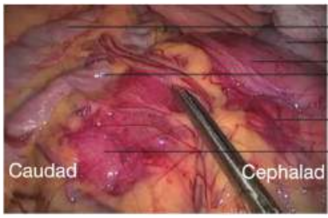

FIG 13 ● Mobilization of the hepatic flexure. With the patient in reverse Trendelenburg position and the transverse colon with its omentum reflected inferiorly, the superior portion of the previous medial to lateral dissection is easily visualized and is seen here in the middle of the photo. Incision into this thin tissue connects with the previous dissection plane and the dissection continues laterally to incise and release the hepatocolic ligaments completing the mobilization of the right colon. After this has been completed, the right colon should be able to be medialized across the midline of the abdomen.

ENTEROCOLONIC ANASTOMOSIS

- Ileocolonic anastomosis may be performed either intracorporeally or extracorporeally.
- We prefer an extracorporeal anastomosis through a periumbilical extraction site, incorporating the supra-umbilical port site. An advantage of this approach is that the anastomosis may be performed according to standard open technique.
- In cancer patients, the extraction site must be sufficiently large to allow for the passage of the tumor-bearing segment. A wound protector is placed into the incision to reduce infection.
- If the terminal ileal or colon mesenteries have not been completely mobilized, or the mesenteries have not been properly ligated, bowel exteriorization may be difficult and associated with a risk for avulsion injury to the mesenteric vessels.
- During bowel exteriorization, it is helpful to initially maintain the reverse Trendelenburg position with the table slightly rotated left-side down to keep the small bowel from falling over the colon and entrapping it.

EXTRACORPOREAL TRANSECTION AND ENTEROCOLONIC ANASTOMOSIS

- Once the right colon and terminal ileum have been delivered through the wound protector, attention is turned to the bowel resection. Investigation of the vascular supply to the planned resection sites prior to division and anastomosis is paramount.
- The mesentery should be carefully inspected and the terminal vessels should be visually assessed for pulsations or pulsatile blood flow should be confirmed by Doppler interrogation. If no pulsations are present, then another site for resection and anastomosis is chosen.
- The terminal ileum and the transverse colon (typically to the right side of the MCV) are transected with a linear stapler. The intervening mesentery is transected with an energy device.
- There are multiple methods to create an anastomosis. We suggest that surgeons use the method with which they are most comfortable. Our preferred approach is to perform a side-to-side, antimesenteric, functional end-to-end, stapled anastomosis in continuity to avoid potential for twisting of the bowel.
- This is done with a colotomy and an enterotomy on the anti-mesenteric side of the specimen about 1 cm or 2 cm away proximal to the planned transection sites. A linear stapler is placed into the enterotomy and colotomy and approximated at their antimesenteric sides. After ensuring that the ileal and colonic mesenteries are free from the closed stapler, it is fired creating the side-to-side enterocolostomy anastomosis (**FIG 14**).
- The common enterocolostomy is closed by using an 85- to 100-mm linear stapler (reload), avoiding narrowing the anastomosis (**FIG 15**).

FIG 14 ● Creation of an extracorporeal side-to-side stapled ileocolonic anastomosis with a linear stapler.

FIG 15 ● Closure of the common enterocolostomy anastomosis opening with a liner stapler.

- The anastomosis is inspected for gross defects or bleeding, both of which can be oversewn. The corners and intersections of the staple lines may be imbricated or reinforced with Lembert sutures.
- An alternative technique includes bowel division and intracorporeal anastomosis with a variety of options for specimen extraction. One advantage of this approach is the ability to avoid a periumbilical incision with its associated risk for hernia in favor of a Pfannenstiel incision.

CLOSURE

- The abdomen should be inspected for hemostasis and to ensure that there has been no inadvertent avulsion injury to the mesentery or twisting of the mesentery. The mesenteric defect will be large after colectomy with proximal vascular ligation; therefore there is neither the need to close the mesentery, nor is it generally possible to do so.
- Any 12 mm port sites are closed and the extraction site can be closed with interrupted suture or according to the surgeon's preference.

PEARLS AND PITFALLS

Patient selection	■ Patients who meet criteria for hereditary nonpolyposis colorectal cancer (HNPCC) or Lynch syndrome should be considered for a subtotal colectomy. ■ Patient should be assessed to ensure they will tolerate pneumoperitoneum and changes in positioning during surgery.
Preoperative planning	■ Ensure a complete colonoscopy was performed. As many as 1 in 20 patients will have synchronous primary cancers. ■ Localize the tumor with CT imaging for larger lesions and colonoscopic tattoo or metallic clip for smaller ones. ■ Careful review preoperative CT imaging identifies locally advanced disease, distant metastases, or aberrant vascular anatomy.
Patient positioning and portplacement	■ Securing the patient to the bed with chest and leg straps is key and allows for extremes in patient positioning. ■ Placing ports in either the midline or contralateral to the target facilitates orientation and maximizes instrument range of motion.
Procedure	■ Completing the medial to lateral dissection from the right branch of the middle colic artery down to the cecum is key to the dissection allowing easier dissection of the lateral ascending colon off of Toldt's fascia. ■ Careful attention to the duodenum and pancreatic head should be maintained while freeing the transverse mesocolon. The duodenum also serves as a landmark for proximal ligation of the ICV. ■ Anticipate variations in the vascular anatomy of the hepatic flexure. The course of the right colic vein in particular is highly variable and it is therefore at risk for avulsion injury especially at the trunk of Henle. ■ Mobilization along the base of the terminal ileal mesentery over the inferior vena cava and toward the ligament of Treitz ensures adequate mobilization for bowel exteriorization and tension-free anastomosis. ■ Sweeping the ascending colon and terminal ileum to the left side of the patient's abdomen is a good test to ensure complete mobilization of the entire right and transverse colon. ■ Ensure an appropriate oncologic resection is performed during all steps of the procedure not leaving behind ileocolic and middle colic lymph nodes.
Orientation	■ Prior to closure, inspect the orientation of the small bowel and its mesentery to ensure that no twists in the bowel were introduced. ■ Closure of the mesenteric defect to prevent internal hernias is not necessary if the defect is large.

POSTOPERATIVE CARE

- Following the procedure, principles of early mobilization and oral intake are observed.
- Early ambulation is encouraged to assist in return of bowel function and any invasive lines or catheters are also removed within 48 hours.
- Diet is initiated with clear liquids on the day of surgery and advanced as tolerated.
- Discharge criteria include (1) ability to maintain oral hydration, (2) adequate pain control without the need for IV narcotics, (3) signs of bowel function (flatus), and (4) afebrile for at least 24 hours. A narcotic minimizing regimen improves recovery.

OUTCOMES

- Laparoscopic procedures, when compared to traditional open surgery, have been shown to have quicker return of bowel function, less requirement of IV narcotics, earlier patient ambulation, fewer surgical site infections, and earlier discharge from the hospital.
- Most importantly, randomized control trials comparing laparoscopic and open colectomies, when performed adequately,

provide equivalent oncologic outcomes with no differences in tumor recurrence and patient survival.

COMPLICATIONS

- Surgical site infection (superficial, deep, and organ space)
- Wound dehiscence
- Hemorrhage
- Anastomotic leak/breakdown
- Bowel obstruction

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Chapter 11

Right Hemicolectomy: Hand-Assisted Laparoscopic Surgery Technique

Matthew Albert   Harsha Polavarapu

DEFINITION

- Hand-assisted laparoscopic surgery (HALS) is a hybrid technique, which allows the surgeon to insert his or her hand into the abdominal cavity through a relatively small incision while preserving the ability to work under pneumoperitoneum. This approach aids in tactile feedback, retraction, and dissection by hand assistance in turn eliminating the technical challenges of conventional laparoscopy while maintaining nearly all of its benefits.[1,2]

INDICATIONS

- Colon cancer
- Colon polyps not amenable to colonoscopic removal
- Inflammatory bowel disease
- Angiodysplasia
- Recurrent right colonic diverticulitis

PATIENT HISTORY AND PHYSICAL FINDINGS

- A thorough history should be taken, including a detailed past medical history, past surgical history, present medications and allergies, and a personal and family history of colon and rectal cancer.
- A detailed family history to assess the risk of hereditary polyposis syndromes is critical in selecting the optimal procedure for the patient. Suspected patients should be offered genetic counseling and testing.
- A detailed physical examination of the patient should be performed to identify any prior surgical incisions and palpable masses to plan for the operation.
- The location, histopathology, and the clinical stage of the lesion is crucial prior to any planned procedure.

IMAGING AND OTHER DIAGNOSTIC STUDIES

- Colonoscopy remains the investigation of choice for localizing the target lesion, for obtaining tissue for histopathology, and for tattooing for intraoperative localization. This is also helpful in identifying synchronous lesions in the remaining colon.
- Computed tomography (CT) scan of the chest/abdomen/pelvis with IV and oral contrast is recommended as the primary staging tool to assess for local organ invasion and for distant metastasis.[3]
- Serum carcinoembryonic antigen (CEA) level is a valuable marker for postoperative surveillance.
- Bone scan and brain imaging should be reserved for symptomatic patients only.

SURGICAL MANAGEMENT

- The goal of surgery is an en bloc resection of the involved segment of bowel and to perform a high ligation of the vascular pedicle permitting adequate removal of associated lymphatics and lymph nodes.
- At least 12 lymph nodes must be harvested to adequately stage the patient and to avoid risk of understaging.[3]

Preoperative Planning

- Routine use of mechanical bowel preparation is not recommended.[4]
- Deep vein thrombosis prophylaxis with sequential compression devices and subcutaneous heparin dosing before induction of anesthesia is administered.
- A Foley catheter is placed prior to the operation.
- Nasogastric/orogastric tube is placed prior to the operation.
- Preoperative antibiotics covering skin and bowel flora are administered prior to induction of anesthesia.

Positioning

- Patient is positioned in a supine position. In order to prevent the patient from sliding during the case, the arms are tucked to the sides, the feet are placed against a padded footboard, and a strap is placed over the thighs (**FIG 1**).
- Alternatively, the patient can be placed in the low lithotomy position to avoid instrument conflict with the lower extremities. The knees should be slightly flexed and the feet firmly planted on the stirrups to prevent undue pressure on the calves and on the lateral peroneal nerves.
- Depending on the location of pathology and body habitus, a 5- to 7-cm incision is made for the hand port in an epigastric, periumbilical, or Pfannenstiel location (**FIG 2**).
- Location of the trocars can be variable based on surgeon's preference. In general, it is best to triangulate all ports to enhance visualization and to prevent instrument conflict inside the abdomen.
- A traditional port placement includes (**FIG 2**)
  - A GelPort hand port through a 6-cm epigastric incision
  - A 5-mm infraumbilical camera port
  - A 5-mm left lower quadrant instrument port
  - A 5-mm left upper quadrant/left anterior flank

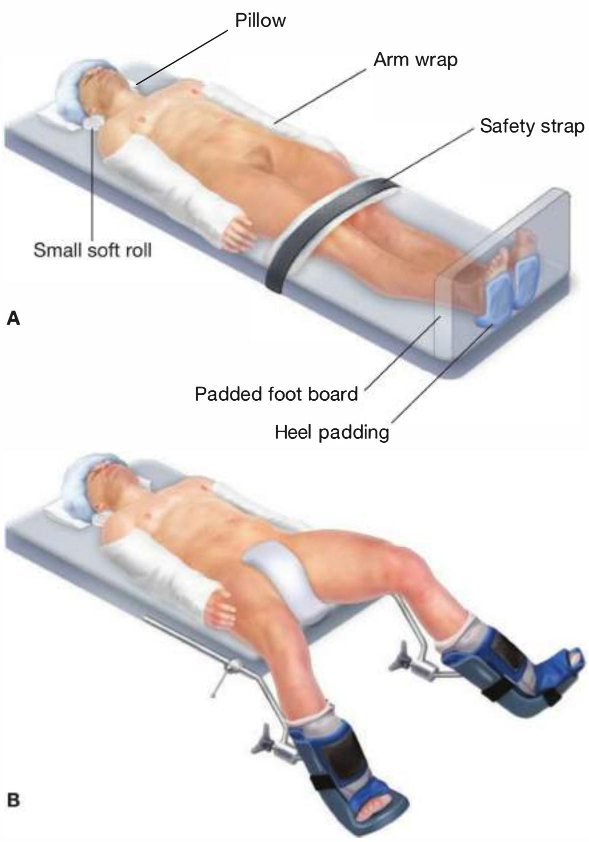

FIG 1 ● Patient positioning. In order to prevent the patient from sliding during the case, the arms are tucked to the sides, the feet are placed against a padded footboard, and a strap is placed over the thighs.

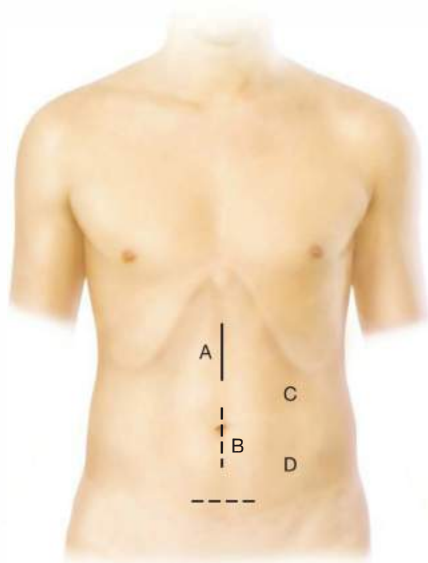

FIG 2 ● Port placement. The hand access port is placed through a 5- to 7-cm epigastric incision *(A)*. Alternatively, it can be placed through a Pfannenstiel or periumbilical incision *(dotted lines)*. A 5-mm camera port is placed infraumbilically *(B)*. Two 5-mm working ports are placed in the left upper *(C)* and left lower *(D)* quadrants.

EXPOSURE

- After placement of the hand port, the abdomen is explored to locate the lesion, to assess the extent of spread, and to palpate the liver and peritoneal cavity for distant metastatic spread.
- In female patients, the ovaries should be examined for metastatic spread or primary neoplasms.
- Pneumoperitoneum is created with carbon dioxide (CO_2) and additional trocars are inserted.
- Patient is placed in a left lateral tilt and slight Trendelenburg position. The small bowel is fanned out along its mesentery to aid in the exposure of the right colon.
- The greater omentum along with the transverse colon is retracted cephalad.
- The cecum is grasped with the hand and retracted toward the anterior abdominal wall using gentle traction to identify the ileocolic vessels.
- The ileocolic pedicle is grasped and retracted toward the anterior abdominal wall (**FIG 3**).

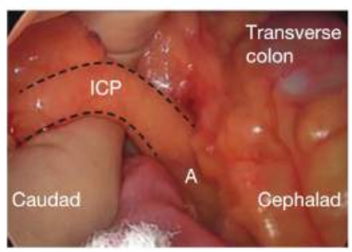

FIG 3 ● The ileocolic pedicle (ICP), identified at its origin off the inferior mesenteric vessels at the root of the mesentery **(A)**, is grasped and retracted toward the anterior abdominal wall.

DIVISION OF ILEOCOLIC PEDICLE

- With the ileocolic pedicle on stretch, a parallel incision is made on the peritoneal layer underneath the pedicle (**FIG 4**) extending to the root of the mesentery and the superior mesenteric vein, using monopolar electrocautery.
- A window is created under the ileocolic pedicle in the avascular plane that separates the pedicle from the retroperitoneum (**FIG 5**).
- The ileocolic pedicle is isolated and divided close to its origin off the superior mesenteric vessels using an energy device, a linear vascular stapler, or surgical clips based on surgeon's preference (**FIG 6**).

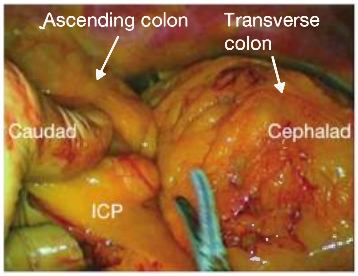

FIG 4 ● With the ileocolic pedicle (ICP) on stretch, a parallel incision has been made on the peritoneal layer underneath the ICP extending to the root of the mesentery. The surgeon, with the left hand now holding the ICP anteriorly, is now ready to open a window through the mesocolon lateral to the ICP.

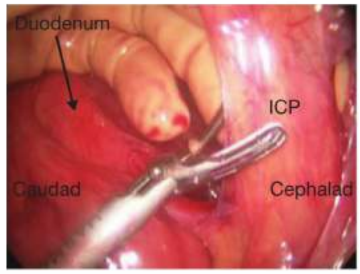

FIG 5 ● The ileocolic pedicle (ICP) has now been completely encircled and is now ready for transection. Notice that the pedicle has been completely separated from the duodenum and other retroperitoneal structures.

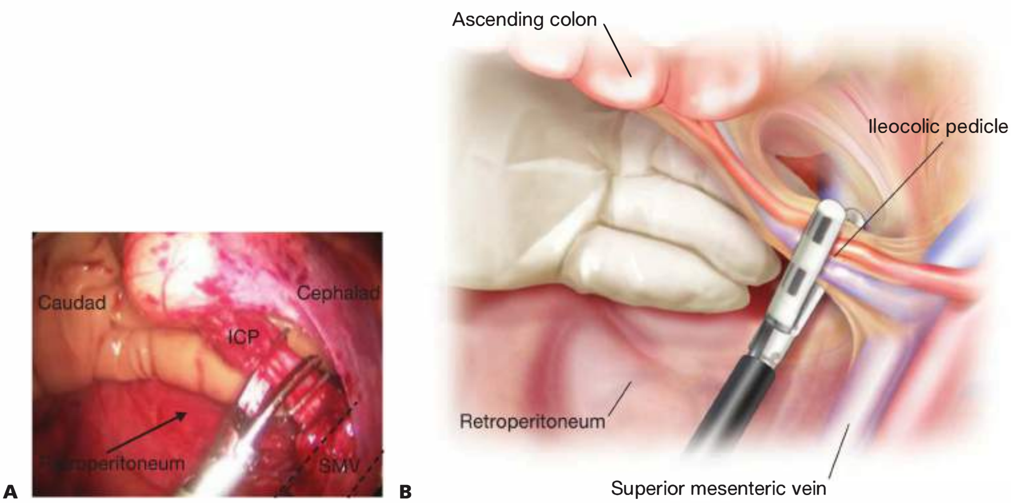

FIG 6 ● **A.** The ileocolic pedicle (ICP) is isolated and divided in between vascular clips with a 5-mm energy device close to its origin off the superior mesenteric vessels (SMV). **B.** Illustration of this step.

MOBILIZATION OF RIGHT MESOCOLON

- Using blunt dissection with a 5-mm energy device, the ascending mesocolon is mobilized off the retroperitoneum (duodenum and Gerota's fascia) using a medial to lateral dissection approach.
- To facilitate exposure, the surgeon's left hand should be pronated and placed underneath the mesocolon, giving upward traction for the retroperitoneal dissection (**FIG 7**).
- Mobilization of the right mesocolon is carried out laterally to the abdominal wall (**FIG 8A**), superiorly to the hepatorenal recess (**FIG 8B**), and medially exposing the third portion of the duodenum (**FIG 8C**).
- At this point, critical structures including the right ureter, the right gonadal vein, and the duodenum are identified and preserved intact in the retroperitoneum (**FIG 9**).

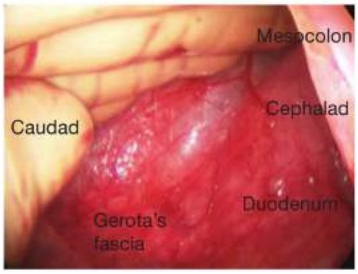

FIG 7 ● The ascending mesocolon is mobilized off the retroperitoneum (duodenum and Gerota's fascia), using a medial to lateral dissection approach. To facilitate exposure, the surgeon's left hand should be pronated and placed underneath the mesocolon, giving upward traction for the retroperitoneal dissection.

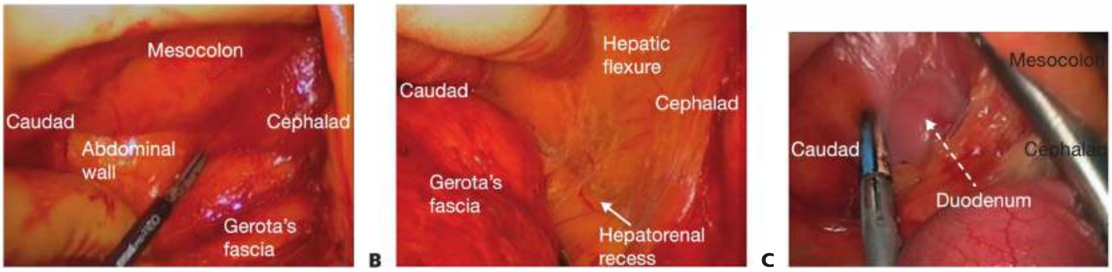

FIG 8 ● **A.** The medial to lateral dissection, performed bluntly with a 5-mm energy device, separates the ascending mesocolon from the retroperitoneal structures (Gerota's fascia and duodenum) until reaching the lateral abdominal wall. **B.** The dissection is carried superiorly until the hepatorenal recess. **C.** The third portion of the duodenum is exposed medially.

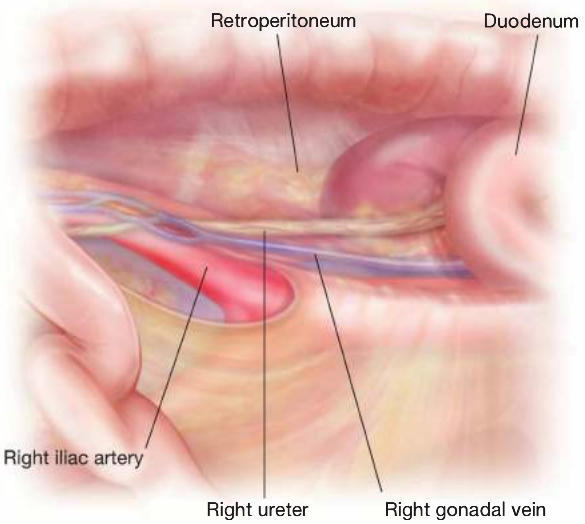

FIG 9 ● After completion of the medial to lateral mobilization of the ascending mesocolon, critical structures including the right ureter, the right gonadal vein, and the duodenum are identified and preserved intact in the retroperitoneum.

LATERAL MOBILIZATION OF THE ASCENDING COLON

- With the patient in a steep Trendelenburg position, the small bowel is retracted out of pelvis, and the base of cecum is grasped and retracted anteriorly toward the abdominal wall.
- With the ileum on stretch, a peritoneal incision is created from the cecum medially along the root of the ileal mesentery (**FIG 10**) to communicate with the retrocolic space previously created by the medial to lateral mobilization of the ascending mesocolon.
- The right ureter and the right gonadal vein are most easily identified at this phase of the operation coursing over the right iliac vessels and into the pelvis (**FIG 11**). Lateral and anterior to the psoas muscle, the lateral femoral cutaneous nerve is also frequently identified.
- The white line of Toldt is incised (**FIG 12**), dividing the only remaining attachments of the ascending colon if the medial to lateral dissection was carried out adequately during the previous step.

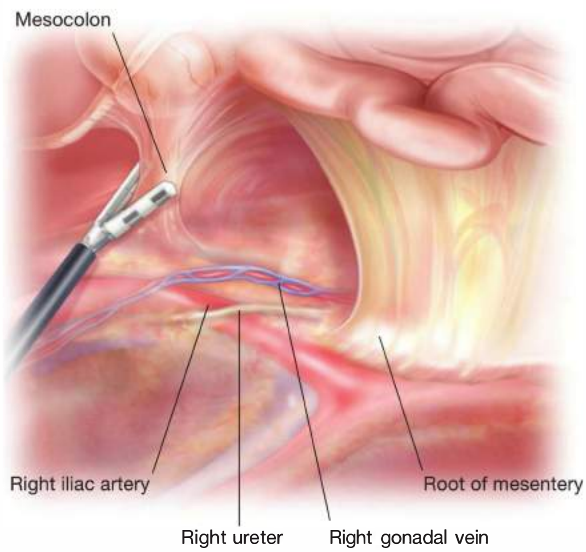

FIG 11 ● After mobilization of the cecum and terminal ileum, the right gonadal vein and the right ureter are seen in the retroperitoneum crossing over the right iliac artery and into the pelvis.

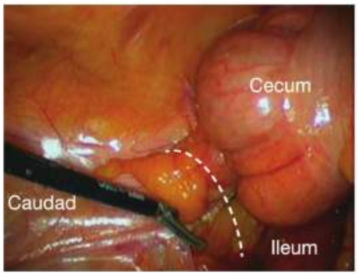

FIG 10 ● With the patient in a steep Trendelenburg position, the small bowel is retracted out of pelvis, and the base of cecum is grasped and retracted anteriorly toward the abdominal wall. With the ileum on stretch, a peritoneal incision is created from the cecum medially along the root of the terminal ileal mesentery.

FIG 12 ● With the surgeon retracting the colon medially, the lateral attachments of the ascending colon (white line of Toldt) are transected with an energy device in a cephalad direction.

MOBILIZATION OF THE HEPATIC FLEXURE AND THE PROXIMAL TRANSVERSE COLON

- The patient is positioned in reverse Trendelenburg position and the hepatic flexure can easily be exposed by grasping the colon in your palm and pulling it downward and medially, as one would do during open surgery.
- The hepatocolic ligament is transected with a 5-mm energy device. The surgeon can facilitate this step by hooking his index finger under the hepatocolic ligament (**FIG 13**).

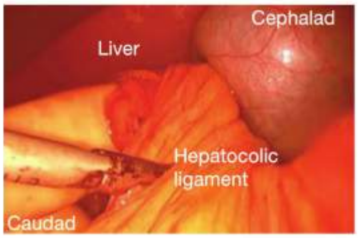

FIG 13 ● Transection of the hepatocolic ligament. The hepatocolic ligament is transected with a 5-mm energy device. The surgeon can facilitate this step by hooking his index finger under the hepatocolic ligament as shown.

- By pulling the transverse colon now downward, the gastrocolic ligament is readily exposed.
- The gastrocolic ligament is transected up to the midtransverse colon with a 5-mm energy device, and the lesser sac entered.
- The extent of mobilization is dictated by the location of the pathology, body habitus, and extraction site.
- With the hepatic flexure and the ascending colon now fully mobilized, we are now ready for the extracorporeal mobilization of the specimen.

BOWEL RESECTION AND ANASTOMOSIS

- Once the colon is completely mobilized, the pneumoperitoneum is desufflated, and the right colon and terminal ileum are exteriorized through the hand port site with the wound protector in place to prevent oncologic and infectious contamination of the wound (**FIG 14**).
- The extracorporeal mobilization of the right colon and terminal ileum should be feasible without any tension. Should there be any tension during the extracorporeal delivery of the specimen, reintroduce it into the abdomen, reinsufflate the pneumoperitoneum, and mobilize the right colon further to avoid potentially troublesome mesenteric tears that could lead to significant bleeding.
- The remaining mesentery of the small bowel and the large bowel is divided followed by the division of the terminal ileum and midtransverse colon with a linear stapler device (**FIG 15**).
- The resected right colon is opened on a side table to confirm complete resection of the target lesion and the specimen is sent for final pathology.
- A side-to-side ileocolic anastomosis is performed (**FIG 16A**). The completed anastomosis is introduced back into the abdominal cavity (**FIG 16B**). Surgeons may choose from either a stapled or a hand-sewn technique for the ileocolic anastomosis.
- The abdomen is reinsufflated to assure that there is good hemostasis as well as a correct bowel orientation.

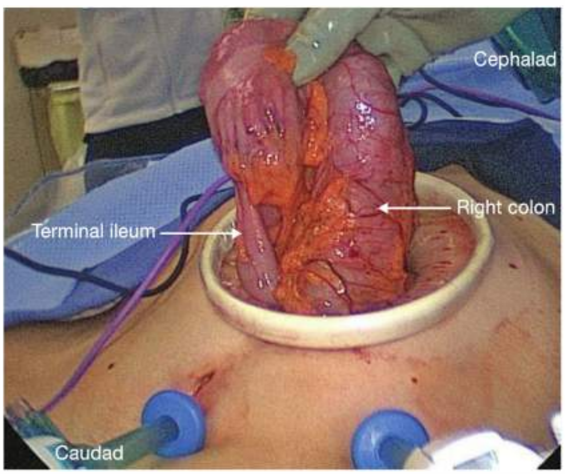

FIG 14 ● Extracorporeal mobilization. The right colon and the terminal ileum are exteriorized through the hand port site with the wound protector in place.

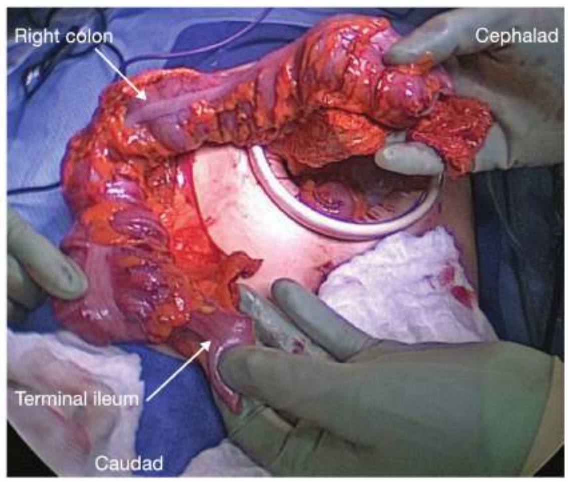

FIG 15 ● Extracorporeal transection. The terminal ileum and the transverse colon have been transected with a linear stapler.

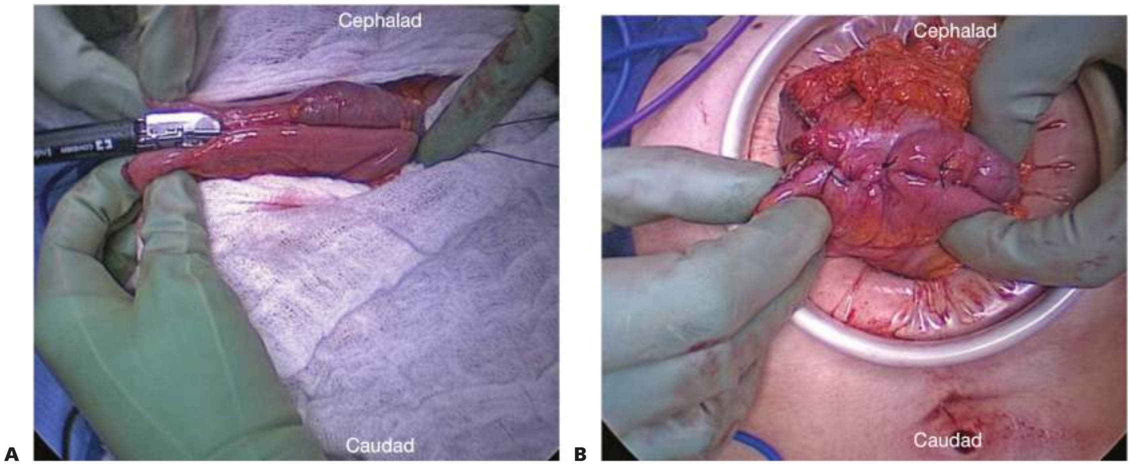

FIG 16 ● Extracorporeal anastomosis. **A.** A stapled side-to-side ileotransverse colon anastomosis technique is shown. **B.** The completed anastomosis will be introduced back into the abdomen.

CLOSURE

- The ports, the hand-assist device, and the wound protector are removed under direct vision.
- Surgical gloves are changed to minimize the chance of a wound infection.
- The hand-port fascial incision is closed with a running absorbable monofilament suture (no. 1 polydioxanone [PDS]).
- All wounds are irrigated and closed with subcuticular 4-0 PDS sutures.

PEARLS AND PITFALLS

Preoperative localization	■ Preoperative localization of the lesion with a tattoo is crucial, especially for polyps, as these can be difficult to identify even with tactile feedback.
Identification of the ileocolic pedicle	■ The ileocecal junction should be elevated to identify the ileocolic vessels as the superior mesenteric vessels can easily be mistaken for the ileocolic vessels.
Avoid the superior mesenteric vein	■ When dissecting high on the ileocolic vessels, care should be taken to avoid the superior mesenteric vein.
Identifying the right ureter	■ The right ureter should be identified and preserved as it can be easily injured if you are in the wrong plane. Stay in the loose areolar plane located between the ascending mesocolon anteriorly and the retroperitoneum posteriorly.
Small bowel orientation	■ Before performing an ileocolic anastomosis, the orientation of the small bowel should be checked, as the small bowel can easily get twisted on itself during the extracorporeal mobilization.

POSTOPERATIVE CARE

- Patients are monitored on a surgical floor bed.
- Start a clear liquid diet on postoperative day 1 and advance diet as tolerated.
- Foley catheter is removed on postoperative day 1.
- Most of the patients are discharged home on postoperative days 2 and 3.

OUTCOMES

- Hand-assisted colectomy has been shown to decrease the total operative time and conversion rate compared to conventional laparoscopy.[2,5]
- The long-term survival of patients with colon cancer correlates with the American Joint Committee on Cancer (AJCC) stage published guidelines.

COMPLICATIONS

- Surgical site infection
- Anastomotic leak
- Postoperative bleeding
- Postoperative ileus
- Intraabdominal infection
- Incisional hernia

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Chapter 12

Right Hemicolectomy: Single-Incision Laparoscopic Technique

Theodoros Voloyiannis

DEFINITION

- Single-incision laparoscopic right hemicolectomy is a refined technique of conventional laparoscopy where a single multichannel laparoscopic port is used via a 2.5- to 5-cm total incision length.
- The goal is to keep the procedure simple, safe, and cost-effective with comparable outcomes to hand-assisted or multiport laparoscopic technique.
- Although single-incision laparoscopy differs from the conventional laparoscopy, it follows the same steps and oncologic principles. It can be completed without difficulty with an extracorporeal anastomosis. An intracorporeal anastomosis can be performed as well; however, it requires advanced laparoscopic skills and the addition of laparoscopic Endo GIA staplers.

DIFFERENTIAL DIAGNOSIS

- The procedure can be performed for benign or neoplastic diseases or condition, including the following:
  - Appendectomy
  - Ileocecectomy
  - Formal right colectomy
  - Extended right colectomy

PATIENT HISTORY AND PHYSICAL FINDINGS

- A detailed history and physical exam is essential preoperatively to determine if the patient is suitable for laparoscopic single-incision right hemicolectomy. Potential contraindications to laparoscopic single-incision right hemicolectomy are summarized in Table 1.
- In case of underlying neoplasia, the size of the tumor determines if it can be extracted without tension via the single-port wound protector. In general, tumors up to 7 cm can be extracted via a 5-cm maximum length single incision. The procedure can still be performed with elongation of the incision for extraction of larger tumors. In that case, the benefit of the single port is eliminated, with the exception of the avoidance of use of multiple laparoscopic ports.
- A large palpable tumor preoperatively with fixation to the abdominal wall or other organs may be a contraindication to single-incision laparoscopy, although excision en bloc with soft tissue abdominal wall is still possible via a single incision in some cases.
- Signs and symptoms of obstructing neoplastic lesion with proximal distended right colon with or without competent ileocecal valve and small intestinal dilation may also suggest contraindication to laparoscopic approach due to difficulty establishing a safe working space with pneumoperitoneum. Anastomosis may be contraindicated in this case.
- It is important to define the underlying pathology—benign versus malignant disease and the location of the lesion preoperatively. Ileocecectomy or right hemicolectomy for neoplasia may require formal lymphadenectomy with en bloc resection of the ileocolic vascular pedicle. Hepatic flexure or proximal transverse colon lesions may require additional resection of the right colic vein or right branch or the middle colic artery and vein and further mobilization of the proximal transverse colon.
- Involvement of other organs or structures, such as right ovary, small intestine, abdominal wall, right ureter, right kidney, duodenum, small intestine, omentum, liver, and gallbladder, may require a hand-assisted laparoscopy or open laparotomy. Potential intraoperative consultation to other subspecialties may be required in these cases. It is the primary surgeons' responsibility to communicate with the consulting service that a single-incision laparoscopic approach is planned.
- Failure to identify the tumor extent preoperatively may lead to longer operative time if a single-port technique is used. Conversion to hand-assisted or open approach is prudent in these cases.
- Presence of preoperative umbilical or other incisional hernia does not preclude a single-incision approach; however, it may require lengthier operative time, extension of the incision, and possibly placement of a xenograft.
- Previous abdominal surgeries with extensive abdominal or pelvic adhesions may increase the operative time. A single incision may actually facilitate a faster abdominal adhesiolysis as it can partially be performed open via the port's wound protector with assistance of a retractor.
- Crohn's terminal ileitis or right colitis with a large phlegmon or perforation with complex fistulae or abscess may preclude a single-incision laparoscopic approach.
- Previous appendectomy is not a contraindication to single-incision laparoscopic right hemicolectomy, as adhesions may be the only intraoperative finding with minimal increase to operative time.

Table 1: Absolute Contraindications to Single-Incision Laparoscopic Right Colectomy

– Complex terminal ileal or right colonic inflammatory bowel disease
– Abscess, fistula, obstruction, perforation
– Colon tumor size of more than 7 cm
– Colon obstruction with proximal massive intestinal distention
– Preoperative decision for complex en bloc resection
– Midline incisional hernia longer than the maximum single incision—5 cm

IMAGING AND OTHER DIAGNOSTIC STUDIES

- Preoperative colonoscopy with India ink tattoo injection is of paramount importance for smaller nonpalpable benign or malignant lesions or polyps, which are not resectable endoscopically. The surgeon must clearly identify the site of the tattoo at 5 cm distal to the lesion preoperatively in the absence of other anatomic landmarks, such as the ileocecal valve or the appendiceal orifice and the cecum itself.
- India ink tattoo by different gastroenterologists has been reported to be placed proximally around the lesion, distal to the lesion, or both proximal and distal to the lesion, leading occasionally to a false distal colonic resection margin.
- Inadvertent extracolonic India ink injection may lead to inflammatory—diverticulitis type—reaction of the surrounding mesentery and omentum, thus making the single-incision laparoscopic colonic mobilization challenging.
- Absence of preoperative tattoo for smaller or nonpalpable lesions distal to the ileocecal valve may lead to failure to localize the lesion intraoperatively, lengthy procedure and possible need for intraoperative colonoscopy, and conversion to laparotomy. This may lead to significant air insufflation of the colon and small intestine unless a carbon dioxide (CO_2) colonoscopic insufflation is available. Compressing the terminal ileum with a laparoscopic grasper during the intraoperative colonoscopy may prevent small intestinal distension.
- Computed tomography of the abdomen and pelvis with oral and intravenous (IV) contrast helps determine the feasibility of a single-incision laparoscopic approach and identifies the exact location of larger right colonic neoplastic lesions, involvement of adjacent organs or structures, mesenteric adenopathy and possible metastatic lesions, hernia, and other abdominal nonrelated pathology. Inflammatory disease of the terminal ileum or right colon is suspected by the presence of phlegmon, abscess, fistula, or obstruction.
- Magnetic resonance imaging (MRI) of the abdomen may assist with the identification of indeterminate liver lesions and with the assessment of metastatic lesions preoperatively.
- Positron emission tomography (PET) computed tomography is not generally needed preoperatively.
- Preoperative barium enema or small bowel follow-through contrast study has generally been replaced by colonoscopy.
- Ultrasound (US) of the abdomen has limited usefulness for the identification of colonic pathology.
- A carcinoembryonic antigen is obtained as baseline tumor marker for surveillance.

SURGICAL MANAGEMENT

Preoperative Planning

- Full bowel preparation is administered the day prior to surgery. Right colectomy without bowel preparation is equally safe but it may increase the weight and volume of the right colon and impair the laparoscopic handling of the colon. Furthermore, extraction of the specimen via a small 3.5-cm single incision may become challenging.
- Preoperative medical or pulmonary cardiac clearance as necessary.
- Correction of preoperative anemia as needed.
- IV antibiotics, venous thromboembolism (VTE) prophylaxis, μu-receptor antagonist (alvimopan) immediately preoperatively, correction of electrolyte abnormalities.

Instrumentation

- A bariatric length, 10-mm 30-degree camera is used. Use a right-angle adaptor for fiberoptic attachment to the camera, if needed, to avoid conflict of the fiberoptic cord with other laparoscopic instruments. Use a preheated camera or other devices for camera lens cleansing. Repeated camera cleansing requires frequent removal via the single port, which adds time to the procedure.
- Two bariatric length laparoscopic bowel graspers are used.
- Bariatric length laparoscopic energy device such as 43-cm LigaSure, 5 mm with monopolar tip, Enseal, or similar is used. Energy devices that produce excessive moisture/fog may impair the visibility as most single-incision laparoscopic ports have a side port for smoke evacuation at the same level with the channel for air insufflation.
- Bariatric length laparoscopic 5-mm suction irrigation
- Laparoscopic smoke evacuator channel
- Laparoscopic scissors
- Laparoscopic 5-mm or 10-mm clip applier (optional)
- Laparoscopic Endoloop polydioxanone (PDS) for the ileocolic vascular pedicle
- Staplers: linear gastrointestinal anastomosis (GIA) 75-mm, double, or preferably triple line, blue staple cartridges
- Second set of instruments for extracorporeal anastomosis

Patient, Team, and Operating Room Setup

- The patient is placed over a foam pad on supine position with the arms and legs tucked to the side and secured to the table with a Velcro safety strap or broad tape across the chest and lower extremities (**FIG 1**).
- Sequential compression devices (SCDs) are applied to the lower extremities.
- A laparoscopic operating room (OR) table with steep tilting is used. Test maximum tilting prior to draping to assess patients' secure positioning on the table.

FIG 1 • Patient positioning. The patient is placed over a foam pad on supine position with the arms and legs tucked to the side and secured to the table with a Velcro safety strap or broad tape across the chest and lower extremities.

- A Foley catheter is inserted and taped over the right thigh in order to avoid urethral trauma during patient positioning changes throughout the operation.
- A bear hugger or other thermal device is applied to the chest and legs.
- Protecting foam pad is placed over the head to protect from injury with laparoscopic instruments.
- The laparoscopic tower and energy devices are placed to the right of the patient's head.
- The surgeon stands to the patient's left side with the assistant standing to his right side (**FIG 2**). The scrub nurse stands by the patient's right leg. One or two high-definition monitors are placed to the patient's right side at eye level in front of the surgeon.

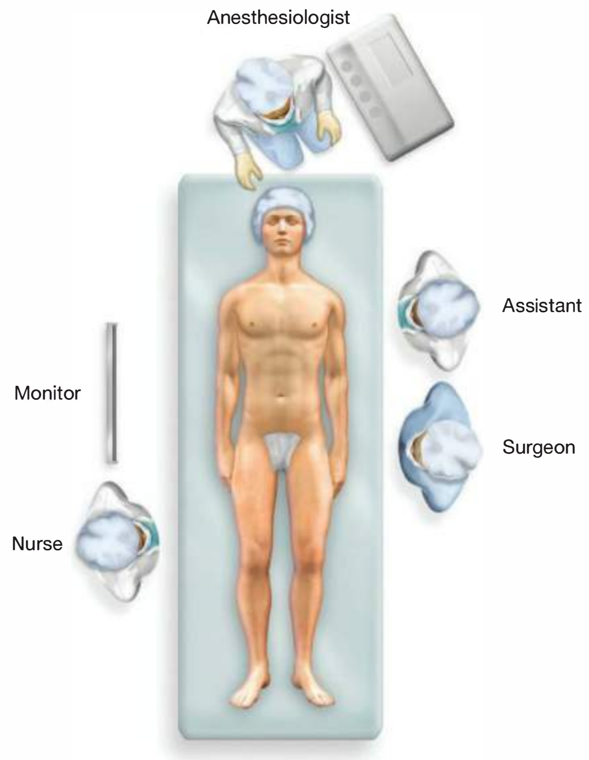


FIG 2 ● Team positioning. The surgeon stands to the patient's left side with the assistant standing to his right side. The scrub nurse stands by the patient's right leg. One or two high-definition monitors are placed to the patient's right side at eye level, in front of the surgeon.

DIAGNOSTIC LAPAROSCOPY—SINGLE MULTICHANNEL PORT TECHNIQUE

- After positioning and securing the patient, the abdominal field is prepped and draped. We recommend laparoscopic draping with side plastic bags/pockets to allow for bariatric instrument placement. All laparoscopic cords are brought via the patient's upper chest side and secured with the drape's Velcro.
- A 3.5-cm vertical midline incision is performed with no. 11 scalpel through the umbilicus (**FIG 3A,B**).
- Assemble all channels of the single port on the back table to avoid losing parts outside the sterile field. Place the laparoscopic multichannel single port (for neoplasia, a single port with a wound protector is required) (**FIG 4A,B**). Insufflate CO_2 pneumoperitoneum to 15 mmHg.
- Perform a diagnostic laparoscopy. The surgical assistant/camera holder and the surgeon stand by the patient's left side, with the assistant to the surgeon's right side. Tilt the OR table to a steep Trendelenburg position and airplane it to the left for maximum exposure of the ileocolic pedicle and the medial mobilization of the small intestine. There is no need for placement of sponges or Ray-Tecs in the abdomen for retraction.
- Minimize excursion/cluster effect around hands and camera between the surgical assistant and the operating

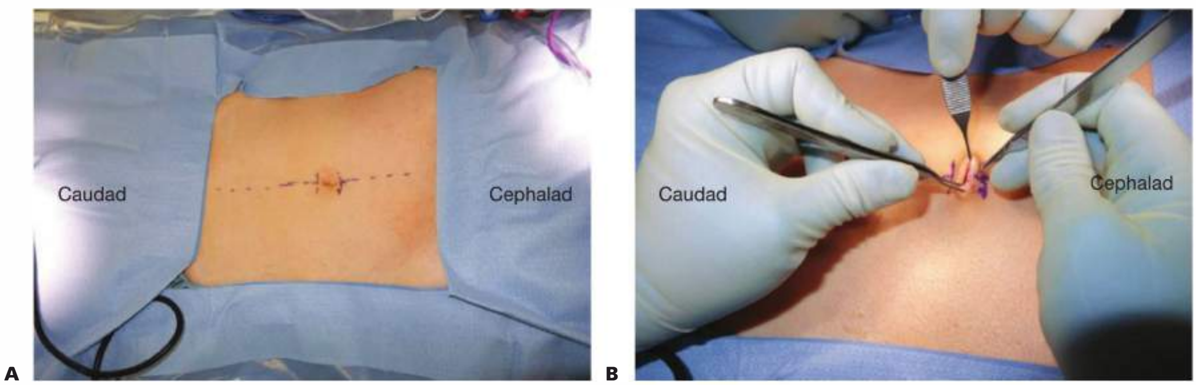
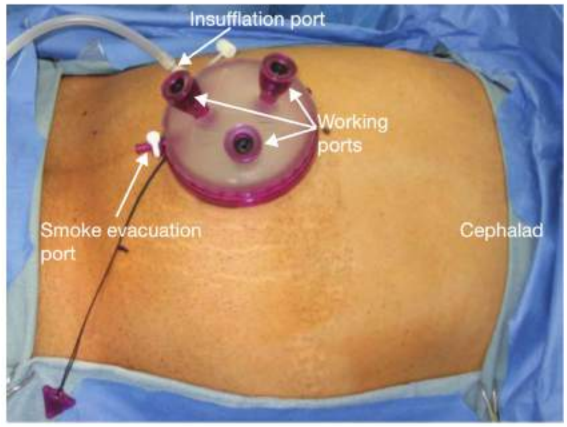


FIG 3 ● Single-incision laparoscopic surgery (SILS) port placement. **A.** Skin markings. **B.** Skin incision.

A



B

FIG 4 ● Single-incision laparoscopic surgery (SILS) port placement and configuration. **A.** A wound protector is used. **B.** A multiport channel with three working ports and insufflation port and a smoke evacuator port is used. The port is assembled on a side table prior to insertion in the patient.

surgeon. Adhere to the principle that the surgeon should position his assisting (nondominant hand) instrument distal tip (for grasping, retracting, or suctioning) as close as possible to his dominant operating instrument tip (i.e., energy device at the dissecting surgical plane). This distance should be about 3 to 4 cm between the two instruments' tips. For example, hold the ileocolic vascular pedicle just above the site of the division site rather than holding the cecum itself which is far more distant from the pedicle. This technique allows achieving a wide angle between the two instruments outside the abdomen as they exit and cross via the single port, thus leading to no instrument cluster effect between the surgeon's hands.

- The assistant camera holder will avoid clustering with the surgeon's instruments outside the abdomen if he or she abducts the camera as far as possible from the surgeons' hands and uses the camera's 30-degree angulation for side view as well as the zoom-in option.
- Minimize the need for frequent instrument exchange via the single port, such as for camera lens cleaning or exchange of graspers with monopolar laparoscopic scissors. Instead, consider using energy devices that provide both dissection and sealing-cutting effect, thus allowing constant progress in the operating field and significant time saving.
- The surgeon and the assistant can either switch sides (caudal and cephalad to the patient's left side) during the various steps of the procedure or just rotate the single port clockwise or counterclockwise while the instruments stay in the abdomen under direct visualization with the camera, thus achieving different angles with the camera, better exposure, and visualization.
- If the surgeon's hands are crossing, then rotating the port or switching positions with the assistant (caudal–cephalad) will improve exposure.
- The OR table is also tilted accordingly during the various steps of the procedure to increase exposure and prevent instrument clustering.

DIVISION OF THE ILEOCOLIC VASCULAR PEDICLE AND MEDIAL TO LATERAL MOBILIZATION OF THE ASCENDING MESOCOLON

- The patient is positioned in a steep Trendelenburg position with the table tilted maximally toward the patient's left side. The surgeon stands on the patient's lower left side, using a grasper in the nondominant hand and an energy device on the dominant hand. The assistant stands up the surgeon's right side holding the camera.
- If the omentum is adherent medially to the right colon, we start the procedure with the dissection of the omentum off the colon or perform an omentectomy to allow for maximum exposure of the ileocolic pedicle and the ascending colon mesentery.
- Dissect the terminal ileal retroperitoneal attachments and mobilize it medially toward the midline.
- Identify the ileocolic vessels as they cross over the third portion of the duodenum (**FIG 5**).
- Perform a medial to lateral mobilization of the ascending mesocolon (**FIG 6**). Dissect under (dorsal) the ileocolic vessels, entering the plane between the ascending mesocolon and the retroperitoneal structures (duodenum and Gerota's fascia). The transition between the fat planes of the ascending mesocolon and Gerota's fascia can be easily identified and aids to stay in the proper dissection plane.
- Using an energy device, we divide the ileocolic vascular pedicle at its origin as it crosses the third portion of the

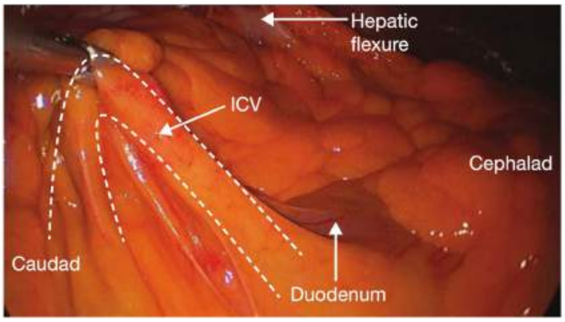


FIG 5 ● Identification the ileocolic vessels (ICV) as they cross over the third portion of the duodenum.

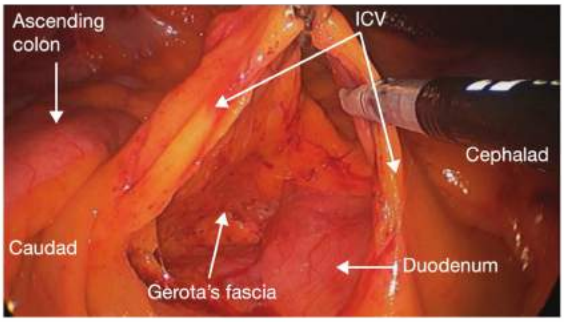


FIG 7 ● Transection of the ileocolic vessels (ICV). Using an energy device, we divide the ileocolic vascular pedicle at its origin as it crosses the third portion of the duodenum.

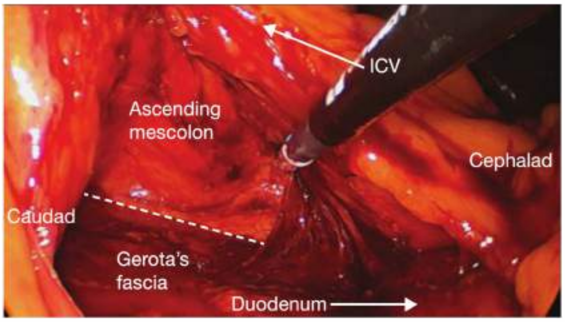


FIG 6 ● Medial to lateral dissection of the ascending mesocolon. Dissect under (dorsal) the ileocolic vessels, entering the plane between the ascending mesocolon and the retroperitoneal structures (duodenum and Gerota's fascia). The transition between the two fat planes (mesocolon and Gerota's fascia) can be easily visualized *(dotted line)*.

duodenum (**FIG 7**) while holding the vessel stump with a grasper to avoid retraction or residual bleeding.

- Place hemostatic clips or Endoloop PDS at the divided stump to secure the hemostasis.
- There is no need for laparoscopic stapled pedicle division unless severe atherosclerosis or vessels larger than 7 mm in size are present, which preclude usage of a laparoscopic energy device. In that case, we may use an Endo GIA stapler with a vascular load.
- Complete the medial to lateral dissection of the ascending colon mesentery, off the retroperitoneal attachments without entering Gerota's fascia, identifying and protecting the right gonadal vessels and the right ureter.
- Continue the medial to lateral dissection of the ascending colon mesentery in a cephalad direction, separating it from the second and third portion of the duodenum and the head of the pancreas in an atraumatic fashion. This will allow for an easier mobilization of the hepatic flexure later during the case.

MOBILIZATION OF TERMINAL ILEUM, ASCENDING COLON, HEPATIC FLEXURE, AND PROXIMAL TRANSVERSE COLON

- Divide the terminal ileal mesentery with energy device flush to the ileocolic vascular pedicle up to the mesenteric border of the terminal ileum at the selected site of proximal intestinal division (**FIG 8**).
- In addition, the terminal ileum is mobilized off the retroperitoneal attachments toward the midline. This will allow for a tension-free extraction via the single port site for the extracorporeal division without tension or risk for avulsing the mesentery. Morbidly obese patients require generous terminal ileum medial mobilization to allow for a tension-free specimen extraction via the single port.

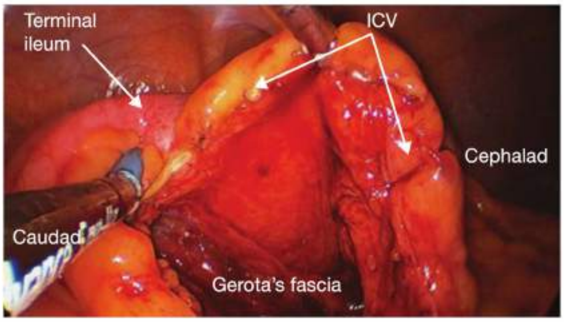


FIG 8 ● Division of terminal ileum mesentery. Transect the terminal ileum mesentery down to the bowel wall with the energy device, keeping the ileocolic vessels (ICV) in the specimen side.

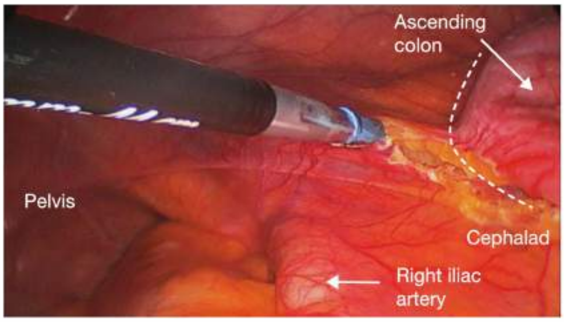


FIG 9 ● Lateral mobilization of the ascending mesocolon. Transect the white line of Toldt *(dotted line)* with the energy device.

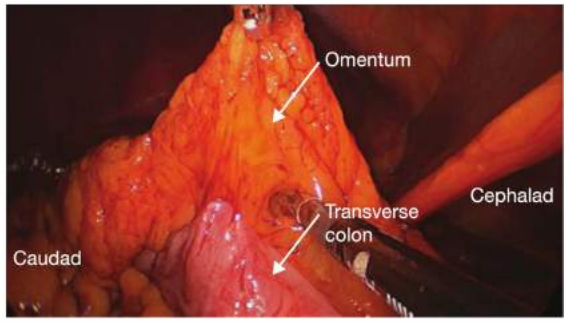


FIG 10 ● Entrance to the lesser sac. Enter the lesser sac via the antimesenteric border of the proximal transverse colon and perform a formal hepatic flexure mobilization using the energy device.

- Mobilize the ascending colon medially by transecting its lateral peritoneal attachments (the white line of Toldt) (**FIG 9**).
- Place the patient on a reverse Trendelenburg position and keep the OR table tilted to the left. The surgeon is positioned now cephalad and the assistant/camera holder is positioned to his or her left side.
- Enter the lesser sac via the antimesenteric border of the proximal transverse colon (**FIG 10**) and perform a formal hepatic flexure mobilization using the energy device.
- Elect the point of distal division of the right colon and divide the corresponding mesentery up to the site of the distal resection margin and to the right of the middle colic vessels (**FIG 11**).
- A more generous distal mobilization of the colon is required compared to hand-assisted laparoscopy, by approximately another 5 cm, to allow for a tension-free extraction of the specimen and to avoid mesenteric avulsion during specimen extraction.

FIG 11 ● Division of the midtransverse colon mesentery. Elect the point of distal division of the right colon and divide the corresponding mesentery up to the site of the distal resection margin and to the right of the middle colic vessels.

EXTRACORPOREAL MOBILIZATION AND TRANSECTION OF THE SPECIMEN

- Grasp the terminal ileum at the proximal resection site securely before evacuating the pneumoperitoneum.
- Place wet lap sponges around the wound protector and use a second towel for the instruments used for creation of the anastomosis in order to avoid fecal contamination to the laparoscopic surgical drapes.
- Extract the terminal ileum first and divide it with a GIA linear 75-mm, double or triple, blue staple load (**FIG 12**). Use a grasper to hold into the terminal ileum stapled stump line and reintroduce into the abdomen.
- Extract the right colon and divide it at the distal site with a GIA linear 75-mm, double or triple, blue staple load (**FIG 13**).
- If the colon with the attached mesentery is too thick or in case of neoplasia the tumor is larger than the incision, then elongate the incision superiorly using an army navy

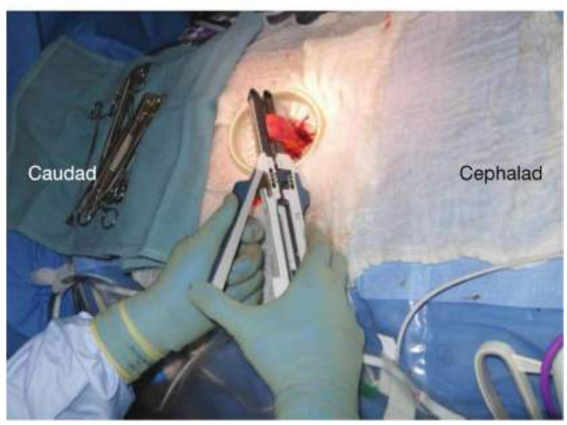


FIG 12 ● Extracorporeal transection of the terminal ileum. Extract the terminal ileum first and divide it with a GIA linear 75-mm double or triple blue staple load.

retractor to "hook" under the fascia and protect the wound protector from perforation. Use a no. 11 scalpel in a sawing motion or electrocautery to elongate the incision as necessary and extract the specimen.

- Divide the remaining mesentery and pass the specimen to pathology, or open the specimen at the back table to confirm adequate margins in case of neoplasia.

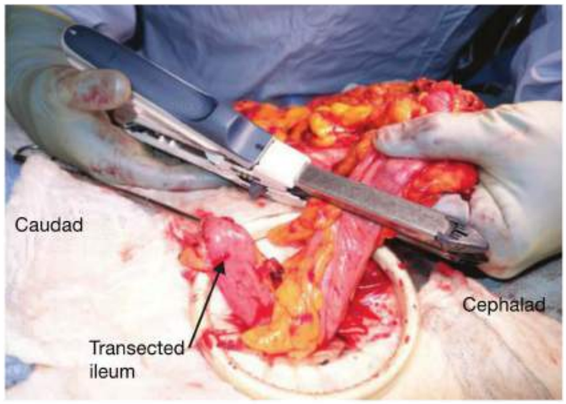


FIG 13 ● Extracorporeal transection of the midtransverse colon. Extract the right colon and divide it at the distal site with a GIA linear 75-mm, double or triple, blue staple load.

EXTRACORPOREAL ANASTOMOSIS

- Perform an extracorporeal side-to-side, functional end-to-end, ileotransverse anastomosis with a GIA linear 75-mm, double or triple, blue staple load (**FIG 14A,B**).
- Inspect the ileal and colonic segments to rule out torsion prior to firing the stapler. The surgeon can palpate with a finger along the mesenteric margin of the terminal ileum mesentery and the distal colon mesentery toward the base at the retroperitoneum and ensure that there is no intestinal torsion.
- Inspect for bleeding from the anastomotic line.
- Approximate the anastomotic stump defect with another GIA linear 75-mm, double or triple, blue staple load. Sometimes, a second load is required, thus eliminating the need for a thoracoabdominal (TA) double staple line, although its use remains on the surgeon's preference.
- Introduce the anastomosis into the abdomen; inspect for bleeding and fecal spillage. Cover the anastomosis with the rest of the omentum or small intestine and ensure there is no torsion of the anastomosis. When in doubt, proceed again with laparoscopic inspection.

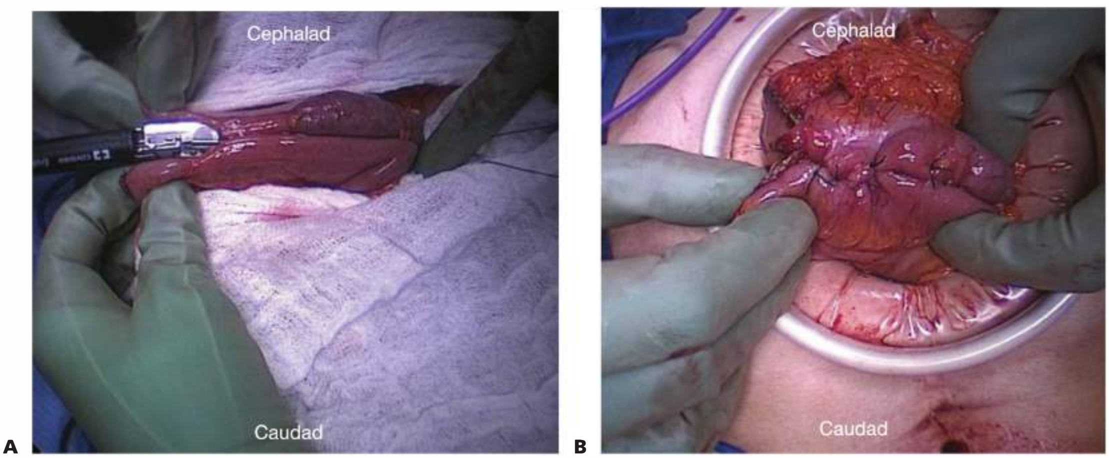


FIG 14 ● Extracorporeal anastomosis. **A.** An anatomic side-to-side, functional end-to-end stapled ileocolonic anastomosis is constructed. **B.** The anastomosis is tension-free and has excellent blood supply.

WOUND CLOSURE

- It is advised to place an antiadhesive sheet posterior to the midline fascia edges while avoiding contact with the anastomotic staple lines. Remove the wound protector and close the fascial incision with no. 1 PDS suture.
- Irrigate the wound copiously with normal saline; obtain wound hemostasis.
- Approximate the skin edges with staples while leaving the umbilical skin edges opened and tucked with a Vaseline gauze with a cotton ball.
- The procedure is a clean contaminated one and leaving the umbilicus skin edges open may protect it from wound infection.

PEARLS AND PITFALLS

Preoperative workup	■ Correct identification of the underlying pathology and extent of the tumor in relation to other organs allows for careful selection of the laparoscopic single-incision technique.
Lesion localization	■ India ink tattoo placement when indicated for preoperative localization of the lesion and the distal resection margin is of paramount importance.
Patient positioning, laparoscopic instruments	■ Securing the patient's position, use of OR table tilting, single port rotation, and usage of bariatric length instruments and camera are necessary for laparoscopic single-incision surgery.
Surgeon and assistant position	■ The surgeon should change his or her position in relation to the assistant several times during the procedure in order to achieve adequate exposure and visualization.
Laparoscopic instrument and tissue handling	■ The tip of the assisting and dominant laparoscopic instruments are positioned as close as possible to each other in the surgical field in order to avoid hand clustering outside the abdomen.

POSTOPERATIVE CARE

- A fast-track postoperative laparoscopic course is initiated.
- The orogastric tube is discontinued in the OR upon completion of the procedure.
- IV acetaminophen, alvimopan, and opioid patient-controlled anesthesia (PCA) or abdominal wall nerve block-"tap" is used as per surgeon's preference the day of surgery. Discontinue the PCA within 36 hours and add IV or oral nonsteroidal antiinflammatory drugs (NSAIDs) such as ketorolac to transition to oral analgesics.
- Ice chips/water sips is introduced the day of surgery with the goal to advance to clear liquids within 24 hours and to a regular high-fiber diet within 48 hours postoperatively.
- The Foley catheter is discontinued within 24 hours.
- Perioperative antibiotics, VTE protocol—mechanical and pharmacologic—as well as early ambulation is initiated within 24 hours of surgery.
- Incentive spirometer is initiated as per standard hospital policy.
- Wound care need is minimal: Remove the umbilical dressing 2 to 3 days postoperatively.
- The patient usually can be safely discharged home within 72 hours when passage of flatus is documented and regular diet is tolerated by at least two consecutive meals, and there are no other adverse postoperative findings such as signs of infection.
- There is no need to wait until the patient has a bowel movement prior to discharge.
- No weight lifting more than 20 lb is recommended for 4 to 6 weeks postoperatively in order to avoid incisional hernia.

OUTCOMES

- Single-port laparoscopic hemicolectomy is considered to be an equally safe and cost-effective technique with better cosmesis, similar morbidity and operative time, possible less postoperative pain and faster return to full activities, possible shorter hospital stay, and comparable oncologic outcomes when performed for neoplastic diseases to conventional hand-assisted or multiport laparoscopic approach.
- It is achieved with equipment that the hospital already has available, with the exception of the single port which is not reusable, and requires no additional training for the operative room personnel while it is reproducible by surgeons who perform advanced laparoscopy.
- It does require one assistant to the surgeon who has advanced laparoscopic skills.
- The laparoscopic single-incision right colectomy technique may contribute to decreased total hospital cost.

COMPLICATIONS

- The procedure has similar morbidity and mortality rates and comparable rates for conversion to laparotomy when compared to conventional laparoscopy.
- Anastomotic leak rate is less than 2%.
- The single-incision laparoscopic technique for right hemicolectomy has the option for conversion to multiport or hand-assisted laparoscopy.
- Because a larger sized laparoscopic port is used, there is a slight increase in the incidence of incisional hernia (1% or more) compared to multiport laparoscopy. However, the incisional hernia rates are similar to the ones in hand-assisted laparoscopy.
- Single-incision laparoscopy may require a longer operative time during the early learning curve. This can complicate an already challenging operation especially for hepatic flexure or proximal transverse colon neoplastic lesions.
- It is intrinsically a one-operating surgeon technique with less involvement of the assistant surgeon and with a potential negative impact on resident education during the learning curve period.

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Chapter 13

Transverse Colectomy: Open Technique

Y. Nancy You

DEFINITION

- The transverse colon is the segment of the abdominal colon between the hepatic and the splenic flexures. The transverse colon is an intraperitoneal organ of variable length, bound by the two flexures, which are secondarily retroperitoneal areas of the colon typically fixed in position.
- The main blood supply to the transverse colon is the middle colic vessels. The transverse colon, with transverse mesocolon and middle colic vessels, lies in intimate proximity to the lesser sac, which is in turn bound by the quadrate lobe of the liver, the stomach, the pancreas, and the omentum. The operative surgeon must be fully familiar with these anatomic relations in order to avoid injury to these nearby structures.
- Transverse colectomy is a relatively uncommon procedure, as pathology in the proximal transverse colon is often addressed by an extended right hemicolectomy, whereas pathology in the distal transverse colon is often addressed by an extended left hemicolectomy.
- Indications for transverse colectomy may be broadly divided into benign and malignant reasons.
- Benign diseases with pathology focally located within the segment of the transverse colon represent the most natural indication for transverse colectomy. Examples may include focal inflammatory processes, localized trauma, or local perforation.
- Transverse colectomy for primary malignancies of the transverse colon has been controversial.[1] Because of the varying contributions to the lymphatic drainage of the transverse colon cancer from the ileocolic, the right colic, and the left colic blood vessels, extended right or extended left hemicolectomy has been preferred over segmental transverse colectomy for primary tumors of the transverse colon.[2]
- Transverse colectomy may be required as a part of a curative en bloc resection of a noncolonic malignancy arising from a nearby organ due to the close proximity of the transverse colon to other structures around the lesser sac. Surgeons must be cognizant of anatomic relations in order to safely carry out the intended operation.

DIFFERENTIAL DIAGNOSIS

- Endoscopic tissue biopsy is a key step in the diagnostic workup of patients with both benign and malignant diseases involving the transverse colon.
- In patients presenting with a locally advanced tumor mass that obliterates the lesser sac and involves adjacent organs such as the stomach, the pancreas, and the transverse colon, care must be undertaken to differentiate malignancies of the colonic origin versus those that arose from adjacent organs but involves the transverse colon secondarily. Tissue diagnosis by biopsy should be secured in order to execute the optimal treatment regimen according to the primary malignancy.

PATIENT HISTORY AND PHYSICAL FINDINGS

- The goals of preoperative assessment should include determining whether urgent versus elective intervention is needed, facilitating intraoperative planning, and assessing the benefits versus risks toward a sound surgical decision.
- The patient should be examined for fitness to undergo an operation through a detailed assessment of patient's medical history, performance status, medication regimens, other medical needs, and psychosocial competency.
- Symptoms such as abdominal cramping, difficulty with passage of stool or flatus, bleeding, or severe pain should be queried. Conditions that would necessitate urgent/emergent rather than elective surgical intervention must be ruled out. Patients with an obstructing transverse colonic lesion and a competent ileocecal valve can rapidly develop a closed loop obstruction with high risks for ischemic colon and perforation and must be attended to emergently (**FIG 1**).
- Elements of prior surgical history that may present intraoperative difficulties such as previous stomach, pancreas, or colonic operations, and prior antecolic or retrocolic bowel bypass reconstructions, must be elicited. Prior operative reports should be obtained and reviewed.

IMAGING AND OTHER DIAGNOSTIC STUDIES

- All patients should ideally undergo both abdominal–pelvic cross-sectional imaging as well as endoscopic examination with possible biopsies.

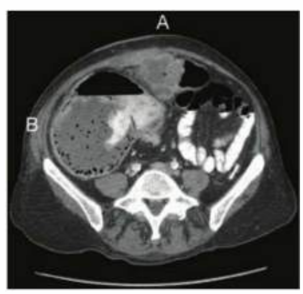

FIG 1 ● CT scan showing an obstructing transverse colonic lesion (*A*) in a patient with a competent ileocecal valve. Closed loop obstruction causes massive dilation of the cecum (*B*). The high risks for ischemia and perforation require emergent surgical intervention.

FIG 2 ● Colonoscopic view of a mass lesion in the transverse colon, which is recognized by the triangular shape of the bowel lumen and the anchoring splenic and hepatic flexures. Histologic diagnosis can be obtained by endoscopic biopsy of the mass.

- Endoscopic examination of the colon should be undertaken preoperatively to confirm the location and the focality of the pathology within the transverse colon (**FIG 2**).
  - Endoscopically, the transverse colon can be recognized by the triangular shape of the bowel lumen as well as by the anchoring landmarks of the splenic and hepatic flexures.
  - If there is any doubt as to whether the lesion will be able to be localized with confidence intraoperatively, then the lesion should be marked with endoscopic tattooing.
  - If there is any concern for involvement of adjacent organs, such as the stomach, an esophagogastroscopy should also be performed.[3]
- Cross-sectional imaging of the abdomen is performed through computed tomography (CT) or magnetic resonance imaging (MRI) scans. Imaging characteristics may supplement histologic data and aid in the differential diagnosis. In addition, percutaneous biopsy may be needed.
  - In cases of malignant disease, imaging will help differentiate between colonic and noncolonic origin of the disease.
  - Presence of distant metastatic disease and evidence of direct local invasion to adjacent organs should be assessed and appropriate intraoperative management plans should be made.
  - Finally, any abnormal-appearing adenopathy along vessels other than the middle colic vascular should be specifically assessed in order to determine whether the particular malignancy would be better managed through an extended right or extended left colectomy rather than a transverse colectomy.

SURGICAL MANAGEMENT

- Thorough preoperative preparation, confirming that the diagnosis is correct, the indication is appropriate, and that possible intraoperative findings have been anticipated and planned for, is the basis for successful intraoperative management and the speedy postoperative recovery.

Preoperative Planning

- The operative surgeon should thoroughly review the patient's history and diagnostic workup to minimize any unexpected and unplanned for intraoperative finding.
- Diagnostic biopsy and histologic results should be verified. A malignant diagnosis should be particularly noted in order to help determine the extent of the bowel resection and lymphadenectomy.
- Documentation from preoperative endoscopy should be reviewed, particularly if the operative surgeon did not perform the procedure. The presence and location of a marking tattoo should be confirmed.
- Preoperative imaging is used to help anticipate any involvement of the adjacent organs and the possible need for en bloc resection intraoperatively. Any need for additional technical assistance from other surgeons should be planned for.
- In cases of perforation and anticipated significant intraperitoneal contamination that may render bowel anastomosis unsafe, plans should be made for ostomy marking and education preoperatively.
- Preoperative bowel preparation, whether antimicrobial and mechanical, mechanical only, or no preparation, is a highly variable practice and is left to the discretion of the practicing surgeon.
- Prophylactic intravenous antibiotics with coverage against gram-positive, gram-negative, and anaerobic flora of the skin and gut are typically administered prior to incision and continued for the first 24 hours.
- Prophylaxis against deep venous thrombosis is typically administered prior to incision and during the hospital stay.

Positioning

- Patients are usually placed in a supine position. If there is any possibility of extending the resection to the left colon or any possible need for intraoperative endoscopy, consideration should be given for placing the patient in lithotomy position.

INCISION AND ABDOMINAL EXPLORATION

- A midline incision extending from the epigastrium to below the umbilicus is made.
- The abdominal cavity is explored for the presence of other pathology not identified by preoperative imaging. In cases of malignant disease, peritoneal lining, omentum, and hepatic and bowel surfaces are inspected and palpated for any evidence of metastatic disease. In women, the pelvic organs, including the ovaries, should be inspected. Any suspicious nodule should be biopsied for pathologic assessment as findings may affect the decision of proceeding to the remaining of the procedure.

OMENTUM DISSECTION AND EXPOSURE OF THE LESSER SAC

- The relationship between the transverse colon pathology and the lesser sac is assessed.
- Exposure to the lesser sac is gained in one of two ways, depending on whether omentectomy is performed or not.
- If disease pathology does not necessitate en bloc omentectomy or if there is desire to preserve as much of the omentum as possible, then greater omentum is retracted cephalad and the transverse colon is retracted caudad. This reveals the avascular plane between the greater omentum and the transverse mesocolon (**FIG 3**). The pale yellow omental fat is distinguished from the fat of the appendices epiploicae of the transverse colon (**FIG 4**). As this plane is dissected, the greater omentum is freed from the transverse colon and mesocolon and entrance into the lesser sac is gained. This can be confirmed by visualization of the posterior wall of the stomach dorsally and of the anterior surfaces of the duodenum, pancreas, and transverse mesocolon ventrally.
- If the disease pathology necessitates en bloc resection of part or all of the omentum, then the gastrocolic ligament should be divided. The gastroepiploic artery arcade is identified along the greater curvature of the stomach. Dissection of the omentum is carried out either proximal (inside of) or distal (outside of) the arcade depending on the extent of the disease, the surgeon preference, and the desire to preserve the gastroepiploic arcade (**FIG 5**). The deeper avascular plane of the lesser sac, deep to the omentum but superficial to the transverse mesocolon, is entered. The omentum is thus isolated and divided between clamps.

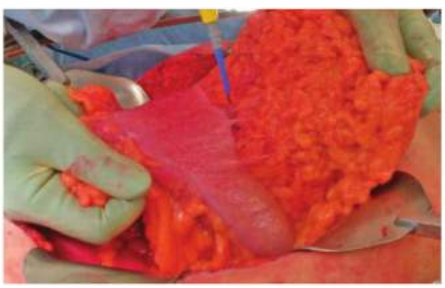

FIG 3 ● Retracting the greater omentum cephalad and the transverse colon caudad helps reveal the avascular plane between the greater omentum and the transverse mesocolon.

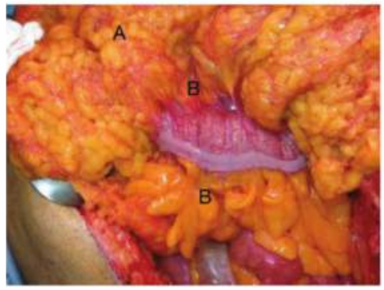

FIG 4 ● The pale yellow cobblestone fat of the omentum (*A*) is distinguished from the bright yellow smooth fat of the appendices epiploicae of the transverse colon (*B*).

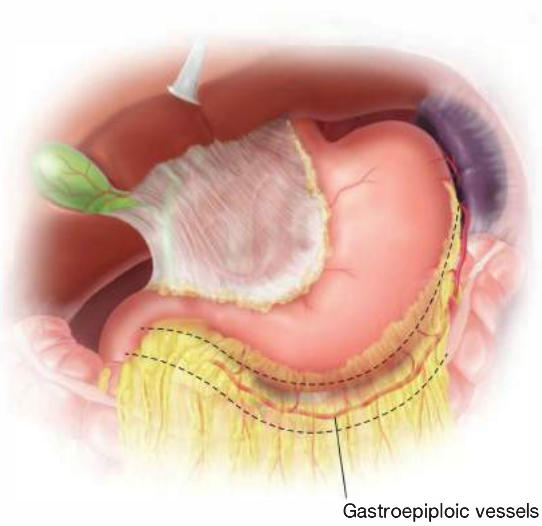

FIG 5 ● Dissection of the omentum is carried out either proximal (inside of) or distal (outside of) the gastroepiploic artery arcade *(dotted lines)* depending on the extent of the disease, surgeon preferences, and the desire to preserve the gastroepiploic arcade.

MOBILIZATION OF THE HEPATIC FLEXURE AND THE SPLENIC FLEXURE

- In order to gain enough mobility of the colon for intraoperative manipulation and to allow for a tension-free anastomosis after resection, it is often necessary to mobilize one or both of the flexures.[4]
- To mobilize the hepatic flexure, attention is turned to the ascending colon. The colon was retracted medially to identify the peritoneal reflection (white line of Toldt). The covering peritoneum of the paracolic gutter is then incised and divided using electrocautery. This avascular tissue plane is followed in a lateral to medial fashion, separating the colonic mesentery from

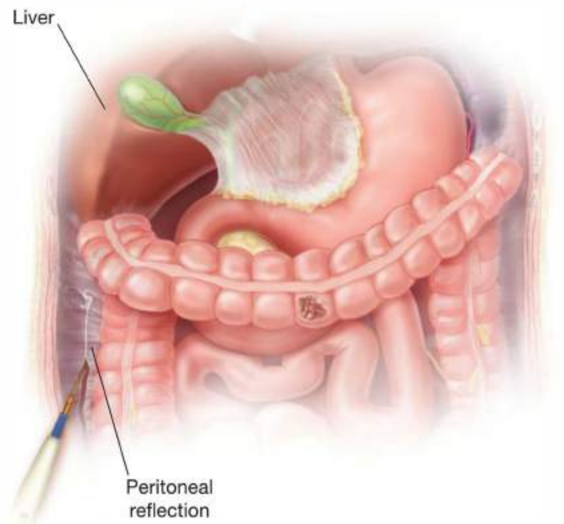

FIG 6 ● Anatomic relations for mobilization of the hepatic flexure: The ascending colon is retracted medially to identify the lateral peritoneal reflection (white line of Toldt); the covering peritoneum is divided to free the hepatic flexure. The hepatic surface, the gallbladder, the duodenum, and the anterior pancreas' surface are in close proximity, and care must be taken to avoid injury to these organs.

the retroperitoneum. This dissection plane is then carried cephalad toward the hepatic flexure, where division of the lateral peritoneal attachments will free the hepatic flexure. As the dissection is carried medially, care must be taken to avoid injury to the retroperitoneal duodenum (**FIG 6**). At this time, this dissection plane should be joined with prior dissection plane of the omentum so that communication to the lesser sac is established.

- To mobilize the splenic flexure, attention is turned to the descending colon. The descending colon is retracted medically to identify the lateral peritoneal attachments in a similar fashion as described in the mobilization of the ascending colon above. The avascular tissue plane is similarly followed and carried cephalad toward the splenic flexure (**FIG 7**). The splenocolic ligament is encountered in this process and divided using electrocautery. As the lower pole of the spleen comes into view, care should be taken to divide any adhesion between the omentum and the capsule as to avoid unintended capsular tears with retraction and dissection. Often, numerous adhesions between the omentum and the appendices epiploicae of the colon are encountered, and care must be taken to separate these either by electrocautery or between clamps to avoid bleeding. Finally, additional avascular ligaments to the stomach and/or the pancreas may be encountered and should be divided. After this, entry into the lesser sac is gained.

FIG 7 ● Mobilization of the splenic flexure. The splenic flexure of the colon (*A*) is retracted medially to identify and release the lateral peritoneal attachments. Care is taken to avoid injury to the spleen (*B*). The renocolic ligament (*C*), the splenocolic ligament (*D*), and the gastrocolic ligament (*E*) are identified and subsequently divided. This allows entry into the lesser sac and frees the distal transverse colon and splenic flexure from posterior retroperitoneal attachments.

The distal transverse colon and splenic flexure are now completely free of posterior retroperitoneal attachments and are fully mobile.

- After completing the dissections outlined in this step, the lesser sac is exposed completely, and the anterior surfaces of the transverse mesocolon should be in full view (**FIG 8**).

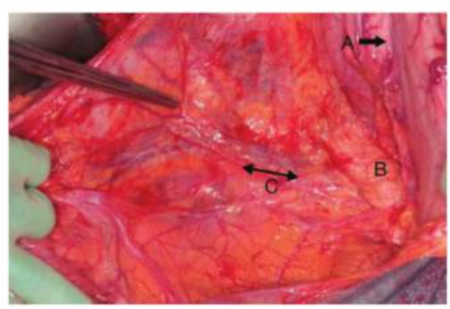

FIG 8 ● After the lesser sac is exposed completely, posterior wall of the stomach (*A*) and anterior surface of the pancreas (*B*) are visualized. The anterior surfaces of the transverse mesocolon with middle colic vessels (*C*) should be in full view.

ISOLATION AND DIVISION OF THE MIDDLE COLIC VESSELS

- The anatomy of the middle colic artery can be highly variable, and often, it does not present as a single vessel.
- The middle colic vessels can usually be identified by visual inspection or palpation along the transverse mesocolon via the lesser sac (**FIG 9**). When proximal ligation is needed, as is in the case for malignant disease, the overlying peritoneum is scored and the vessels should be dissected up to the lower border of the pancreas and ligated at this location (**FIG 9**). Care should be taken to avoid avulsion injury to the smaller collateral venous branches from the pancreaticoduodenal arcade and to avoid clamp injury to the pancreatic parenchyma. When the root of the middle colic vessels is identified, the surrounding nodal-bearing mesenteric tissue should be swept toward the specimen side. The vessels can then be isolated and controlled with suture ligature.
- If the middle colic vessels and the lesser sac are involved by the disease pathology and/or obliterated, then the middle colic vessels can be approached from the root of the small bowel mesentery. After the transverse mesocolon is retracted cephalad, the root of the mesentery is exposed. The overlying peritoneum is scored and dissected away to expose the anterior surface of the superior mesenteric artery.[5] The superior mesenteric artery is followed cephalad until the middle colic branches off, and the origin of the middle colic vessels can be isolated at this location (**FIG 10**). Extreme care must be undertaken to prevent injury to the underlying superior mesenteric vessels.

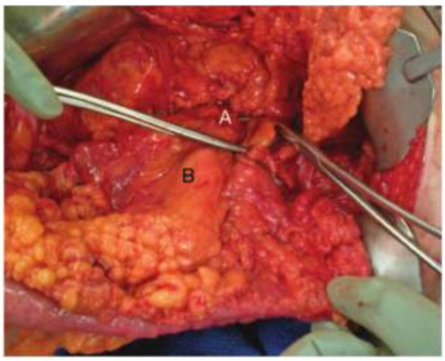

FIG 9 ● The middle colic vessels (*A*) are identified in the transverse mesocolon (*B*) and then dissected and taken between clamps. When proximal ligation of the middle colic vessel is required, the vessels are transected at the inferior border of the pancreas.

FIG 10 ● At the root of the small bowel mesentery, superior mesenteric artery (*A*) is followed cephalad until the middle colic branches off (*B*).

BOWEL RESECTION AND ANASTOMOSIS

- After division of the middle colic vessels, the blood supply to the transverse colon is maintained by the marginal artery, which can be found along the entire colon.
- The length of the bowel resection is determined by the extent of disease pathology and by the extent of the vascular supply. In cases of benign inflammatory disease, a margin of normal, healthy colon should be present for reanastomosis. In cases of primary malignancy of the transverse colon, a minimum gross negative margin of 5 cm proximal and distal to the tumor should be present.
- Once the points of proximal and distal bowel resection are identified, the presence of pulsatile blood supply to the cut ends via the marginal artery should be verified. If adequate blood supply cannot be confirmed, the length of the resection must be extended to points where blood supply is present.
- In most cases, bowel continuity is immediately reestablished. However, in cases of gross peritoneal contamination, gross inflammation, grave systemic illness, and others, the safety of a bowel anastomosis may be questioned, and creation of an end colostomy with either a mucous fistula or a long distal blind limb may be wise. A second-stage procedure can be performed for delayed reanastomosis.
- Once the decision for immediate bowel anastomosis is made, the mesenteric orientation is checked to ensure that there is no twisting.
- The bowel anastomosis can be performed in a variety of ways, depending on the surgeon's preference. The most common methods include a hand-sewn end-to-end technique or a stapled side-to-side (functional end-to-end) technique.
  - Using the hand-sewn technique, the divided ends of the colon are aligned end-to-end. The anastomosis is created in two layers, with an outer layer

of interrupted sutures placed into the seromuscular layer of the bowel wall and an inner layer of running suture placed full thickness, incorporating the bowel mucosa (**FIG 11**).

- In the stapled technique, the ends of the bowel are divided with a linear stapler. These divided ends of the colon are then aligned side-to-side. Small enterotomies are made typically by excising a corner off each staple line, allowing the jaws of the linear stapler to be inserted and the stapler to be fired (**FIG 12**). The area of the enterotomy through which the stapler has been inserted is then closed either by sutures or by a second firing of the stapler. Staple lines are inspected for hemostasis. Areas of crossing staple lines may be imbricated with interrupted suture in a Lambert fashion.
- If there is well-vascularized omentum nearby, it may be patched over the anastomosis to help future contain any anastomotic leakage postoperatively.

- The size of the mesenteric defect between the right and left colon should be assessed. Small- and moderate-sized defects should be closed to prevent internal hernia and any mesenteric twisting. Typically, if the middle colic vessels had been ligated at their origins, the defect is large and closure is not necessary.

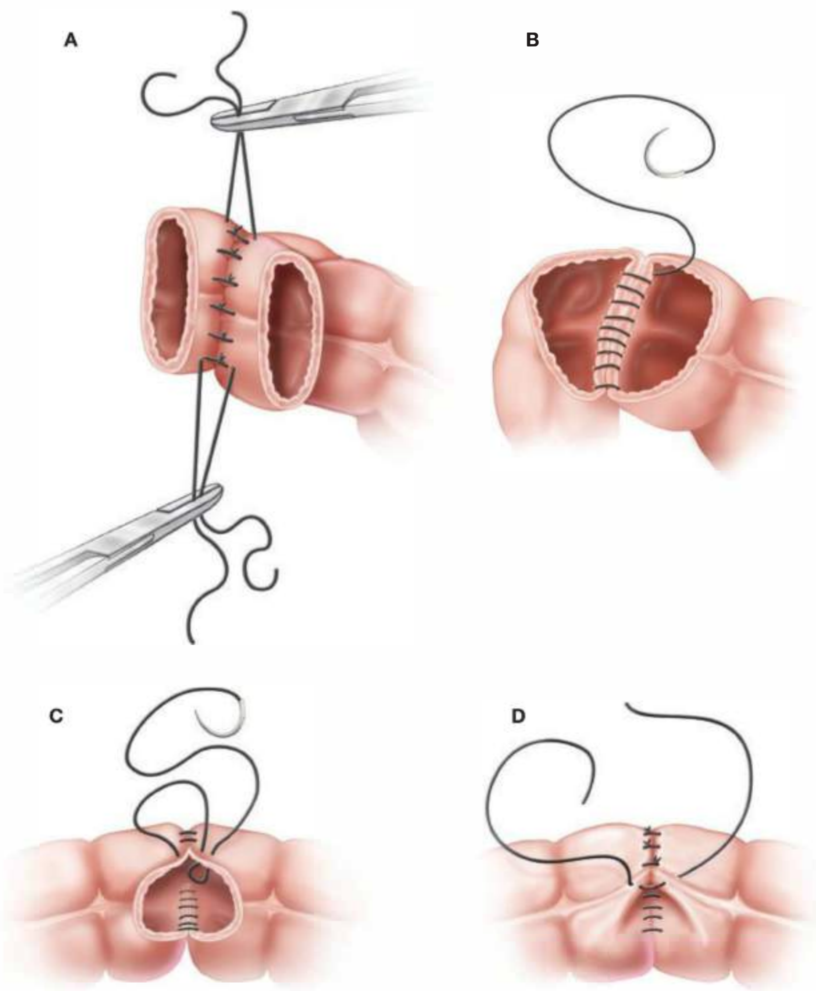

FIG 11 ● In a hand-sewn end-to-end colocolonic anastomosis, the divided ends of the colon are aligned **(A)**; the anastomosis is typically created in two layers, with an outer layer of interrupted sutures and an inner layer of running suture **(B–D)**.

FIG 12 ● In a stapled side-to-side (functional end-to-end) colocolonic anastomosis, the ends of the bowel are aligned side-to-side. Small enterotomies are made by excising a corner off each staple line, allowing the jaws of the linear stapler to be inserted into each lumen. The stapler is fired.

ABDOMINAL CLOSURE

- The abdominal fascia is closed after placing any remaining omentum between the bowel loops and the incision if possible. The skin incision is closed using absorbable subcuticular suture or staples. Abdominal drain is not placed.

PEARLS AND PITFALLS

Diagnostic and preoperative assessments	■ Any pathology outside of the transverse colon, transverse mesocolon, and middle colic vessels should be assessed on preoperative imaging, and an extended right or an extended left hemicolectomy should be performed if necessary. ■ In patients presenting with a large tumor mass, anatomic relations to the pancreas, duodenum, stomach, and mesenteric vessels should be carefully accessed. ■ Endoscopic and/or percutaneous tissue biopsy should be obtained to help differentiate malignancies of colonic versus noncolonic origin to allow for optimal treatment planning. ■ Patients presenting with an obstructing transverse colonic lesion and a competent ileocecal valve require emergent surgical attention to avoid perforation secondary to a closed loop large bowel obstruction. ■ The potential need for an ostomy in cases where bowel anastomosis may not be safe should be anticipated to allow for preoperative ostomy marking and education.
Omental dissection and exposure of the lesser sac	■ Exposure to the lesser sac can be gained with or without an omentectomy. ■ The pale granular yellow of the omental fat can be distinguished from the bright, smooth yellow of the fat of the colonic appendices epiploicae to help identify the avascular dissection plane.
Mobilization of the hepatic and/or splenic flexure	■ The surgeon should not hesitate to mobilize either or both of the flexures, as it often greatly facilitates intraoperative manipulation and facilitates a tension-free bowel anastomosis.
Isolation and ligation of the middle colic vessels	■ When the root of the middle colic vessels is approached through the lesser sac, injury to the small veins at the inferior border of the pancreas should be avoided. ■ When the root of the middle colic vessels is approached from the root of the small bowel mesentery, injury to the superior mesenteric vessels should be avoided.
Bowel resection and anastomosis	■ A transverse colectomy can be easily converted to an extended right or an extended left hemicolectomy if needed by intraoperative findings. ■ In some cases, immediate bowel anastomosis may not be safe, and an end colostomy can be made with either a mucous fistula or a long distal blind limb for delayed reanastomosis.

POSTOPERATIVE CARE

- Patients should receive routine postoperative care including adequate analgesia, aggressive pulmonary toilet, and early ambulation.
- Patients are typically kept on no more than a clear liquid diet the night of the operation in case there is a need for any emergency intervention and then advanced to a soft diet by the time of discharge.
- An occasional patient may experience diarrhea, which requires initiation of medicinal fiber and/or Imodium for symptom control.

OUTCOMES

- Patients generally tolerate a transverse colectomy well. The risk of anastomotic complications requiring reoperation is less than 5%, and a colostomy is not routinely required.
- Leakage from the colocolonic anastomosis may manifest as peritonitis, colocutaneous fistula, or localized intraperitoneal abscess.
  - Patients with clinical signs of sepsis and peritonitis should be managed by prompt return to the operation for reexploration, washout, resection of the prior anastomosis, and creation of end colostomy and mucous fistula.
  - Localized abscesses may collect in the subhepatic, subphrenic, and lesser sac spaces. The diagnosis can be made by CT of the abdomen, and clinically stable patients may be managed by percutaneous drainage.
- Superficial wound infection occurs in 10% to 15% of the cases and should be managed by incision and drainage of any subcutaneous abscess.
- Transverse colectomy is not expected to significantly alter bowel function postoperatively.[6] Although some patients may experience more frequent and looser stools during the immediate postoperative period, most patients reported an average of 1 to 2 stools per day and adapt to a normal bowel regimen over 6 to 12 months.

COMPLICATIONS

- Bleeding
- Wound infection
- Anastomotic leak
- Intraabdominal abscess
- Poor bowel function

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Chapter 14

Laparoscopic Transverse Colectomy

Govind Nandakumar   Sang W. Lee

DEFINITION

- Transverse colectomy refers to removal of the portion of the colon between the hepatic flexure and the splenic flexure—the transverse colon. This portion of the colon derives its blood supply from the right and left branch of the middle colic vessels in addition to collateral flow from the ileocolic, right colic, and left colic vessels. Transverse colectomy is commonly performed for tumors and/or polyps of this region. An alternative approach to these tumors is to perform an extended right or extended left colectomy. This chapter focuses on laparoscopic transverse colectomy.

PATIENT HISTORY AND PHYSICAL FINDINGS

- A complete history and physical focusing on the underlying pathology is essential. For patients with colon cancer and/or polyps, a detailed surgical history, personal cancer history, and family history is essential.
- Preoperative genetic counseling and testing may be indicated based on age and family history.
- Presence of an inherited cancer syndrome such as familial adenomatous polyposis or hereditary nonpolyposis colon cancer syndrome may require a total colectomy rather than a transverse colectomy.
- Prior abdominal surgery, distension, and obstruction are important to elicit in the history and physical examination prior to making a decision regarding open versus laparoscopic approach.
- History or physical examination suggestive of focal abdominal pain and tenderness are suggestive of abdominal wall invasion and more extensive or open surgical approach may be needed.
- History and physical examination should also evaluate the cardiovascular and respiratory systems to assess the ability to tolerate pneumoperitoneum.
- Nutritional status and recent history of major weight loss should be considered in performing primary anastomosis.

IMAGING AND OTHER DIAGNOSTIC STUDIES

- All patients with colon cancer and/or a polyp should have a complete extent of disease workup including carcinoembryonic antigen (CEA), computed tomography (CT) of the abdomen and pelvic, chest X-ray, colonoscopy, and routine preoperative testing.
- The CT should be reviewed carefully to assess adjacent organ involvement, metastatic disease, and obstructive disease.
- Laparoscopic approach may not be feasible in the presence of massive distension and obstruction.
- Large bulky tumors with a tethered mesentery or adjacent organ involvement may also preclude laparoscopy.
- Colonoscopy and evaluation of the entire colon is important to ensure there are no synchronous lesions proximal or distal to the area of resection.
- For small nonobstructing lesions, endoscopic tattoo marking should be performed prior to surgery.
- Endoscopic tattooing should be performed just distal to the tumor and in three quadrants.
- In general, tumors that are identified on CT scan can be readily identified laparoscopically and do not require a tattoo.

SURGICAL MANAGEMENT

Preoperative Planning

- The patient receives a mechanical bowel preparation to facilitate handling of the colon and to facilitate intraoperative colonoscopy if required. The need for bowel preparation is controversial. The consequences of a leak may be more significant without preparation. Laparoscopic handling of the colon is easier after mechanical bowel preparation.
- The patient is seen and evaluated by the surgical and anesthesia teams in the preoperative area on the day of surgery.
- Most patients are offered and elect to have an epidural or intravenous catheter for patient-controlled anesthesia.
- A second- or third-generation cephalosporin or ertapenem is used for antibiotic prophylaxis within 1 hour of skin incision and redosed as needed. No antibiotics are administered postoperatively.
- Venodyne boots and 5,000 units of subcutaneous heparin are used for deep vein thrombosis prophylaxis.

Positioning

- The patient is positioned in a modified lithotomy position with both arms tucked to the sides. It is essential to ensure that all pressure points, fingers, and calves are padded adequately.
- Use of a beanbag and cloth tape allows extreme positioning with decrease in possibility of patient sliding.
- Alternatively, use of gel pads commonly available in the operating room (OR) makes routine taping of patient not necessary.
- Use of shoulder braces should be avoided as they can cause brachial plexus injury.
- Prior to draping, the patient is placed in steep Trendelenburg and the table is rotated to ensure that the patient is secured well.
- It is essential to ensure that both knees are in line with the torso in order to avoid collision of instruments to patient's thighs when working in the upper quadrants of the abdomen. The abdomen is prepped from the nipples to the midthigh.
- Access to the anus is always maintained for possible intraoperative colonoscopy.
- **FIG 1** (laparoscopic setup) shows the OR setup for this procedure. Monitors are placed over the shoulders of the patient so that the surgeon, pathology, and monitors are situated in line.

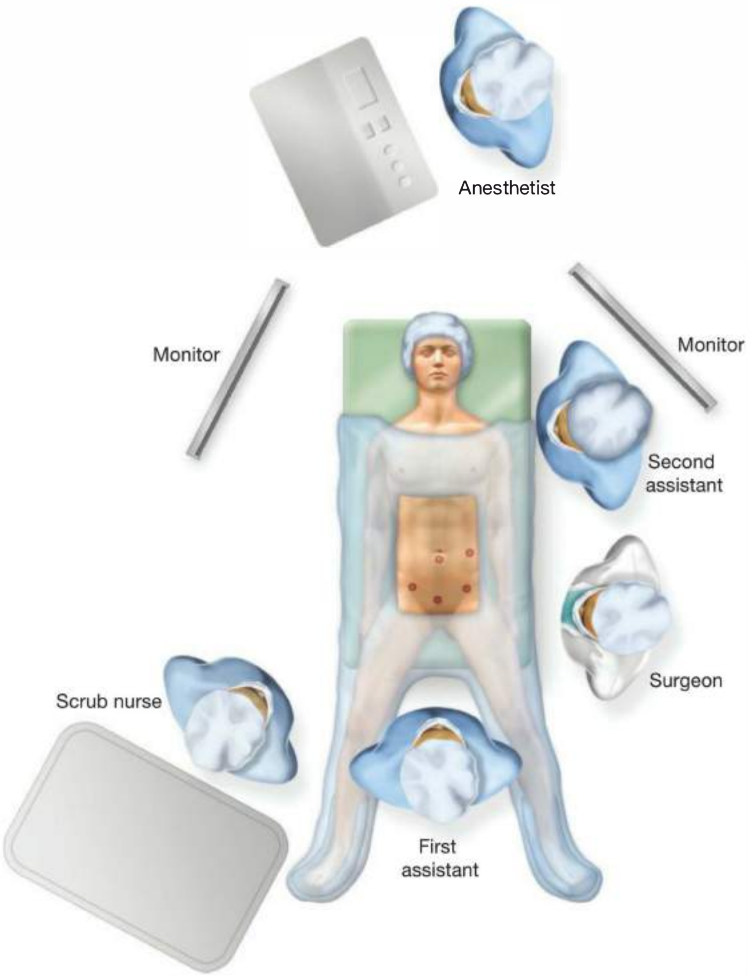

FIG 1 ● Illustrates the patient setup. A modified lithotomy position allows the surgeon or assistant to stand between the legs and to have access to the anus for intraoperative colonoscopy.

SKIN INCISIONS

- A Hasson technique is used to achieve access to the abdomen at the umbilicus.
- Four 5-mm trocars are placed—two on either side of the abdomen lateral to the rectus with one hand breadth between the trocars. An optional fifth trocar can be placed in the suprapubic area if required for retraction. **FIG 2** (trocars) shows the typical trocar placement.

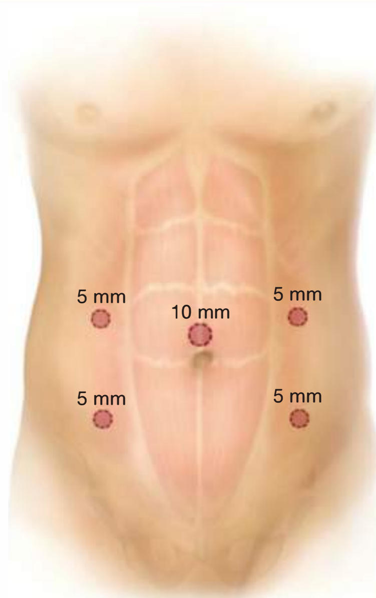

FIG 2 ● We use this standard configuration of trocar placement for the majority of laparoscopic colon and rectal operations.

LAPAROSCOPIC EXPLORATION

- The abdomen is systematically explored in all four quadrants to look for metastatic disease and/or unexpected pathology.
- Knowledge of the mesenteric anatomy is essential for a successful laparoscopic approach.
- **FIG 3** (colon anatomy) shows the colon with its major vascular pedicles. Also depicted is the gastrocolic trunk of Henle that can be a source of bleeding if not recognized during the dissection.
- The right colic vessels commonly originate from the ileocolics (85%).
- The middle colic arteries commonly have more than two branches (55%).

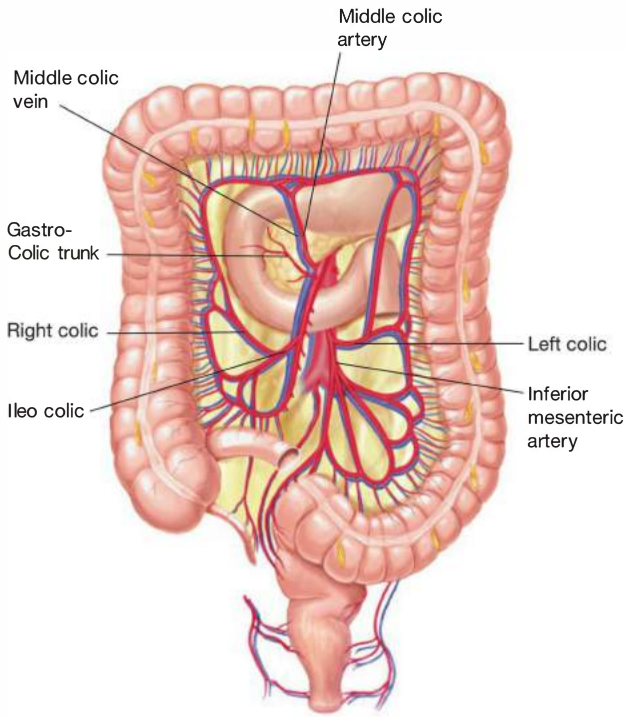

FIG 3 ● Shows the major vascular pedicles to the colon and the marginal artery that maintains collateral circulation.

PEDICLE LIGATION

- The ileocolic, middle colic, and left colic vessels are first identified (**FIG 4**). Identification of the vascular pedicles is facilitated by traction on the colon to tent the mesentery. Adequate exposure is achieved by grasping each flexure and retracting superiorly and laterally (**FIG 5**).
- A window is created in the colon mesentery between the ileocolic and middle colic vessels. With appropriate traction and countertraction, the retromesenteric dissection is continued superiorly, medially, and laterally into the lesser sac (**FIG 6**).
- Care is taken to protect the duodenum, head of the pancreas, and the superior mesenteric artery (SMA) and vein during the dissection.
- The middle colic vessels can be divided at the common trunk or divided individually after bifurcation (**FIG 7**). There is significant variation in the anatomy of the middle colic trunk.
- Our practice is to use a bipolar vessel-sealing device to divide the pedicles, but clips and staplers are also options to divide the pedicles. It is important to ensure that the SMA and vein are protected and that sufficient cuff of the vascular pedicle is retained to control bleeding should the vessel sealers fail.
- Strong anterior traction on the transverse colon mesentery optimizes middle colic dissection and decreases the likelihood of inadvertent injury to SMA.

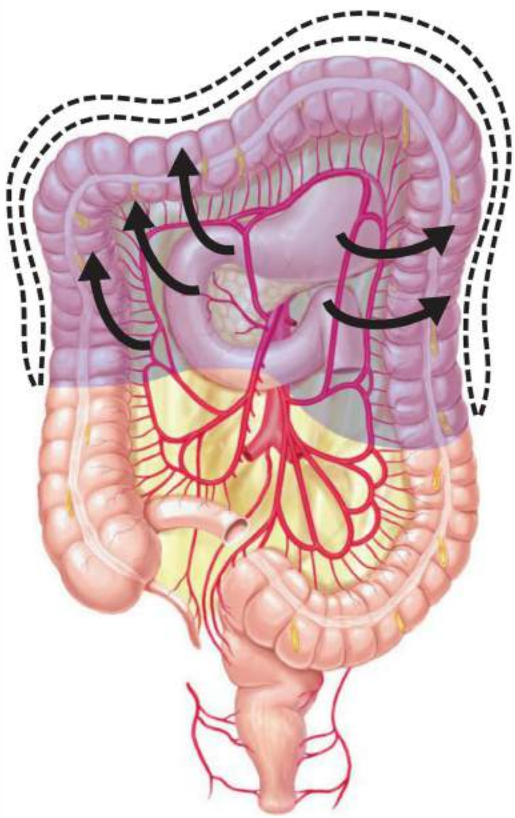

FIG 4 ● Appropriate traction on the colon in the direction of the *arrows* exposes the mesentery and allows for identification of the major vascular pedicles.

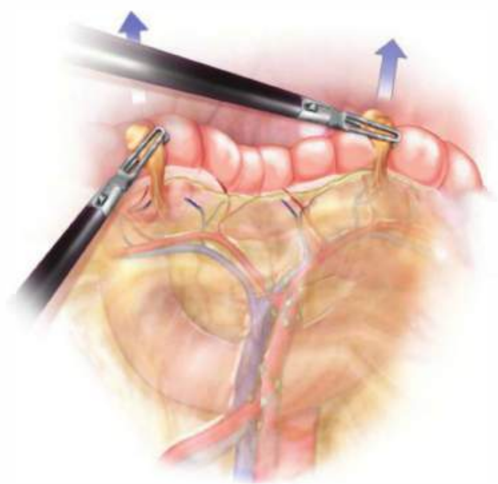

FIG 5 ● Cephalad and lateral traction is used to visualize the middle colic vessels.

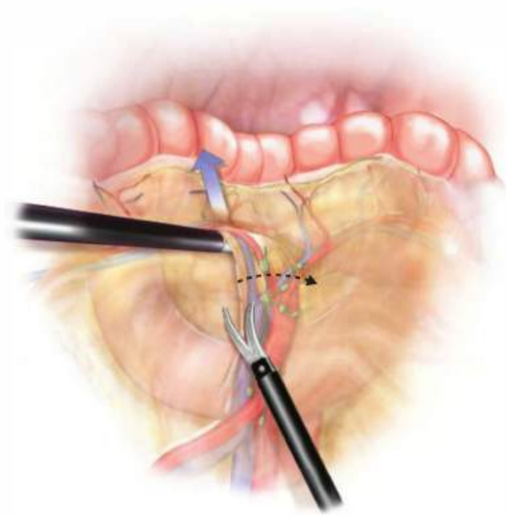

FIG 6 ● A window is created to the right of the middle colic vessels.

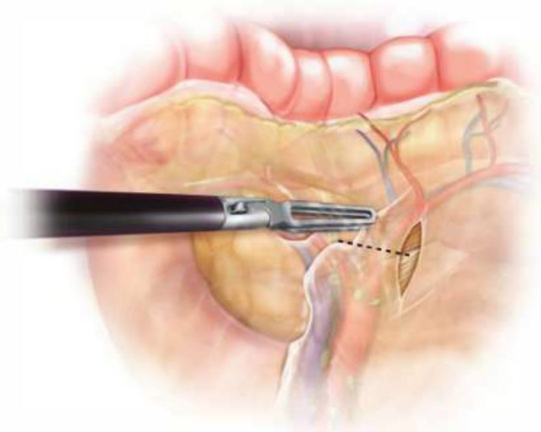

FIG 7 ● After adequate mobilization and protecting the duodenum and pancreas, the middle colic vessels are divided.

RETROMESENTERIC DISSECTION

- Right retromesenteric dissection
  - Laterally, the dissection is carried to the white line of Toldt and the hepatic flexure (**FIG 8**).
  - Medially, the dissection is carried to the root of the middle colic vessels and anterior to the head of the

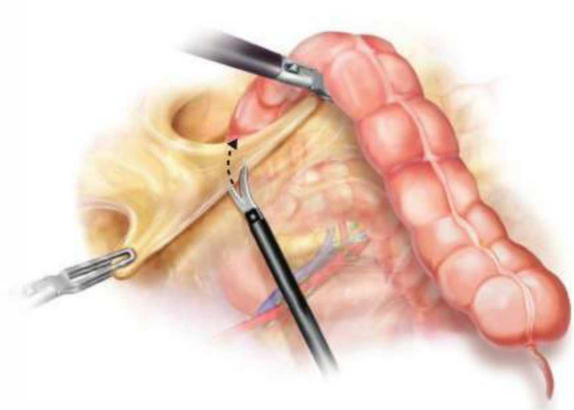

FIG 8 ● The lateral attachments of the colon are taken down, ensuring there is no thermal injury to the bowel.

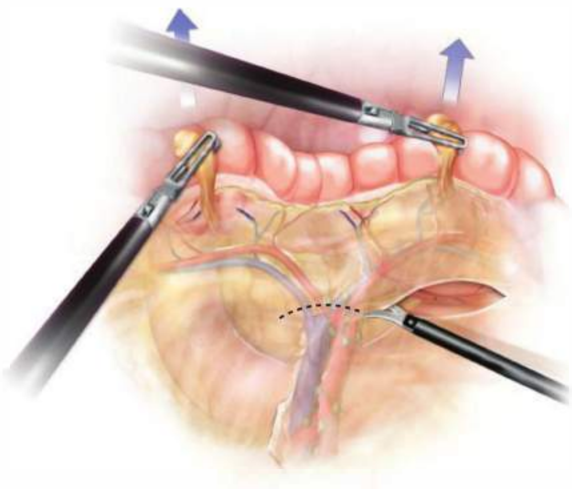

FIG 9 ● Dissection of the middle colic vessels.

pancreas and the duodenum (**FIG 9**). The gastrocolic venous trunk is often encountered during this dissection and can be a source of bleeding if not recognized and controlled (**FIG 10**).

- Superiorly, the dissection is carried cephalad to the transverse colon wall.
- The remaining attachments to the liver are taken down (**FIG 11**).

- Left retromesenteric dissection
  - A similar dissection is carried out on the left side, creating a window between the left colic and middle colic vessels (**FIG 7**).

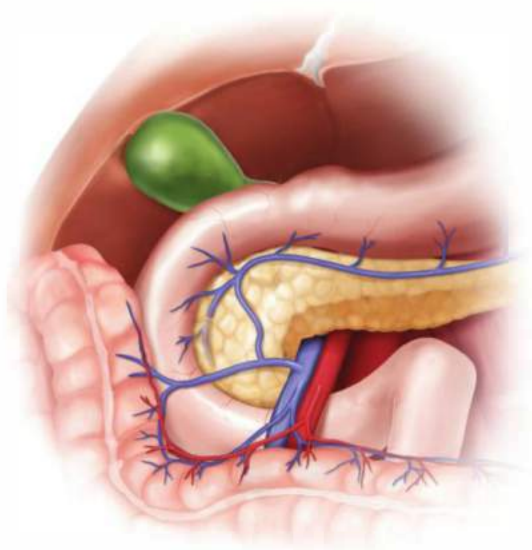

FIG 10 ● Early identification and control of the gastrocolic trunk prevents bleeding and injury to the superior mesenteric vein.

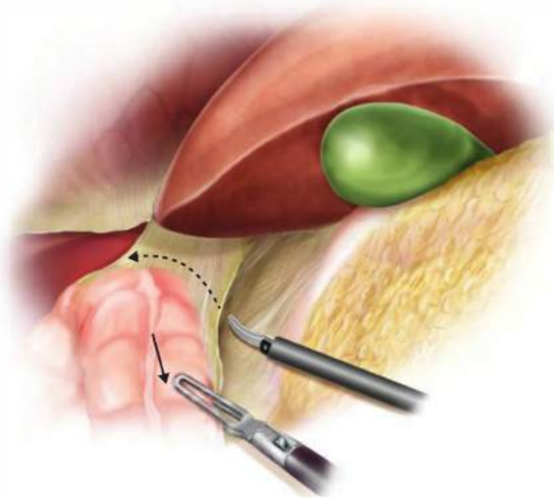

FIG 11 ● Remaining attachments of the hepatic flexure of the colon to the liver are taken down. The dissection is facilitated by working close to the colon.

  - Laterally, the dissection is carried to the white line of Toldt and the splenic flexure of the colon (**FIG 12**).
  - Medially, the dissection is carried to the root of the middle colic vessels.
- Superiorly, the dissection is carried to the inferior border of the pancreas and continued along the avascular plain between the left colon mesentery and the tail of the pancreas (**FIG 13**).
- At this point, the colon mesentery should be completely mobilized. The transverse colon is only held by the lateral attachments, the omentum, and the pedicles.

FIG 12 ● Splenic flexure mobilization requires takedown of the splenocolic ligament.

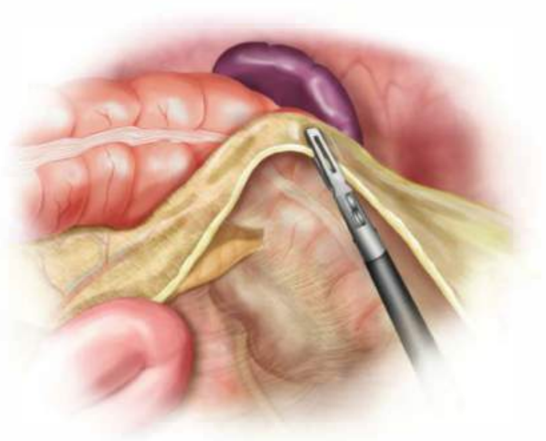

FIG 13 ● To achieve adequate mobilization, the posterior attachments along the inferior border of the pancreas need to be dissected with entry into the lesser sac.

RELEASE OF LATERAL ATTACHMENTS AND THE OMENTUM

- The omentum is next taken off the transverse colon (FIG 14). The lateral attachments are taken down on both sides. The dissection should be started in the midtransverse colon where the two leaves of the greater omentum are fused together. Visualization of the posterior wall of the stomach ensures that the surgical dissection is in the proper plane into the lesser sac. It is important to protect the colon from thermal injury during this portion of the dissection.

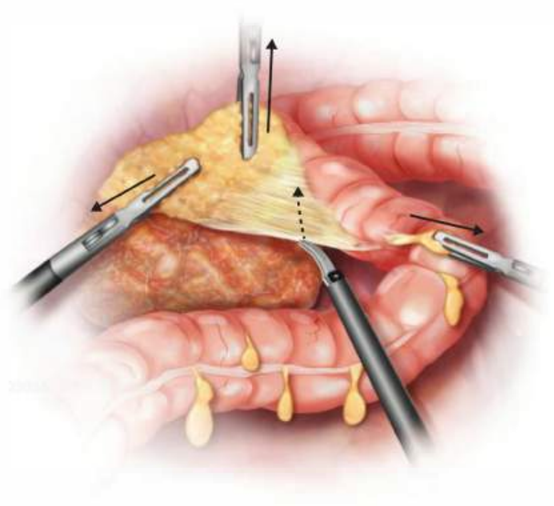

FIG 14 ● The omentum is dissected off the transverse colon. The omentum is left on the colon around the tumor to ensure an en bloc resection. Early entry into the lesser sac and identification of the posterior wall of the stomach facilitates an efficient dissection.

- In addition to mobilizing the transverse colon, the right colon, with the hepatic flexure, and the left colon, with the splenic flexure, need to be fully mobilized. This will allow for specimen extraction and the creation of a tension-free anastomosis (FIG 15).

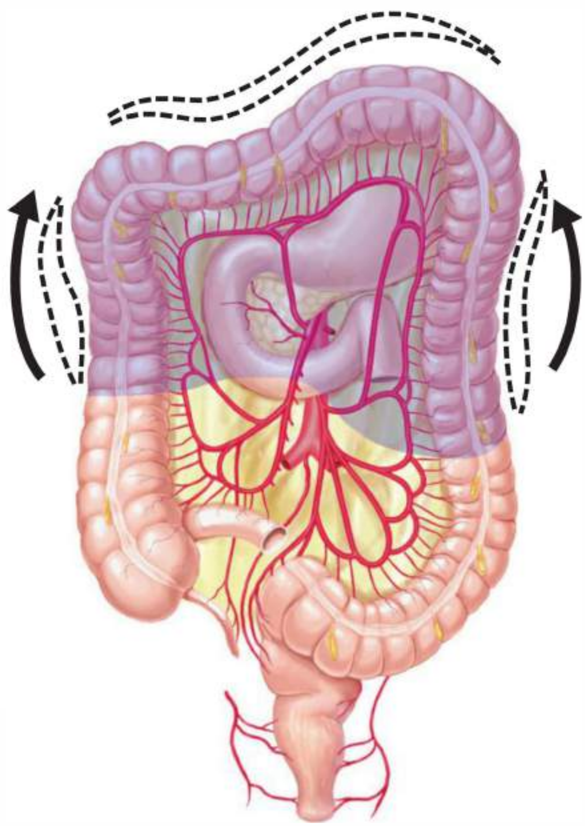

FIG 15 ● Complete mobilization of the hepatic and splenic flexures allows for safe specimen extraction and tension-free anastomosis.

SPECIMEN EXTERIORIZATION AND ANASTOMOSIS

- The periumbilical incision is commonly extended as an extraction site and a wound protector is placed (**FIG 16**).
- The mobilized transverse colon is exteriorized. Any remaining mesentery is divided.
- A linear stapler is used to divide the colon proximal to the hepatic flexure and distal to the splenic flexure as shown (**FIG 16**).
- The specimen is either sent for gross examination or opened in the OR to ensure that adequate margins (5 cm for cancer) were obtained.
- If the lesion is located laterally, additional pedicles can be taken as needed.
- A side-to-side functional end-to-end stapled anastomosis or a hand-sewn anastomosis can be fashioned based on the preference of the surgeon (**FIG 17**).
- The colon is replaced in the peritoneal cavity, and the operative area is examined for hemostasis.
- If there is concern for bleeding, the pneumoperitoneum can be reestablished prior to closure.
- Routine closure of the colonic mesenteric defect is not necessary as complications are minimal.[1]
- The extraction site fascia is closed, the trocars are removed under direct visualization, and the skin is closed.

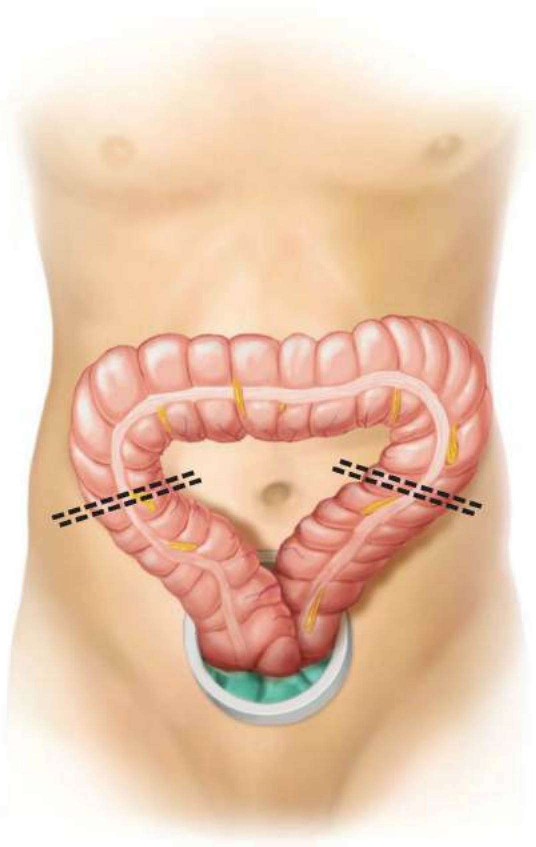

FIG 16 ● Periumbilical incision with wound protector to extract specimen.

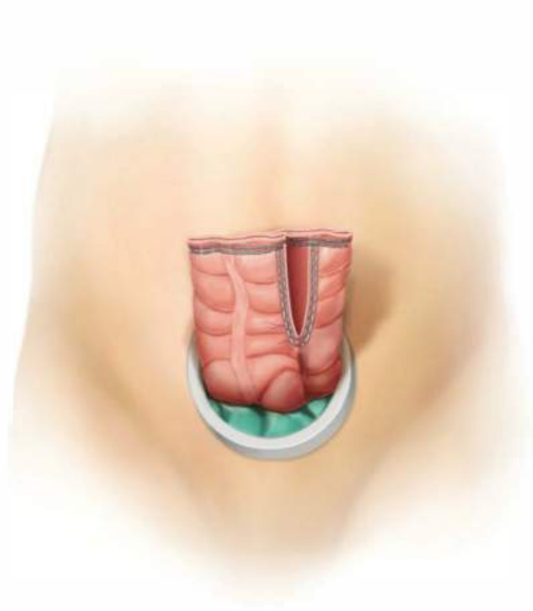

FIG 17 ● Side-to-side functional end-to-end stapled anastomosis through a wound protector is illustrated.

PEARLS AND PITFALLS

Indications	■ Extended right or left colectomies may be more appropriate for tumors located closer to the flexures. ■ Laparoscopy may not be feasible in obstructing tumors with massive bowel distension or tumors with extensive local invasion. History of prior surgeries is not a contraindication to laparoscopy.
Placement of incisions (trocars)	■ Lateral to the rectus and at least 7–8 cm between each trocar to avoid clashing of instruments. ■ The extraction incision is usually at or superior to the umbilicus.
Positioning	■ Thighs should be parallel to the floor and knees in line with the torso to prevent collision of the instruments with the knees.

Laparoscopic retraction, manipulation, and dissection	▪ Care should be taken when dissecting over the pancreas to avoid causing bleeding from the gastrocolic venous trunk of Henle. ▪ The superior mesenteric artery and vein should be protected during vessel ligation. ▪ Bipolar energy devices may not be effective in sealing calcified vessels. Endoloops should be available to control unexpected bleeding. ▪ Vessel-sealing devices can lead to lateral spread of thermal energy, and the colon should be protected during dissection. ▪ Intraoperative colonoscopy is useful if the exact location of the tumor is unclear. ▪ A hand access port can serve as a useful adjunct to complete difficult and challenging dissections.
Anastomosis	▪ Complete mobilization of both flexures is essential for a tension-free anastomosis. ▪ Inadequate mobilization of the splenic flexure can lead to traction injury of the spleen. ▪ In cases where there is tension, an extended right colectomy is safer as the small bowel is freely mobile. ▪ A wound protector is useful in minimizing contamination and limiting the length of the extraction incision.

POSTOPERATIVE CARE

- The patient is sent to the postsurgical unit and is usually given sips after recovery from anesthesia. Diet is advanced on postoperative day 1 to clear liquids and solids after passing flatus.
- The Foley catheter is removed on day 1 and oral pain medications started once the patient tolerates solid food.
- The patient is usually discharged on day 3 or 4 when the patient is on oral pain medications, tolerating a diet, and passing flatus.

OUTCOMES

- Large multicenter randomized trials have validated the oncologic safety and potential short-term benefits of laparoscopic surgery for colon cancer.[2,3] Transverse colon cancers were not included in these major trials.
- Smaller retrospective studies have concluded that the oncologic outcomes for laparoscopic treatment of transverse colon cancer are equivalent to the open approach. They also reported some potential short-term benefits.[4–6]
- There is limited data on laparoscopic transverse colectomy for benign lesions.
- Laparoscopic transverse colectomy is technically challenging and may carry a higher incidence of conversion to open surgery during the procedure.[7]
- This procedure is best performed by surgeons experienced with open resections of the transverse colon and those with significant laparoscopic colorectal experience.

COMPLICATIONS

- Bleeding
  - A medial to lateral dissection approach allows early identification and control of the major vessels and may avoid bleeding.
  - It is important to remain in the avascular plane between the mesentery and retroperitoneum. Significant oozing is a sign that the dissection may be too anterior into the mesentery or too posterior into the retroperitoneum.
  - Clips and endoloops are rarely required with modern energy and vessel-sealing devices but should be easily available to control bleeding, especially in patients with calcified vessels.
  - Postoperative abdominal hemorrhage can be managed with repeat laparoscopic exploration.
  - Postoperative intraluminal hemorrhage is best managed with carbon dioxide colonoscopy and endoluminal control.
- Splenic injury
  - It is safest to dissect toward the spleen rather than to retract the colon away from the spleen and cause a traction injury.
  - Complete mobilization of the splenic flexure will avoid traction injury during the extracorporeal portion of the operation.
  - Splenic injury can usually be managed with pressure and hemostatic agents.
  - Occasionally, with uncontrollable bleeding or with injury to the hilum, splenectomy may be required.
- Anastomotic leak
  - A tension-free anastomosis is facilitated by complete mobilization of both flexures.
  - Pulsatile blood flow is confirmed at the mesenteric transection line.
  - If the proximal margin is devascularized, conversion to an extended right hemicolectomy with an ileocolonic anastomosis may be safer.
  - Small leaks may be managed nonoperatively.
  - Larger leaks with peritonitis or contamination will likely require proximal diversion.
  - In extreme cases, the anastomosis may need to be taken down and converted to an end stoma.
- Serosal or full-thickness injury to the bowel
  - Careful dissection with attention to the possibility of lateral thermal spread is important.
  - The duodenum should be completely dissected off the mesentery and protected prior to pedicle ligation.
  - The small and large bowels are also at risk for puncture or shear injury during insertion of laparoscopic instruments.
- Deep and superficial surgical site infection
- Early and later incisional hernia formation

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Chapter 15

Transverse Colectomy: Hand-Assisted Laparoscopic Surgery Technique

Daniel Albo

DEFINITION

- Transverse colectomy refers to removal of the portion of the colon between the hepatic and the splenic flexures. The transverse colon derives its blood supply primarily from the middle colic vessels. In addition, the transverse colon receives collateral blood flow from the left and right marginal arcades (marginal artery of Drummond and arch of Riolan, respectively).
- Hand-assisted laparoscopic surgery (HALS) is a minimally invasive surgical approach that uses conventional laparoscopic-assisted (LA) surgery techniques but with the addition of a hand-assist device that allows for the introduction of one of the surgeon's hands into the surgical field. The hand-assist device is placed at the projected specimen extraction site. HALS in colorectal surgery retains all of the same advantages of conventional LA surgery over open surgery, including less pain, faster recovery, lower incidence of wound complications, and reduction of cardiopulmonary complications, especially in the obese and in the elderly.
- HALS has significant advantages over conventional LA colorectal surgery, including
  - Reintroduces tactile feedback into the field
  - Shorter learning curves; easier to teach
  - Shorter operative times and lower conversion to open rates
  - Allows for insertion of multiple ports through the hand-assist device
  - Allows for the introduction of laparotomy pads into the field (helps keeping the small bowel and omentum out of the way, particularly in the obese)
  - Higher usage rates of minimally invasive surgery

DIFFERENTIAL DIAGNOSIS

- Focal inflammatory processes, localized trauma, or local perforation
- Colon cancer located in the midtransverse colon. Cancers located at the flexures may necessitate extended right or left hemicolectomies in order to ensure adequate lymphadenectomy.
- Other tumors locally extending into the transverse colon (i.e., gastric, pancreatic, adrenal tumors, sarcomas) may necessitate en bloc transverse colectomy when resecting the primary tumor to achieve negative margins.

PATIENT HISTORY AND PHYSICAL FINDINGS

- Patients with colon cancer generally present with occult bleeding and anemia. Patients may also present with high-grade obstructing symptoms (crampy abdominal pain and constipation). More advance tumors may present with a complete large bowel obstruction. If these patients have a competent ileocecal valve, they develop a closed loop large bowel obstruction and present with severe right lower quadrant abdominal pain and abdominal distention secondary to a massive colonic dilation proximal to the obstructing lesion. These patients should be taken to the operating room emergently. Unopposed, this will ultimately cause an ischemic perforation of the cecum leading to a catastrophic fecaloid peritonitis and potential oncologic contamination of the abdominal cavity leading to carcinomatosis.
- A detailed personal and family history of colorectal cancer, polyps, and/or other malignancies should be elicited. Physical examination should include a routine abdominal examination, noting any previous incisions.

IMAGING AND OTHER DIAGNOSTIC STUDIES

- A full colonoscopy with documentation of all polyps should be performed. Lesions that are unresectable endoscopically and/or are suspicious for cancer should be tattooed to facilitate localization during surgery. If there is any concern for involvement of adjacent organs, such as the stomach, an esophagogastroscopy should also be performed.
- A computed tomography (CT) scan of the chest, abdomen, and pelvis evaluates for potential metastases. In patients with a large bowel obstruction, the CT scan shows dilation of the right colon and cecum, collapse of the distal colon, and a paucity of fluid and gas in the small bowel (**FIG 1**).
- A preoperative carcinoembryonic antigen level is obtained.

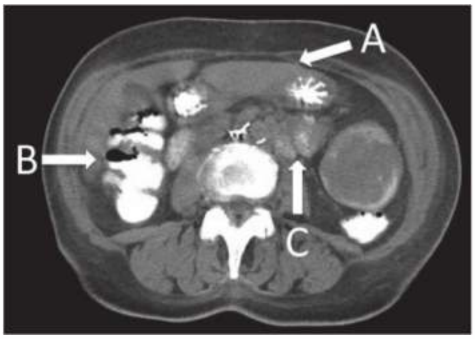


FIG 1 ● CT scan shows a large obstructing colon cancer in the transverse colon (*A*) with dilation of the cecum (*B*) and a paucity of fluid and gas in the small bowel (*C*).

SURGICAL MANAGEMENT

Preoperative Preparation

- Clinical trials have shown no need for mechanical bowel preparation.
- Intravenous cefoxitin is administered within 1 hour of skin incision.
- Use hair clippers if needed and chlorhexidine gluconate skin preparation.
- Preoperative time-out and briefing is performed.

Equipment and Instrumentation

- 5-mm camera with high-resolution monitors
- 5-mm clear ports with balloon tips. They hold ports in the abdomen and minimize their intraabdominal profile during surgery.
- Atraumatic graspers and laparoscopic endoscopic scissors
- A blunt tip, 5-mm energy device
- 60-mm linear reticulating laparoscopic staplers with vascular and tan loads
- We use the GelPort hand-assist device due to its versatility and ease of use. This device allows for the introduction/removal of the hand without losing pneumoperitoneum.

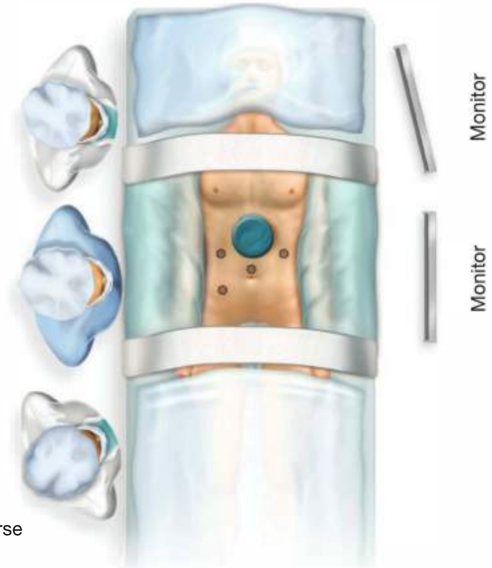


FIG 2 • Patient and team setup.

Patient Positioning and Surgical Team Setup

- This is the single most critical determinant of success in laparoscopic colorectal surgery (**FIG 2**).
- Place the patient on a supine position, with the arms tucked and padded (to avoid nerve/tendon injuries). The patient is taped over a towel across the chest without compromising chest expansion.
- The surgeon starts at the patient's right lower side with the scrub nurse to the surgeon's right side. The assistant stands at the surgeon's left side.
- Align the surgeon, the ports, the targets, and the monitors in straight line. Place monitors in front of the surgeon and at eye level to prevent lower neck stress injuries.
- Avoid unnecessary restrictions to potential team movement around the table. All energy device cables exit by the patient's upper left side. All laparoscopic (gas, light cord, and camera) elements exit by the patient's upper right side.

TECHNIQUES

PORT PLACEMENT AND OPERATIVE FIELD SETUP

- Insert a GelPort through a 5- to 6-cm epigastric incision. This incision will be also used for specimen extraction, transection, and anastomosis. Placement in the epigastric area greatly facilitates dissection of the middle colic vessels through a supramesocolic approach (see step 7).
- Insert three 5-mm working ports in the right upper, right lower, and left upper quadrants. Insert a 5-mm camera port above the umbilicus. Triangulate the ports so the camera port is at the apex of the triangle. This avoids conflict between the instruments and prevents disorientation ("working on a mirror").

OPERATIVE STEPS

- Our HALS transverse colectomy operation is highly standardized and it consists of nine steps:
  - Transection of the inferior mesenteric vein (IMV)
  - Medial to lateral dissection of the descending mesocolon
  - Transection of the left colic artery
  - Mobilization of the sigmoid off the pelvic inlet
  - Mobilization of the descending colon
  - Mobilization of the splenic flexure
  - Mobilization of the right colon
  - Transection of the middle colic vessels (supramesocolic approach)
  - Extracorporeal transection and anastomosis

Step 1. Transection of the Inferior Mesenteric Vein

- This is the critical "point of entry" in this operation. At the level of the ligament of Treitz, the IMV is easy to visualize and is far from critical structures that can be injured during its dissection (no iliac vessels or left

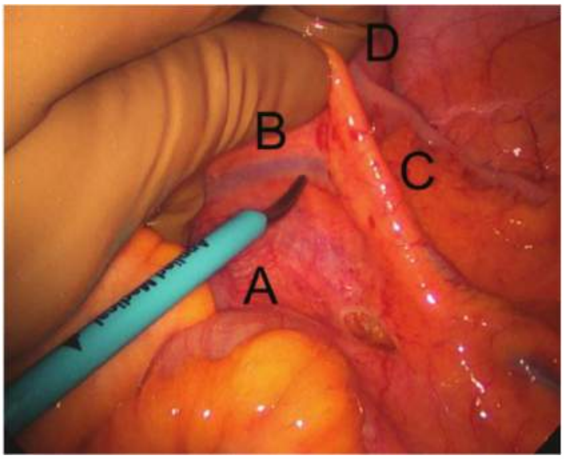


FIG 3 ● Step 1: Key anatomy. Ligament of Treitz *(A)*. IMV *(B)*. Left colic artery *(C)* as it separates from the IMV and goes toward the splenic flexure of the colon *(D)*.

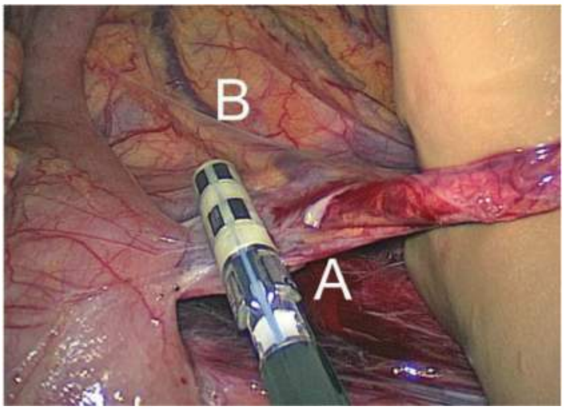


FIG 4 ● Step 1: Transection of the IMV *(A)* cephalad of the left colic artery *(B)*.

ureter nearby). This will be the only time when a true virgin tissue plane is entered. Every step will setup the following ones, opening the tissue planes sequentially.

- The patient is placed on a steep Trendelenburg position with the left side up. Using the right hand, move the small bowel into the right upper quadrant (RUQ) and the transverse colon and omentum into the upper abdomen. If necessary, place a laparotomy pad to hold the bowel out of the field of view especially in obese patients. This pad can also be used to dry up the field and to clean the scope tip intracorporeally. Make sure that the circulating nurse notes the laparotomy pad in the abdomen on the white board.
- Identify the critical anatomy: IMV, ligament of Treitz, and left colic artery (**FIG 3**).
- If there are attachments between the duodenum/root of mesentery and the mesocolon, transect them with laparoscopic scissors. This will allow for adequate exposure of midline structures.
- Pick up the IMV with the left hand. Dissect under the IMV and in front of Gerota's fascia with endoscopic scissors, starting at the level of the ligament of Treitz and proceeding toward the inferior mesenteric artery (IMA). The assistant provides upward traction with a grasper.
- Transect the IMV cephalad of the left colic artery (which moves away from the IMV and toward the splenic flexure of the colon) with the 5-mm energy device (**FIG 4**), thus preserving intact the left-sided marginal arterial arcade and maintaining the blood supply to the descending colon segment.

Step 2. Medial to Lateral Dissection of the Descending Mesocolon

- The surgeon's hand and the assistant's grasper retract the IMV/left colic pedicle at the cut edge of the descending mesocolon upwards towards the enterior abdominal wall. He or she then dissects the plane between the mesocolon and Gerota's fascia (readily identified by the transition between the two fat planes) with a 5-mm energy device (**FIG 5**). We like to dissect this space by gently pushing the retroperitoneum down with the blunt tip of the 5-mm energy device.
- Dissect caudally under the IMV/left colic artery toward the takeoff of the left colic artery off the IMA. Dissect laterally until you reach the lateral abdominal wall. This will greatly facilitate step 5. Dissect superiorly between the splenic flexure and the tail of the pancreas. This will greatly facilitate step 6.

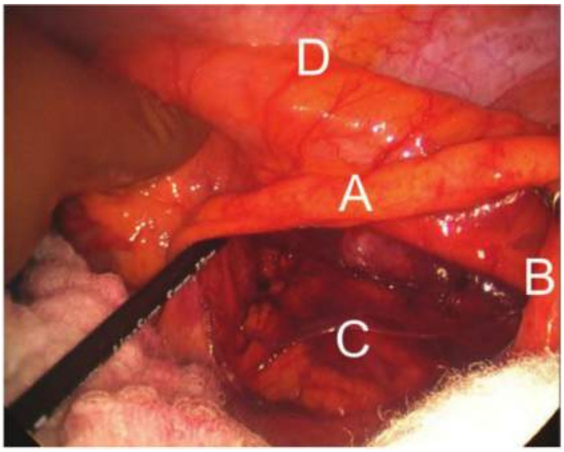


FIG 5 ● Step 2: Medial to lateral dissection of the descending mesocolon. The surgeon is holding the splenic flexure upward. Notice that there is a laparotomy pad on the field holding the small bowel out of the way and helping provide excellent exposure. The left colic artery is located in the medial edge of the descending mesocolon *(A)*. IMA *(B)*. Gerota's fascia *(C)*. Descending colon *(D)*.

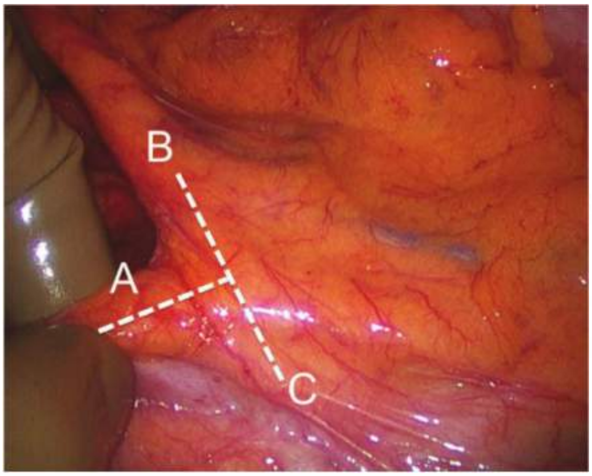


FIG 6 ● Step 3: Critical anatomy. The letter T formed between the IMA *(A)* and it's left colic artery *(B)* and SHA *(C)* terminal branches.

Step 3. Transection of the Left Colic Artery

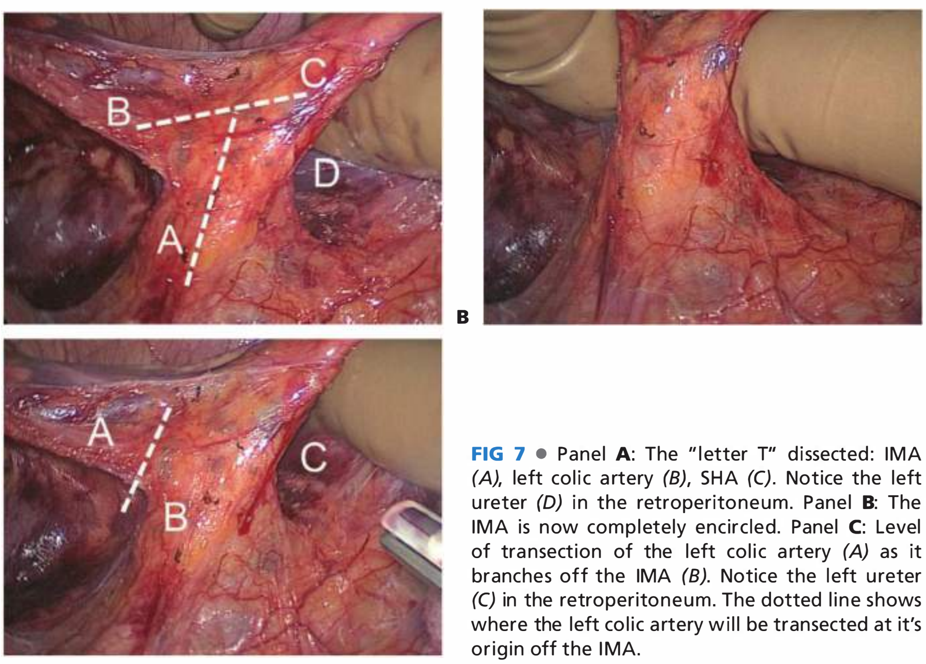
- Identify the critical anatomy: The "letter T" formed between the IMA and its left colic and superior hemorrhoidal artery (SHA) terminal branches (**FIG 6**).
- Holding the SHA up with the left hand, dissect the plane along the palpable groove between the SHA and the left iliac artery using laparoscopic scissors and a 5-mm energy device. Preserve the sympathetic nerve trunk intact in the retroperitoneum. Identify the left ureter in front of the left iliac artery and psoas muscle, and medial to the gonadal vessels before transecting anything (**FIG 7A**).
- Dissect with your thumb and index finger around and behind the IMA (**FIG 7B**)
- Visualize the letter "T" formed between the IMA, the left colic artery, and the SHA (**FIG 7A**). Transect the left colic artery as it takes off the IMA with the energy device (**FIG 7C**). The surgeon can now complete the dissection of the mesocolon off the retroperitoneum in a superior to inferior direction down to the level of the pelvic inlet. This will greatly facilitate steps 4 and 5.

Step 4. Mobilization of the Sigmoid off the Pelvic Inlet

- The surgeon pulls the proximal sigmoid colon medially with the left hand and the assistant pulls the distal sigmoid colon medially with a grasper (**FIG 8A**). Transect the lateral sigmoid colon attachments to the pelvic inlet with laparoscopic scissors in your right hand. Stay medially, close to the sigmoid and mesosigmoid, to avoid injuring the left ureter (**FIG 8B**). You should readily enter the retroperitoneal dissection plane dissected during the previous step.
- Dissect caudally until reaching the left side of the Douglas pouch.

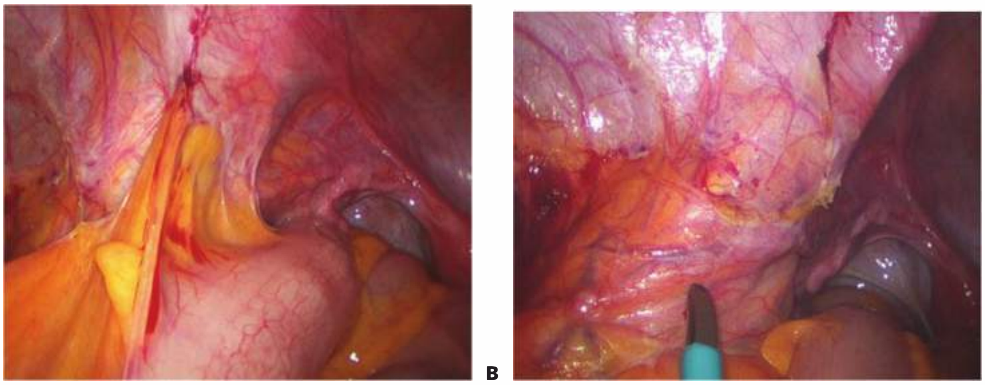
Step 5. Mobilization of the Descending Colon

- Retract the descending colon medially with your left hand. Transect the white line of Toldt up to the splenic flexure using endoscopic scissors or energy device with your right hand through the left-sided port. You should readily enter the retroperitoneal dissection plane dissected during step 2.



A B C

FIG 7 ● Panel **A**: The "letter T" dissected: IMA *(A)*, left colic artery *(B)*, SHA *(C)*. Notice the left ureter *(D)* in the retroperitoneum. Panel **B**: The IMA is now completely encircled. Panel **C**: Level of transection of the left colic artery *(A)* as it branches off the IMA *(B)*. Notice the left ureter *(C)* in the retroperitoneum. The dotted line shows where the left colic artery will be transected at it's origin off the IMA.

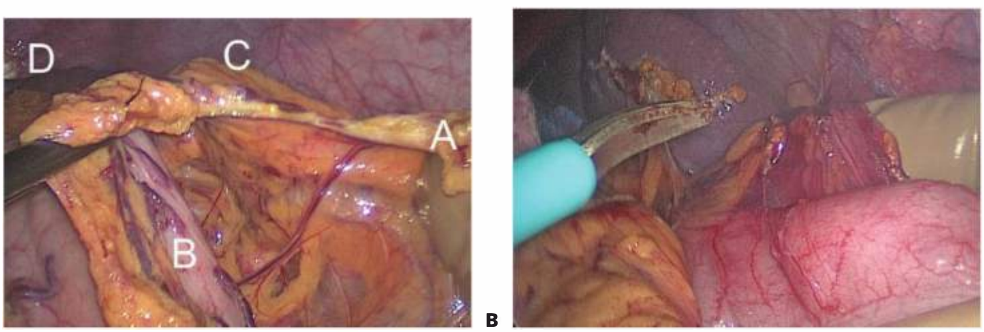


A B

FIG 8 ● Step 4. Panel **A**: Medial traction on the sigmoid exposes its lateral attachments to the pelvic inlet. Panel **B**: After the sigmoid mobilization is completed, the left ureter is visualized as it crosses over the left iliac artery.

Step 6. Mobilization of the Splenic Flexure

- Place the patient on reverse Trendelenburg position with the left side up to help displace the splenic flexure down out of the left upper quadrant.
- With the assistant pulling the transverse colon downward with a grasper, the surgeon lifts the stomach up with his left hand and transects the gastrocolic ligament in between the stomach and transverse colon using a 5-mm energy device through the RUQ port site (**FIG 9A**). This allows for entrance into the lesser sac and provides for an excellent view of the splenic flexure.
- Transect the gastrocolic ligament (from medial to lateral) with the 5-mm energy device, staying close to the transverse colon and avoiding the spleen. Proceed laterally to the splenic flexure.
- Because the dissection performed in step 2 completely separated the splenic flexure of the colon from the



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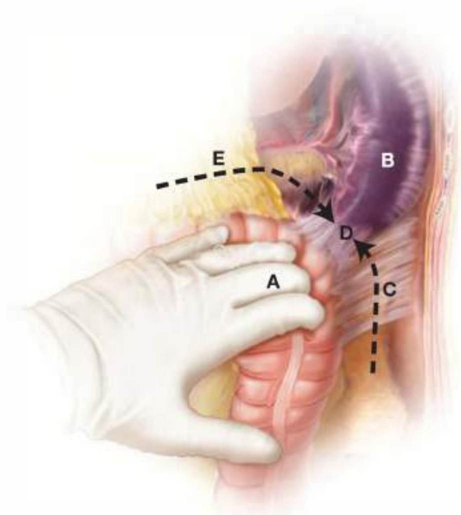

C

FIG 9 ● Mobilization of the splenic flexure. Panel **A**: The partially transected gastrocolic ligament is visible between the transverse colon *(A)* and the stomach *(B)*. Notice the excellent view of the lesser sac laterally toward the splenic flexure of the colon *(C)* and the spleen *(D)*. Panel **B**: The surgeon is "hugging" the splenic flexure with his hand and "hooking" his index finger under the splenocolic ligament allowing for an excellent exposure and transection of this ligament with an energy device. **C**: Splenic flexure mobilization. The surgeon retracts the splenic flexure of the colon *(A)* downwards and medially, exposing the attachments of the splenic flexure to the spleen *(B)*. The phrenocolic *(C)* and splenocolic *(D)* ligaments are transected in an inferior to superior, and lateral to medial direction. The gastrocolic ligament *(E)* is then transected in a medial to lateral direction, until both planes of dissection meet and the splenic flexure is fully mobilized.

retroperitoneum, the surgeon can now slide his or her right hand under the splenic flexure, holding the splenic flexure up with the index finger "hooked" under the splenocolic ligament. This allows for an easy transection of the splenocolic ligament with an energy device (FIGS 9B and C). The left colon should be now fully mobilized to the midline.

Step 7. Mobilization of the Right Colon

- Standing at the left side of the table, the surgeon completes the transection of the gastrocolic ligament until reaching the hepatic flexure of the colon using a 5-mm energy device.
- At this point, the hepatocolic ligament is readily visible. Slide your right index finger under it, hold it upward, and transect it with a 5-mm energy device.
- Proceeding on a superior to inferior dissection, transect to the right white line of Toldt with laparoscopic scissors. Fully mobilize the ascending colon off the retroperitoneum with the 5-mm energy device. This dissection should proceed from a lateral to medial as well as from a superior to inferior direction. Stay in front of the duodenum, the head of the pancreas, and Gerota's fascia.

Step 8. Transection of the Middle Colic Vessels (Supramesocolic Approach)

- Dissection and transection of the middle colic vessels can be one of the most daunting maneuvers in colorectal surgery. Traditionally, these vessels are approached inframesocolically by dissecting the root of the mesotransverse colon at the intersection with the root of the mesentery where the venous anatomy is extremely variable and complex. The superior mesenteric vein (SMV) and its branches, and the gastrocolic venous trunk of Henle and its branches, surround the middle colic vessels. Venous tears tend to travel distally to the next major tributary. In terms of the SMV and the gastrocolic trunk of Henle, this next "tributary" is the portal vein confluence, which lies in a retroperitoneal plane for which you do not have control at this time.
- In order to prevent potentially devastating bleeding complications during the dissection and transection of the middle colic vessels, we have developed a supramesocolic approach to these vessels. The hand-assisted technique greatly facilitates the performance of this technique and makes it very safe.
- The superior aspect of the transverse mesocolon is now readily visible, with the middle colic vessels easily palpable as they cross the third portion of the duodenum in the midtransverse colon (FIG 10). With the assistant pulling down on the transverse colon downward with a grasper, the surgeon "picks up" the middle colic vessels supramesocolically with his or her right thumb and index finger. Using his or her left hand, the surgeon now dissects under the middle colic vessels with the 5-mm energy device, completely encircling the middle colic vessels with the thumb and index finger. With great exposure and control, the surgeon now transects the middle colic vessels with the 5-mm energy device.

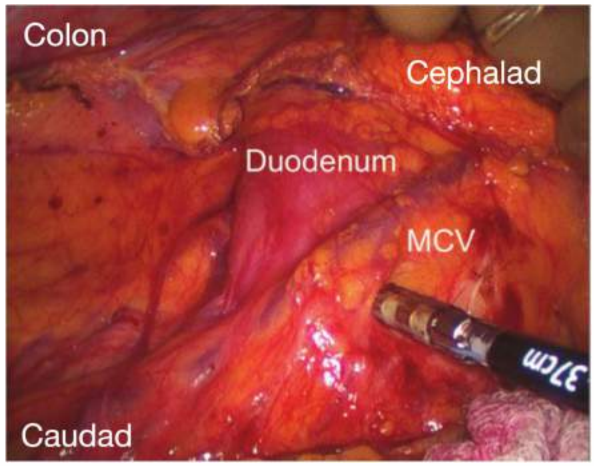

FIG 10 ● Supramesocolic transection of the middle colic vessels (MCV). The MCV are readily visualized at this point through a supramesocolic approach as they cross over the third portion of the duodenum. This allows for a safe dissection and transection with a 5-mm energy device.

- During this approach, the transverse mesocolon separates the SMV and the gastrocolic venous trunk of Henle from the middle colic vessels shielding them and, thus, greatly reducing the potential risk of serious venous injuries. It also allows for a very high transection of the middle colic vessels and, therefore, a great lymphatic nodal capture.
- Prior to the extracorporeal mobilization, we transect the right colic vessels intracorporeally (FIG 11). Hold the transverse colon up with the right hand; while the assistant retracts the right colon anteriorly and laterally,

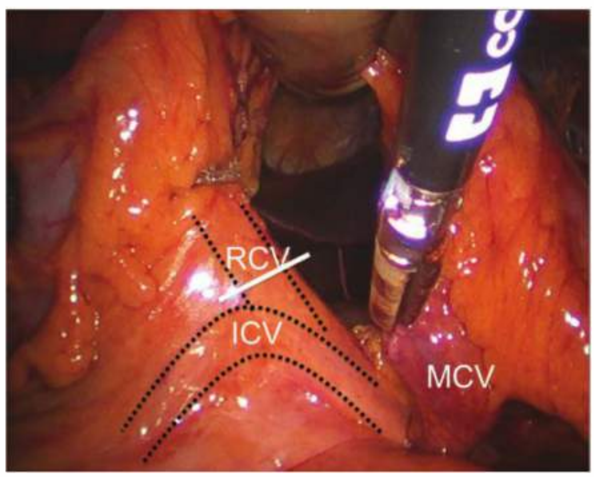

FIG 11 ● Transection of the right colic vessels. The surgeon is holding the transverse colon (with the right-sided vascular arcade along its mesenteric border) up. The *solid white line* shows where to transect the right colic vessels (RCV) as they branch off the ileocolic vessels (ICV). Transected middle colic vessels (MCV).

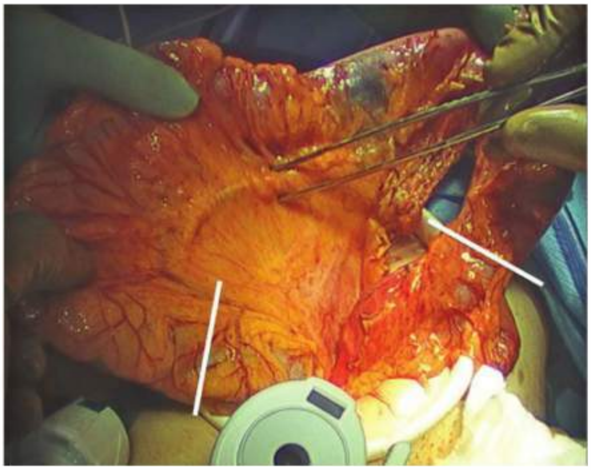

FIG 12 ● Extracorporeal mobilization and transection. The specimen is exteriorized without any tension. The *white solid lines* show where to transect the colon proximal and distal to the hepatic and splenic flexures, respectively. The tattooed target in the midtransverse colon and the vascular arcade (arch of Riolan) are readily visible.

expose the right-sided vascular arcade that connects the right branches of the middle colic vessels with the right colic vessels (the arch of Riolan). You can now safely transect the right colic vessels at its origin from the ileocolic vessels.

Step 9. Extracorporeal Transection and Anastomosis

- Deliver the transverse colon through the epigastric incision with the wound protector in place to minimize the chance of wound infection and oncologic contamination of the wound. Should there be any tension, reintroduce the colon into the abdominal cavity and mobilize the right and/or left colon more laparoscopically. Excessive traction during this step can lead to troublesome vascular injuries on mesenteric structures.
- Transect the colon extracorporeally proximal to the hepatic flexure and distal to the splenic flexure with a linear 60-mm endostapler with tan loads (**FIG 12**). The transverse colon specimen contains the middle, right, and left colic pedicles.
- At this point, we perform an extracorporeal, anatomic side-to-side, colocolonic anastomosis with a 60-mm linear endostapler using a vascular load (**FIG 13**). We avoid using the stapled colonic ends in the anastomosis to prevent potential ischemia at the staple lines intersection. The anastomosis should be tension-free and have an excellent blood supply. We do not close the anastomotic mesenteric gap to prevent potential damage to its blood supply.
- The anastomosis is reintroduced into the abdominal cavity. After changing gloves, all ports are removed. Wounds are closed with absorbable sutures and sealed off with Dermabond. We place a bilateral subcostal nerve block with bupivacaine for postoperative analgesia purposes.

FIG 13 ● Extracorporeal stapled side-to-side colocolonic anastomosis. The anastomosis is tension-free and has excellent blood supply.

PEARLS AND PITFALLS

Setup	■ Proper patient, team, port, and instrumentation setup is critical.
Operative technique	■ Point of entry: IMV at the ligament of Treitz. ■ Complete every step. Each step sets up the next ones sequentially. ■ Vascular dissection to visualize the letter T of the IMA and its SHA and left colic branches; identify left ureter prior to left colic transection. ■ Supramesocolic approach to the middle colic vessels is critical to prevent serious venous injuries.
Pitfall: dissecting anterior to the SHA	■ Solution: Identify "groove" between left common iliac artery and SHA and dissect in between the two vessels.
Pitfall: tension during extraction of the specimen	■ Reintroduce the colon into the abdominal cavity and mobilize the right and/or left colon further. Tension during the extraction phase can lead to serious bleeding problems.

POSTOPERATIVE CARE

- Postoperative care is driven by clinical pathways that includes the following:
  - Pain control: Intravenous acetaminophen for 24 hours (start in the operating room) followed by intravenous ketorolac for 72 hours (if creatinine is normal). The subcostal nerve block greatly reduces the need for narcotics.
  - Deep vein thrombosis (DVT) prophylaxis with enoxaparin starting within 24 hours of surgery
  - No additional antibiotics, judicious use of intravenous fluids
  - No nasogastric tube. Remove Foley catheter on postoperative day 1.
  - Early ambulation, diet ad lib, aggressive pulmonary toilet
  - Targeted discharge: postoperative day 3

OUTCOMES

- HALS leads to improvements in short-term outcomes, including less pain, faster recovery, shorter hospital stay, and lower incidence of cardiac/pulmonary complications when compared to open surgery.
- When compared to conventional laparoscopy, HALS results in higher usage rates of minimally invasive surgery, shorter learning curves, lower conversion rates, shorter operative times, and shorter hospital stays.
- For cancer resection, minimally invasive surgery oncologic outcomes are at least comparable to those of open surgery.

COMPLICATIONS

- Wound infections and hernias are markedly reduced versus open surgery.
- Anastomotic leak rates should be below 5%.
- Ureteral injury: critical to identify the left ureter prior to vascular transection
- DVT: low risk with use of DVT prophylaxis
- Cardiac and pulmonary complications: significantly reduced compared to the open surgery approach

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Chapter 16 Left Colectomy for Colon Cancer

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DEFINITION

- Left colectomy for cancer is defined as the resection of the left colon in which the extension must correspond to the distribution of the lymphovascular drainage of the tumor-compromised segment, having as the result negative borders on histopathologic studies, along with in block extirpation of the lymphovascular tissue that nurtures that zone of the colon with a minimum number of 12 lymph nodes available to be evaluated by a histopathologic study.[1]

DIFFERENTIAL DIAGNOSIS

- Most of patients with left colon tumors must have a cancer histologic diagnosis before being taken to surgery.
- However, there are existing cases in which the biopsies taken by colonoscopy do not identify the presence of a neoplasia. In these cases, it is recommended to take another biopsy set. If a second set is not diagnostic, it is recommended to proceed with the colectomy and obtain the pathologic study from the surgical specimen.
- The differential diagnoses for left colon cancer include complicated diverticular disease with stenosis, intraluminal foreign bodies with an inflammatory reaction, neoplastic invasion from adjacent organs (especially ovaries), and colonic endometriosis.

PATIENT HISTORY AND PHYSICAL FINDINGS

- The patient's medical record must be complete, including a detailed description of signs and symptoms; medical history, with special attention to the evolution of symptoms; food intake and weight changes; and a thorough physical examination, including rectal examination. The abdomen must be carefully palpated, aimed to search for lumps, carcinomatosis, or ascites. The lymphatic nodal basin must be examined as well.
- Family history of cancer is especially important, including two generations, and asking for the presence of colon, gastrointestinal, breast, endometrial, and prostate cancer. This will allow the identification of possible cases of familiar colon cancer.
- The clinical evaluation must include a subjective global assessment of nutritional status to identify the patients who may benefit from perioperative nutritional therapy.[2]
- The physiologic risk of the patient must be evaluated according to his or her age, intercurrent diseases, and type of surgery, following the institutional preoperative evaluation guidelines.

IMAGING AND OTHER DIAGNOSTIC STUDIES

- Carcinoembryonic antigen (CEA): The baseline preoperative result and postsurgical control must be obtained as an assessment for complete tumor resection. On the other hand, the absolute presurgical value is an independent variable for survival.[1]
- Abdominal computed tomography is the most sensitive and specific test for detection of intraabdominal metastases.[1]
- Chest computed tomography is the most sensitive and specific test to detect mediastinal and lung metastases.[1]
- Total colonoscopy: Regardless of the primary localization of the tumor, every patient should have a complete colonoscopy study whenever possible, because 2% to 9% of the patients may have synchronous tumors.[1] The colonic enema with double contrast may be used in those patients in whom the colonoscopy is not possible.
- Tumor histologic studies that describe the cell differentiation and the extent of the invasion.

SURGICAL MANAGEMENT

Preoperative Planning

- The extension and type of procedure must be thoroughly discussed with the patient and family. This includes the possibility of a temporary or permanent colostomy.
- Left colectomy is a major surgery that has potential for postoperative morbidity and mortality. It is desirable to discuss with the patient the local statistical rates for morbidity and mortality before obtaining the informed consent.
- There is controversy about the effectiveness and need of mechanical preparation of the bowel before the colectomy.[3–5] I personally use a "mild" preparation with 2 days of liquid diet and polyethylene laxatives the day before the surgery, achieving the evacuation of large fecal residues. I do not demand a crystalline wash before the surgery.
- In the operating room, before initiating the anesthetic act, it is desirable to follow a checklist in which every professional involved in the surgical act must participate. This list should include at least patient identification, type of surgery, type of anesthesia, expected events during the surgery, the need for blood components, prophylactic antibiotic, surgical devices availability, and potential adverse events and their prevention.

Positioning

- The surgery is performed with the patient in a supine position. The arms should ideally be tucked to the sides, allowing freedom of movement for the surgical team. If one extended arm is required, it should be placed at an angle of 90 degrees and the right arm is preferred.
- If a colorectal anastomosis with a circular stapler is assumed, the patient should be in the lithotomy position. In this case, one must ensure that the patient's thighs maintain a horizontal plane with the patient's abdomen, for them not to interfere with the surgeon's arms (**FIG 1**). The lower extremities' position in the brackets must protect them from neuropraxias or vascular compressions.
- The surgical team setup is shown in **FIG 2**.
- The surgical table must allow inclinations in every way, which will be necessary to expose regions with difficult access, such as the splenic flexure of the colon.
- The patient must be secured to the surgical table adequately to prevent body displacements with position changes of the surgical table.

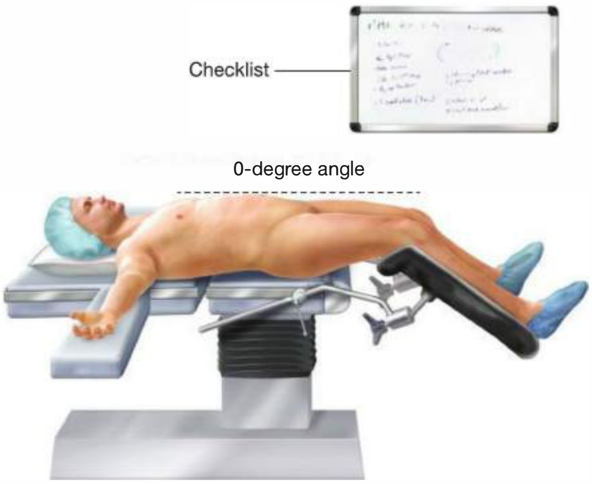


FIG 1 ● Correct position of the patient in the operating table. Note the horizontal position of the thighs to ensure free movement of surgeon's arms and hands.

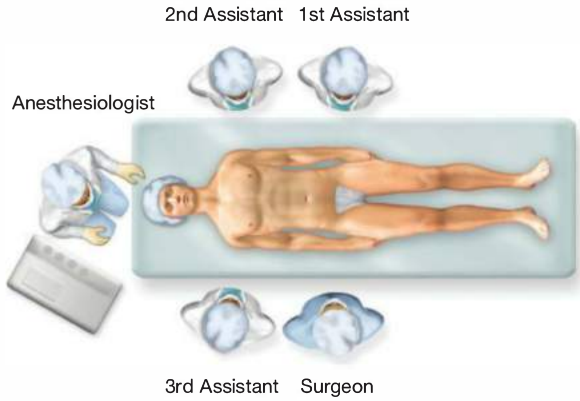


FIG 2 ● Surgical team setup.

LAPAROTOMY, REVISION OF PERITONEAL CAVITY, AND SURGICAL FIELD PREPARATION

- A medial supra- and infraumbilical laparotomy is performed, carrying the incision down to the pubis, which will improve pelvic exposure. Once the abdominal cavity is opened, it is advisable to protect the wound edges from bacterial and cellular contamination by placing an Alexis® wound protector or similar instrument (**FIG 3A,B**).
- Following this, one should explore the abdominal cavity, emphasizing in the search for liver metastases and synchronous colon tumors, especially in patients in which the total colonoscopy was not possible due to an obstructive tumor.
- Next, the small bowel is displaced toward the right upper quadrant of the abdomen and contained using pads and abdominal rolls. I personally prefer not to eviscerate the patient because this increases manipulation of the intestines and therefore increases the possibility of postoperative ileus. In order to achieve good pelvic and distal descending colon exposure, the patient is placed in a Trendelenburg position. A slight inclination of the surgical table toward the right can be helpful. Placement of a Bookwalter retractor facilitates operative exposure.
- The exact location of the left colon tumor is identified and the extent of colonic and lymphovascular pedicle resection is defined (**FIG 4**).

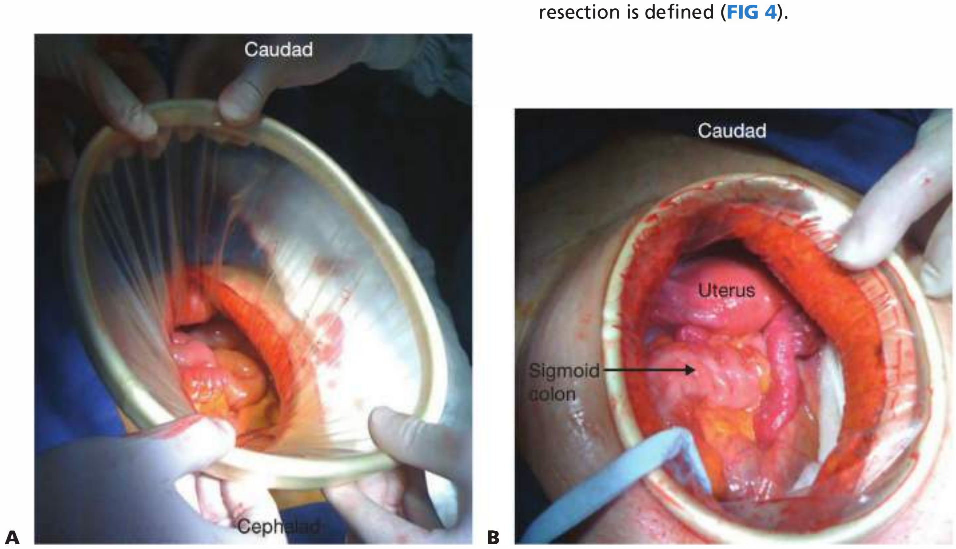


FIG 3 ● **A,B.** The Alexis® retractor has been placed to protect the wound from fecal and tumoral contamination.

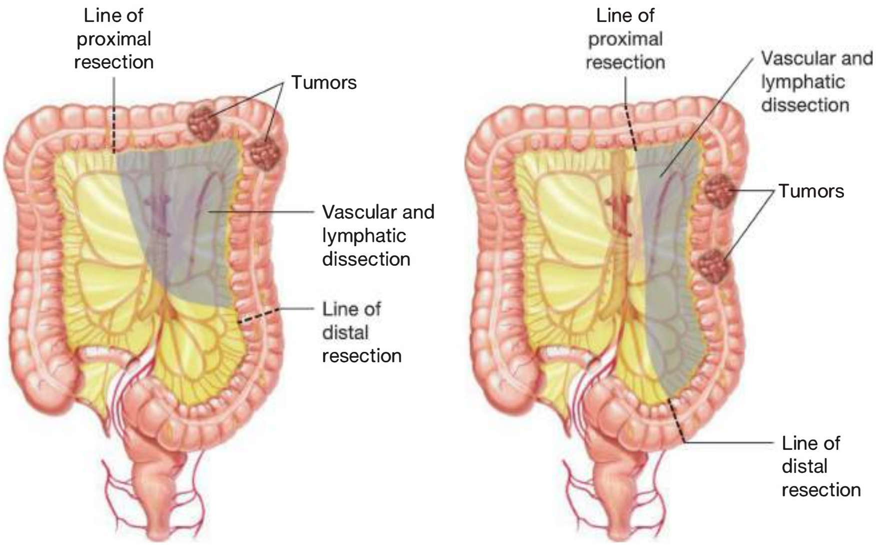


FIG 4 ● Levels of colon and lymphovascular pedicle resection in accordance to tumor localization.

IDENTIFICATION OF THE LEFT URETER AND START OF LEFT COLON MOBILIZATION

- The sigmoid colon is retracted toward the right side, and the lateral peritoneal fold is exposed up to the pelvic ring.
- Peritoneal sectioning is initiated with the monopolar electrocautery in a cephalocaudal direction. The loose retroperitoneal tissue is exposed and it can be separated with a combination of blunt and sharp dissection in order to identify the gonadal vessels, the left ureter, and the left common iliac artery. It is useful to know that the left ureter is always medial to the gonadal vessels, crossing over the common iliac artery prior to its bifurcation. The left ureter is marked with a vessel loop, being careful of including its accompanying longitudinal vascularization (FIG 5).
- At this point, an avascular tissue plane located in between the ureter and the gonadal vessels in the back and the mesentery of the sigmoid and descending colon in the front should be searched for. Using blunt dissection, it is possible to separate these structures in a cephalad direction, staying in front of Gerota's fascia, which should be preserved intact. Meanwhile, the descending colon mesentery is elevated. At the end of this maneuver, the descending colon mesentery will be raised, containing the inferior mesenteric artery (IMA) and its branches and the inferior mesenteric vein and its tributaries (FIG 6).

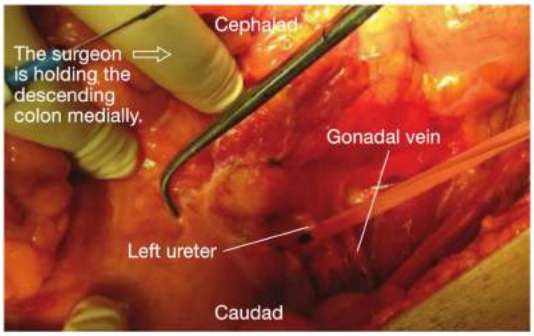


FIG 5 ● The left ureter, located medial to the gonadal vessels, has been identified and marked.

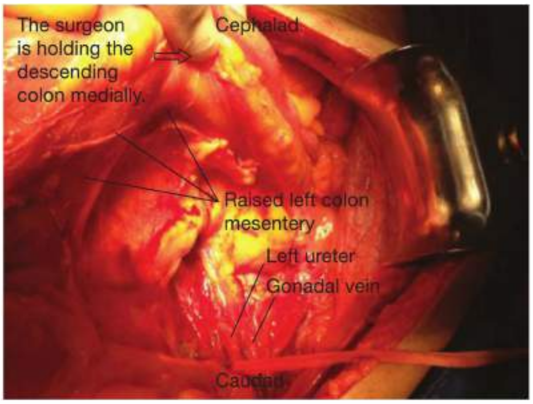


FIG 6 ● The left colon mesentery has been raised. The retroperitoneal structures are exposed.

LATERAL TO MEDIAL DISSECTION AND VASCULAR ISOLATION

- The sigmoid and descending colon are retracted laterally, and the peritoneum is sectioned in a vertical direction from the ligament of Treitz to the pelvic inlet, anterior to the aortic artery pulse. At this time, it is possible to see a slight hematoma behind the root of colonic mesentery, product of the previously described lateral dissection. Sectioning the loose tissue in the mesentery root (under the superior hemorrhoidal vessels) communicates the medial and lateral dissection planes (**FIG 7**).
- Lateral to the fourth portion of the duodenum and below the inferior pancreatic border, it is possible to identify the inferior mesenteric vein. The inferior mesenteric vein is then ligated and divided (**FIG 8**).
- On this anatomic plane, one should continue sectioning the mesentery in a caudal direction, remaining 1 cm ahead the aorta in order to preserve the abdominal sympathetic plexus (hypogastric trunk). In almost every patient, it is possible to observe the hypogastric trunk as it traverses over the promontory. The hypogastric trunk divides into the right and left hypogastric trunk, which can be identified in the right and left posterolateral pelvis, respectively (**FIG 9**). These nerves must be preserved in order to avoid autonomic dysfunction postoperatively.
- The IMA, identified a few centimeters above the aortic bifurcation, is ligated and divided. In proximal tumors, this division can be performed at the origin of left colic artery in order to preserve the IMA, sigmoidal vessels, and superior hemorrhoidal arteries intact. This ensures preservation of a well-vascularized sigmoid colon for the anastomosis, without compromising the oncological extent of the lymphadenectomy (**FIG 4**).

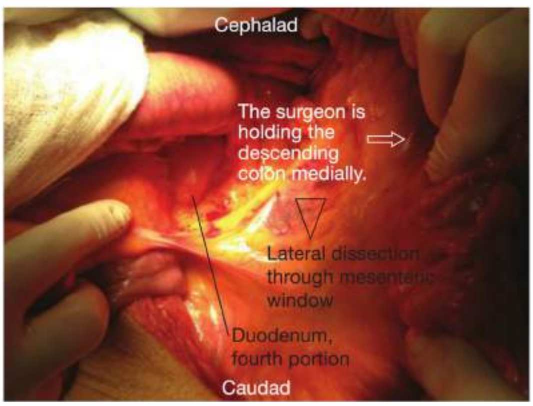


FIG 7 ● Medial view of dissection. The fourth portion of duodenum is seen in the surgeon's left and the assistant is retracting the left colon laterally. Notice the slight hematoma behind the root of the colonic mesentery in the right, indicating the zone of dissection under the superior hemorrhoidal vessels.

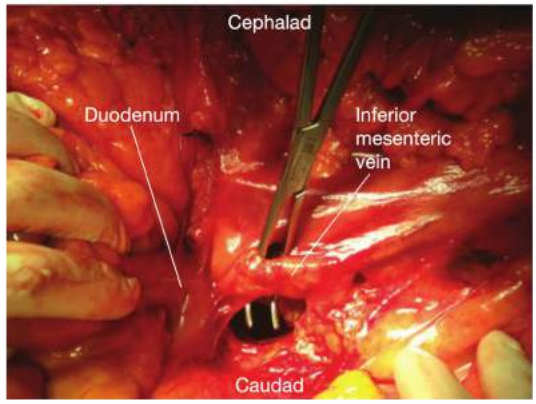


FIG 8 ● The inferior mesenteric vein has been dissected and is ready to be transected.

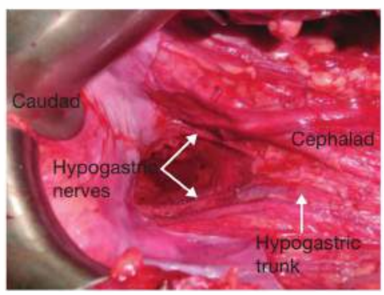


FIG 9 ● View of sympathetic plexus and origin of the left and right hypogastric nerves.

MOBILIZATION OF THE SPLENIC FLEXURE

- At this time, the only remaining step needed for a full mobilization of the left colon is the mobilization of the splenic flexure. This maneuver can be challenging, because the splenic flexure can have a very deep location in the left upper quadrant of the abdomen.
- The lateral peritoneum sectioning is continued from the initial incision in a cephalic direction as far as possible, avoiding excessive traction of the splenic flexure in order to prevent splenic lacerations. This dissection can be done with a monopolar scalpel or with a bipolar vessel-sealing device.
- The final approach to the splenic flexure should be complemented with another point of dissection that is initiated in the transverse colon to the left of the middle colic vessels. At this point, the gastrocolic ligament is transected, entering the lesser sac (**FIG 10**). The gastrocolic ligament is then transected from medial to lateral with a monopolar scalpel or with a bipolar vessel-sealing device, leaving the greater omentum attached to the surgical specimen.
- With a combined traction of the transverse and descending colon, it is now easier to expose the splenocolic ligament, allowing for its transection with a monopolar scalpel or with a bipolar vessel-sealing device (**FIG 11**). The left colon is now fully mobilized all the way to the midline.

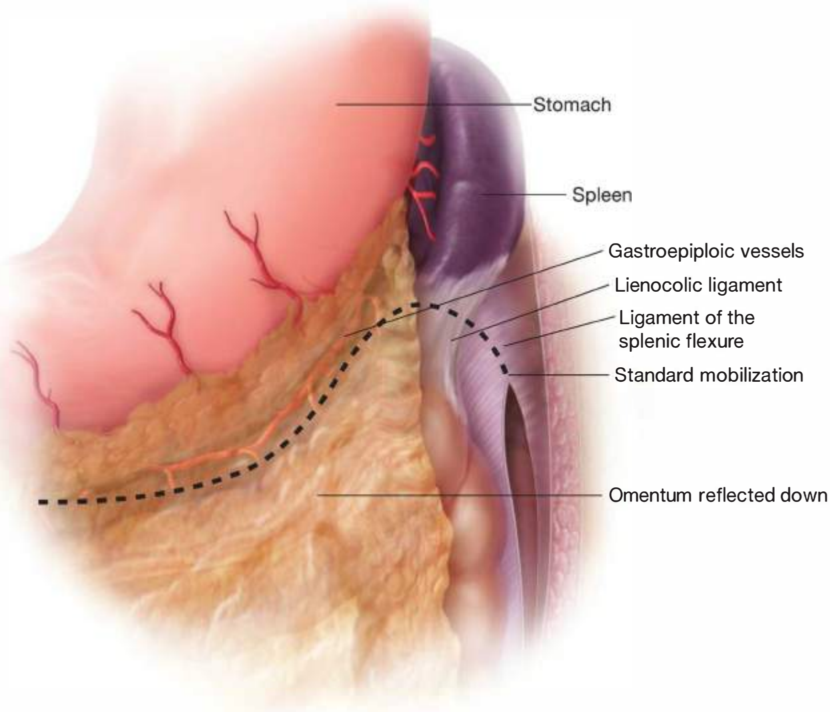
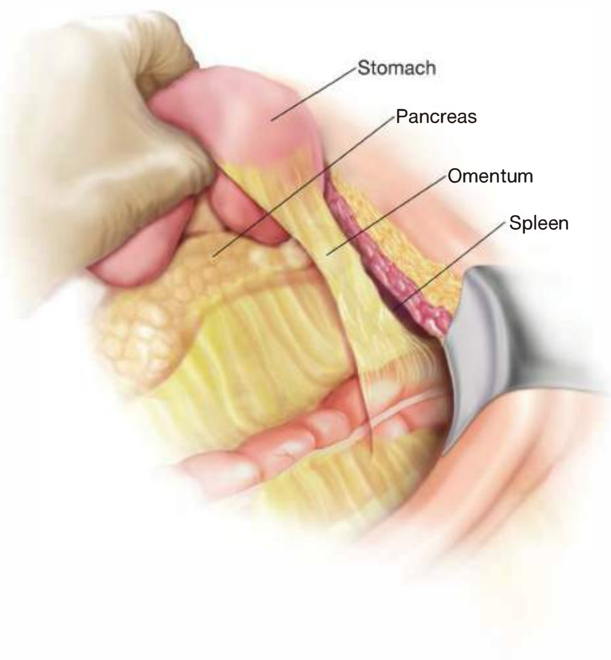
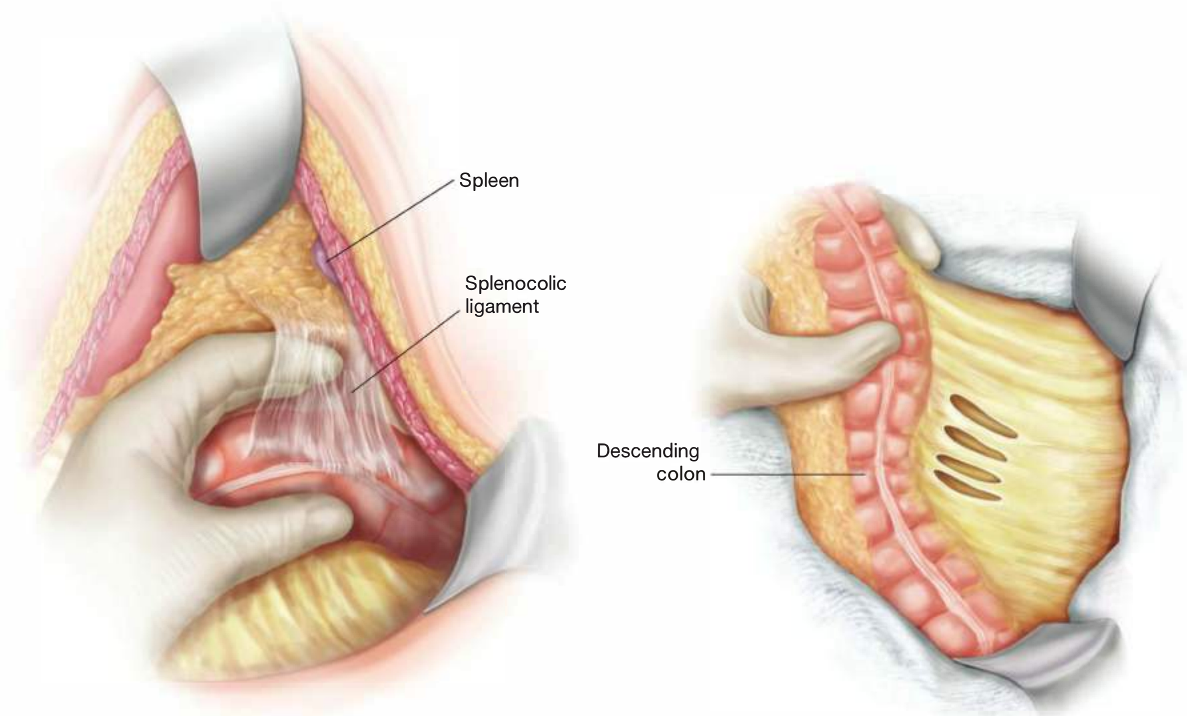


FIG 10 ● The gastrocolic ligament will be transected, starting to the left side of the middle colic vessels and proceeding from medial to lateral and around the splenic flexure of the colon, until the lateral dissection spleen is reached.



A

FIG 11 ● **A–C.** Exposure of the splenocolic ligament. Once the medial and lateral dissection planes are connected, the splenocolic ligament is easily visualized and is now ready to be transected. *(continued)*



B C

FIG 11 ● *(continued)*

COLON EXTRACTION AND ANASTOMOSIS

- At this time, a colon segment from the distal third of the transverse colon down to the rectosigmoid junction could be taken to the midline and externalized through the laparotomy incision (**FIG 12**). The transection points are chosen based on the oncologic margins needed, ensuring an adequate capture of the appropriate lymphovascular pedicles (**FIG 4**). In thin patients, it is possible to feel the pulse of the marginal artery near the points of transection. In more obese patients, or if the pulse is not palpable, the presence of a normal color in the colon is a good indicator of adequate perfusion on the colonic segments to be used for the anastomosis.
- If the extension of the resection allows preserving the sigmoid colon, a side-to-side transverse colon–sigmoid anastomosis with a mechanical stapler is advisable (**FIG 13A1,A2**). If the sigmoid colon has to be included in the resection specimen, then an end-to-end colorectal anastomosis with circular stapler via a transanal route must be performed (**FIG 13B1,B2**). It is critical that the anastomosis is tension-free; full mobilization of the splenic flexure ensures that this is possible.

FIG 12 ● The left colon is now fully mobilized and is exteriorized through the surgical incision. Full mobilization of the splenic flexure will ensure a tension-free anastomosis.

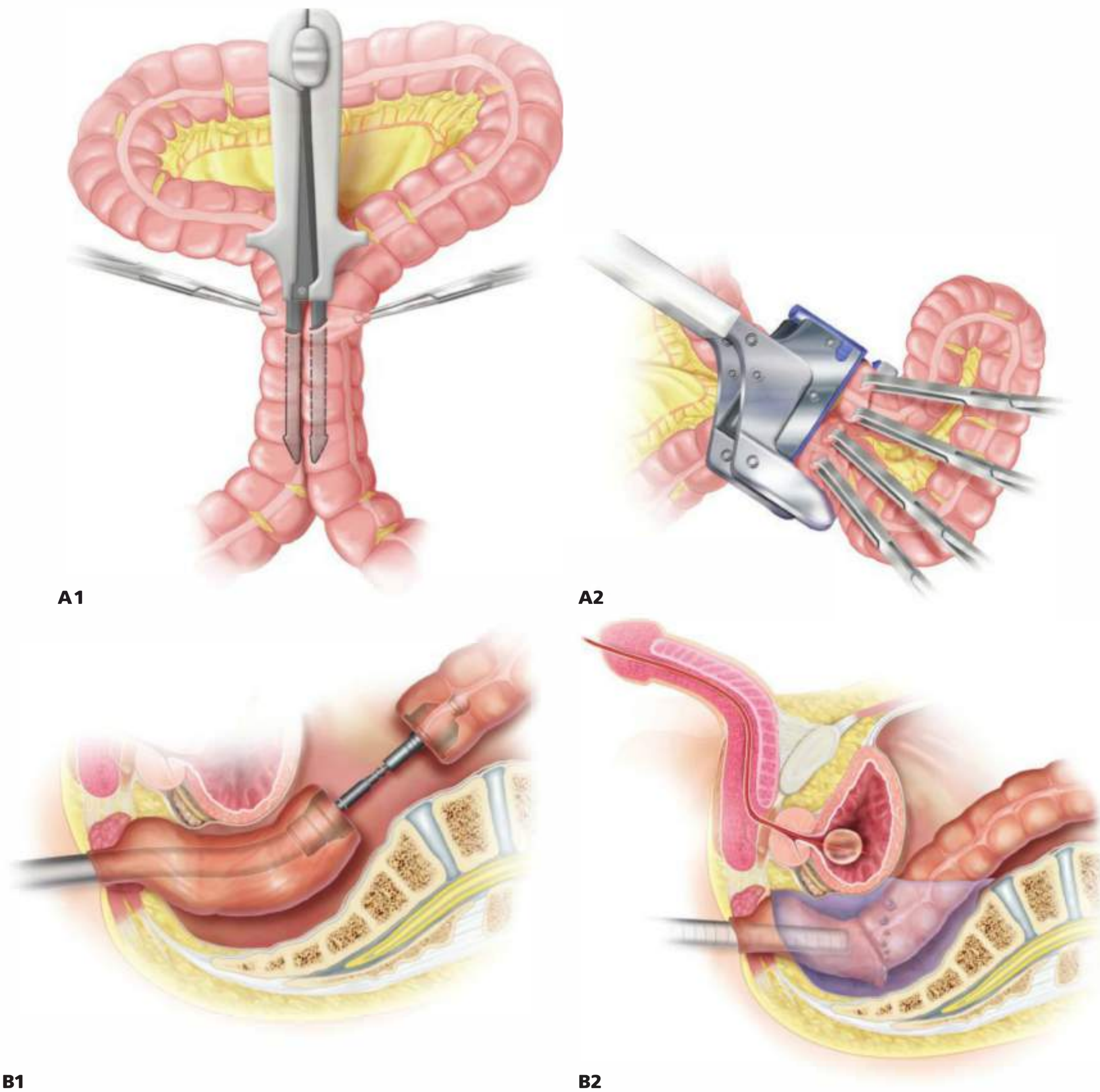


FIG 13 ● Anastomosis: **A1.** Side-to-side stapled transverse colon–sigmoid anastomosis. **A2.** Completion of the anastomosis and resection of the left colon specimen with a thoracoabdominal (TA) stapler. **B1.** End-to-end stapled colorectal anastomosis. **B2.** Completed colorectal anastomosis tested under water. Air bubbles identified during insufflation of the anastomosis indicate an anastomotic leak.

FINAL REVIEW AND CLOSURE OF THE PERITONEAL CAVITY

- Once the anastomosis is completed, the surgical bed must be reviewed to identify and control small bleeding retroperitoneal points, which are frequent. The vessel loop is removed from the left ureter and the anastomosed colon is left in the retroperitoneum. The rest of the abdominal cavity is checked, the surgical pads are counted, and the abdominal cavity is closed in the usual way.

PEARLS AND PITFALLS

Patient position	▪ An improper position with hip flexion will make it difficult to maneuver during the whole procedure. Make sure the patient's thighs are completely horizontal.
Left ureter identification	▪ The left ureter must be identified all the way through and not just at the entrance to the pelvis. At the arterial ligation point, this organ can become medial and be injured. Make sure to identify it during the vascular isolation.
Splenic flexure mobilization	▪ It is usually the most challenging step of this operation. It must be done with patience, good lighting, and using the dual (medial and lateral) approach previously described.
Tension-free anastomosis	▪ Full mobilization of the splenic flexure is critical for a tension-free anastomosis. Anastomotic tension can lead to anastomotic leaks.

POSTOPERATIVE CARE

- Fluid resuscitation with Ringer's lactate to maintain a urinary output of 1 mL/kg/hr without overhydration
- Pain control with patient-controlled analgesia or epidural analgesia
- Early oral intake and patient mobilization
- Early removal of bladder catheter
- Venous thrombosis prophylaxis according to guidelines
- Routine use of nasogastric tube is not recommended.
- No postoperative antibiotics are needed.

OUTCOMES

- The patient's prognosis depends on the tumor staging, which is determined by the histopathologic study of the specimen (pTNM).[6]
- Many patients will require adjuvant chemotherapy according to the tumor stage.[7]

COMPLICATIONS

- Surgical site infection
- Hematomas
- Anastomotic leak
- Peritonitis
- Prolonged postsurgical ileus
- Incisional hernia

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Chapter 17 Left Hemicolectomy: Laparoscopic Technique

Erik Askenasy

DEFINITION

- A "left hemicolectomy" can be a nebulous term because three colonic segments lie in the left abdomen: the splenic flexure, the descending colon, and the sigmoid colon. At times, this can lead to consternation during surgical planning or even intraoperatively. Remembering that the location of the pathology guides the extent of colonic resection as well as the associated vascular and regional lymph nodes can provide much needed clarity. Additionally, understanding the vascular anatomy of the left colon and its common variations is essential for a well-vascularized and tension-free anastomosis.
- The left colon develops embryologically from the hindgut and contains three segments: the splenic flexure, the descending colon, and the sigmoid colon. The splenic flexure is located in the left upper quadrant and is supplied by antegrade flow from the left branch of the middle colic as well as retrograde flow from the left colic artery. Griffith's point is typically found in the splenic flexure and refers to the watershed area between these two arteries and represents a circulatory communication between the superior and inferior mesenteric arteries. The descending colon lies in between the sigmoid colon and the splenic flexure and is supplied by the left colic artery. Finally, the sigmoid colon is located in the left lower quadrant and is supplied by the sigmoidal arteries, branches of the inferior mesenteric artery (IMA) after the takeoff of the left colic artery. In this chapter, we will focus on the splenic flexure and the descending colon.
- A surgeon must be ready for "surprises" when entering the abdomen for a lesion in the descending colon, because there can be wide variation between the location of the target lesion as reported during flexible colonoscopy and the actual location found during surgery. The exact type and extent of resection will be dictated by the lymphovascular pedicles associated with the location of the target lesion (**FIG 1**).
- Laparoscopic surgery provides many advantages to the patient, including the following:[1–4]
  - Less pain
  - Faster return to work
  - Quicker return of bowel function
  - Shorter hospital stay

DIFFERENTIAL DIAGNOSIS

- Common indications for laparoscopic left hemicolectomy
  - Cancer of the splenic flexure or descending colon
  - Diverticular disease and its sequelae, including colovesicular or colovaginal fistulas

PATIENT HISTORY AND PHYSICAL FINDINGS

- Most patients with early-stage colon cancer are asymptomatic, with lesions found on colonoscopy performed for screening purposes or secondary to a positive fecal occult blood test.
- Late-stage colon cancer can present with abdominal pain, unexplained weight loss, melena, iron deficiency anemia, or a change in bowel habits. Obstructive symptoms are typically secondary to circumferential tumors.
- Patients with uncomplicated diverticulitis report episodic pain in the left lower quadrant associated with fever, changes in bowel habits, and/or bloating.
- The spectrum of symptomatology for complex diverticulitis can be as benign as those for uncomplicated

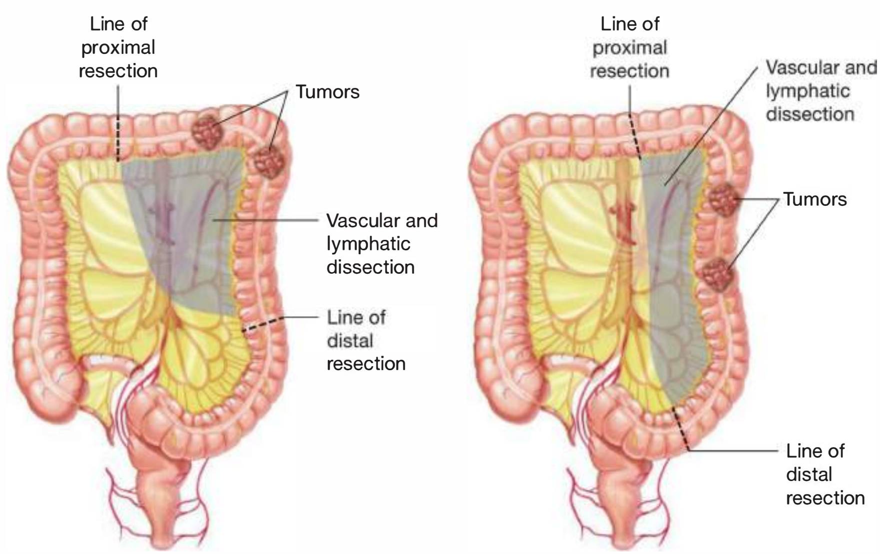


FIG 1 ● Extent of lymphovascular pedicle resection based on location of the primary tumor.

diverticulitis but can progress to localized or even generalized peritonitis.

- Patients with neoplastic or inflammatory erosion into adjacent organs, such as the bladder or vagina, can present with pneumaturia, fecaluria, or fecaloid vaginal discharge.
- A thorough family history of colon or rectal cancer, polyps, and/or other malignancies should be elicited.
- Physical examination should include the following:
  - Abdominal examination, focusing on localized tenderness, masses, and previous scars
  - Digital rectal examination to assess for blood as well as sphincter function

IMAGING AND OTHER DIAGNOSTIC STUDIES

- A full colonoscopy is essential. If a lesion is identified and it is suspicious for malignancy, the area should be tattooed to aid in intraoperative localization.
- In malignancy, a triple-phase computed tomography (CT) chest/abdomen/pelvis scan is performed to evaluate for metastases and locoregional extent of disease as well as to delineate the vascular anatomy. A preoperative carcinoembryonic antigen level should also be obtained.
- In diverticulitis, a routine CT abdomen/pelvis scan with oral and intravenous (IV) contrast is obtained.

SURGICAL MANAGEMENT

Preoperative Preparation

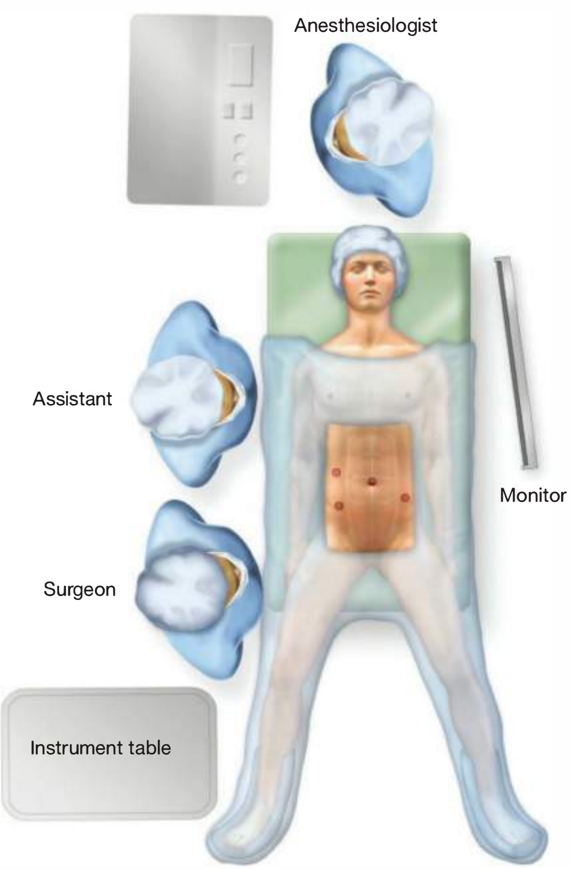
- Although preoperative bowel preparation is controversial, we routinely use it, as it makes the bowel easier to handle.
- Chlorhexidine shower the evening prior to surgery
- Normothermia maintained with Bair Hugger (36°C to 37°C) perioperatively
- Euglycemia maintained perioperatively
- One gram of Rocephin and 500 mg of Flagyl are administered within 1 hour of skin incision.
- Hair clippers are used to clear the field.
- Chlorhexidine is used for skin preparation; Betadine is used for perineal preparation.
- Preoperative time-out and briefing

Equipment and Instrumentation

- One Hasson trochar, one 12-mm port, and two 5-mm ports
- A 10-mm, 45-degree camera (may use 5 mm if quality of camera is acceptable)
- Atraumatic bowel gaspers, laparoscopic endoscissors, and a 5-mm energy device

Patient Positioning and Surgical Team Setup

- For pathology proximal to the mid–descending colon, the patient is placed on a supine position. Otherwise, the patient is placed on a lithotomy position.
- Both arms are tucked and padded. Wide silk tape is applied over two towels across the patient's chest in an "X" figure to secure the patient (**FIG 2B**).



A

B

C

FIG 2 ● **A.** Patient, ports, and team setup. **B.** Wide silk tape is applied over two towels across the patient's chest in an X figure to secure the patient. **C.** The thighs are positioned parallel with the floor to minimize encroachment on the surgeon's right operating arm.

- The patient is positioned such that the anus is easily accessible.
- The legs are placed in Allen stirrups, making sure the heel is flush against the base. Pressure points are padded posteriorly and laterally.
- The thighs are positioned parallel with the floor to minimize encroachment on the surgeon's right operating arm (**FIG 2C**).
- Thighs are wrapped with warm blankets to minimize heat loss during surgery.
- Draping is performed to allow for easy access to the perineum.
- The surgeon starts at the patient's right lower side with the assistant to his or her left. The assistant drives the camera while the surgeon uses both working ports (**FIG 2A**).
- A single monitor is needed and located on the patient's left side, across from the surgeon and at or slightly below eye level.
- All laparoscopic cables should come in from the patient's upper left side. All energy devices, Bovie, and suction should come in from the patient's upper right side. This setup prevents cluttering of the field and facilitates movement of the team around the table.

PORT PLACEMENT AND OPERATIVE FIELD SETUP

- A Hasson trochar is placed at the umbilicus. This serves as the camera port as well as the extraction site. If the pathology is located in the distal descending colon, a 12-mm port is placed in the right lower quadrant and a 5-mm port is placed in the right midquadrant. If the pathology is more proximal, then the two right abdominal ports are shifted cephalad a few centimeters (**FIG 2A**).
- A 5-mm port can be placed in the left lower quadrant to aid with takedown of the white line of Toldt and with the splenic flexure mobilization.

OPERATIVE STEPS

- Although slight adjustments may be necessary based on the exact location of the lesion, laparoscopic surgery for lesions in the splenic flexure or in the descending colon should be standardized to maximize operative efficiency, following these sequential steps:
  - Placement of the omentum above the transverse colon
  - Transection of the superior mesenteric vein (SMV)
  - Transection of the left colic artery or the IMA (depending on pathology location)
  - Medial to lateral dissection of the descending mesocolon
  - Transection of the gastrocolic ligament and entrance into the lesser sac
  - Transection of the white line of Toldt
  - Mobilization of the splenic flexure
  - Extracorporeal resection and anastomosis
  - Closure of abdominal wounds

Step 1. Placement of Omentum above the Transverse Colon

- The patient is placed in a steep Trendelenburg and rotated to the right. Omental attachments to the pelvis are taken down with an energy device. The omentum is then placed over the transverse colon and into the left upper quadrant (**FIG 3**).

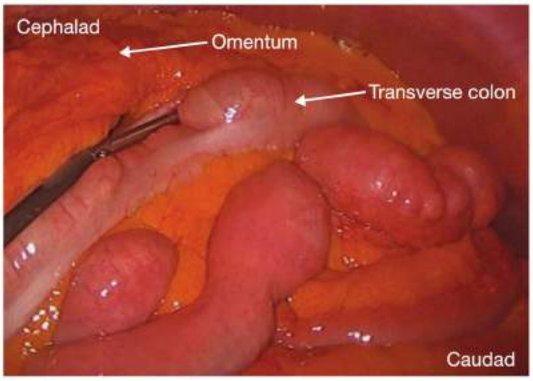


FIG 3 • The omentum is placed over the transverse colon.

Step 2. Transection of the Inferior Mesenteric Vein

- The inferior mesenteric vein (IMV) serves as the gateway to the retroperitoneum. Entering this plane in the correct location will facilitate the rest of the operation. The small bowel is swept to the right and the ligament of Treitz is exposed. If necessary, a Ray-Tec sponge can be placed in to the abdomen through the 12-mm port to assist with exposure.
- The IMV, located lateral to the ligament of Treitz, and the left colic artery are identified (**FIG 4A**).
- Start by picking up the IMV just lateral to the ligament of Treitz and dissect under it with either hot scissors or an energy device.
- Encircle the IMV and transect it with either a stapler or an energy device (**FIG 4B**).
- Lift up on the cut IMV and begin exposure of the retroperitoneal plane (**FIG 4C**).
- There is a "bare area" of mesentery between the left colic artery and the middle colic artery. Using an energy device, take this mesentery 1 cm from the lateral edge of the duodenum as far lateral as it is safe. Care must be taken here to avoid angling up toward the colon and risk injuring the marginal artery (**FIG 4D**).

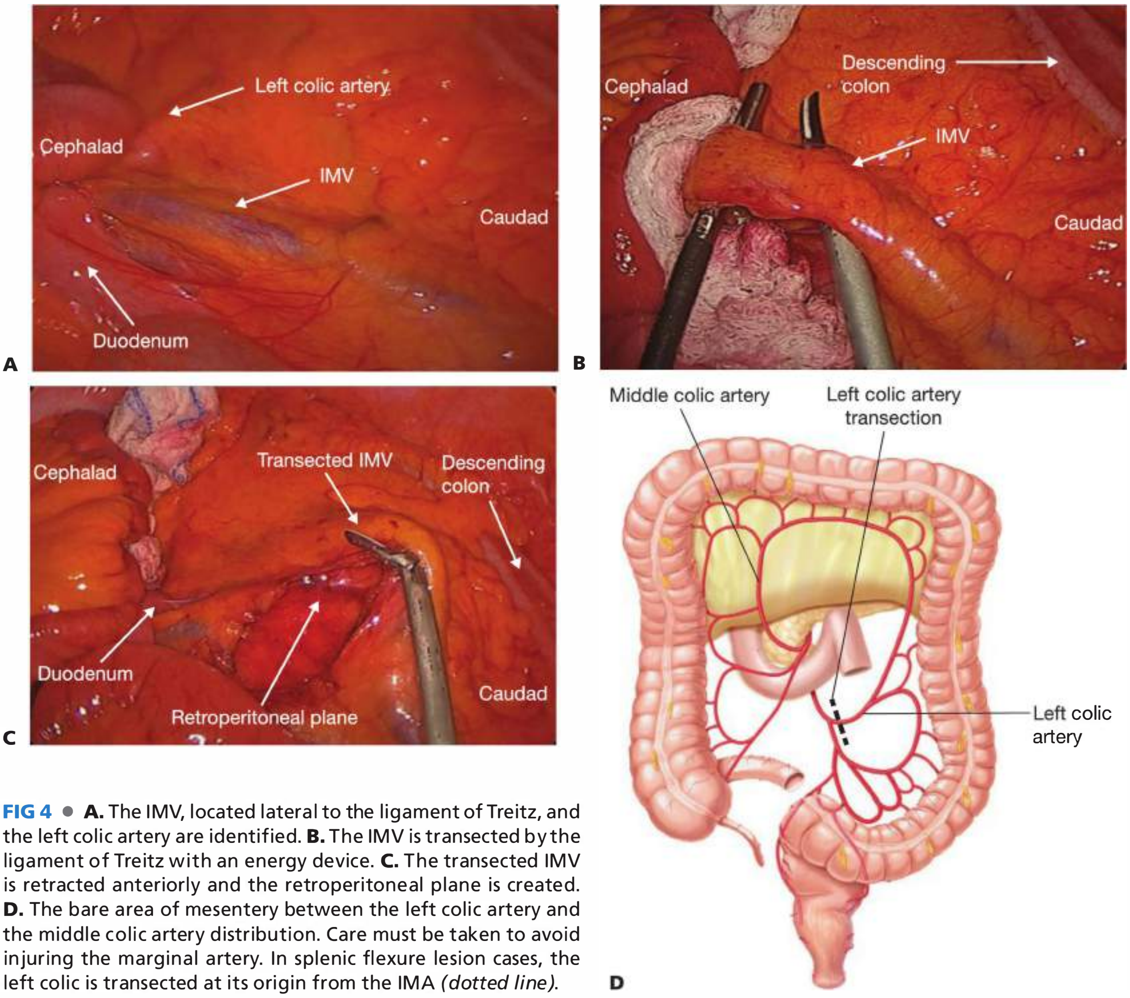


FIG 4 ● **A.** The IMV, located lateral to the ligament of Treitz, and the left colic artery are identified. **B.** The IMV is transected by the ligament of Treitz with an energy device. **C.** The transected IMV is retracted anteriorly and the retroperitoneal plane is created. **D.** The bare area of mesentery between the left colic artery and the middle colic artery distribution. Care must be taken to avoid injuring the marginal artery. In splenic flexure lesion cases, the left colic is transected at its origin from the IMA *(dotted line)*.

Step 3. Transection of the Left Colic Artery or the Inferior Mesenteric Artery

- Proceeding with the dissection caudally, the left colic artery can be readily identified branching off the IMA. For splenic flexure lesions, transection of the left colic artery at its origin of the IMA using an energy device or stapler provides an adequate lymphovascular pedicle (**FIGS 4D** and **5A**).
- Lesions located in descending colon frequently require inclusion of the sigmoid in the specimen, necessitating a high IMA transection to perform an adequate lymphadenectomy.
- In these patients, the mesodescending colon is dissected caudally until the left colic artery is appreciated and the retroperitoneal plane is created.
- The groove in between the superior hemorrhoidal artery (SHA) and the left iliac artery is identified. The surgeon elevates the SHA and incises the peritoneum under it using hot scissors or an energy device.
- The avascular retroperitoneal plane is swept down bluntly and the left ureter and gonadal vessels are identified and pushed posteriorly into the retroperitoneum. This retroperitoneal dissection plane is carried in a cephalad direction until all that remains between the superior and inferior dissections is the IMA.
- Lifting up on the IMA and its terminal branches, the SHA and the left colic artery will form what appears to be a letter "T" (**FIG 5A**). The IMA is then transected at its origin off the aorta with a vascular load stapler (**FIG 5B**).

Step 4. Medial to Lateral Dissection of the Descending Mesocolon

- The retroperitoneal plane, dissection of which was initiated during the IMV transection step, is now easily accessible. The surgeon completes dissection of this space, avascular plane, located between Gerota's fascia posteriorly and the descending mesocolon anteriorly, by holding the mesocolon up with a grasper while

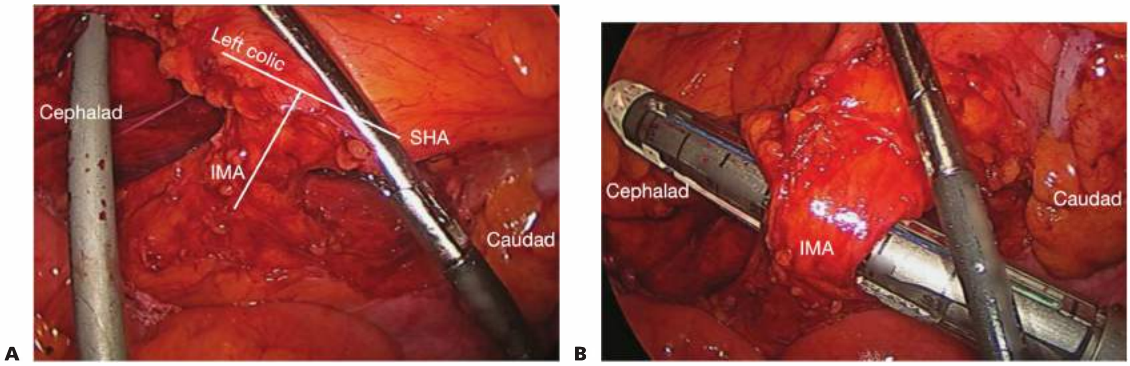


FIG 5 ● **A.** The "letter T." The IMA and its terminal branches, the SHA and the left colic artery, form what looks like a letter T. **B.** High IMA transection with linear vascular load stapler.

pushing the retroperitoneum down bluntly with an energy device (**FIG 6**). If needed, an additional 5-mm port is placed in the right upper quadrant for the assistant to help retract the mesocolon anteriorly.

- The retroperitoneal plane is continued until the abdominal wall is reached laterally and until the splenic flexure reached superiorly. The inferior extent of the retroperitoneal dissection depends on the location of the pathology. For lesions at the splenic flexure where the IMA has been left intact, the retroperitoneal dissection continues distally until further dissection is prohibited by the IMA. For lesions at the distal descending colon, where the IMA has been transected, the dissection continues until the pelvic inlet is reached.

Step 5. Transection of the Gastrocolic Ligament and Entrance to the Lesser Sac

- The transverse colon is retracted downward and the stomach is retracted superiorly, exposing the gastrocolic ligament. The gastrocolic ligament is then transected medially with an energy device until the lesser sac is entered.
- Transection of the gastrocolic ligament then proceeds along the distal transverse colon until the splenic flexure is reached (**FIG 6**). Care must be taken to avoid inadvertent injury to the colon.

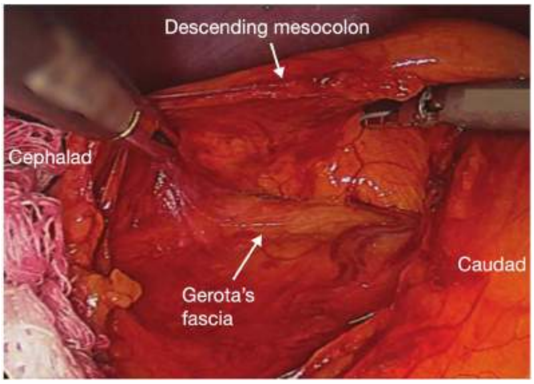


FIG 6 ● Completion of the medial to lateral dissection. The dissection proceeds in the plane located between the descending mesocolon anteriorly and Gerota's fascia posteriorly.

Step 6. Transection of the White Line of Toldt

- The descending colon is now only attached to the lateral abdominal wall by the lateral peritoneal attachments (the white line of Toldt). Medial retraction of the descending colon allows for good exposure of these lateral peritoneal attachments.
- Standing on the right side of the table, the surgeon then takes down the white line of Toldt using hot scissors.
- Alternatively, the surgeon can move in between the patient's legs, place a 5-mm port in the left lower quadrant, and transect the white line of Toldt moving up the left gutter, until reaching the splenic flexure of the colon.

Step 7. Splenic Flexure Mobilization

- The splenic flexure is now encountered. The patient is placed on a reverse Trendelenburg position, helping bring the splenic flexure into view.
- The surgeon and the assistant retract the splenic flexure inferiorly and medially, exposing the splenocolic and phrenocolic ligaments. These ligaments are then transected with a 5-mm energy device (**FIG 7**).
- The splenic flexure and descending colon are now completely free of any attachments and fully mobilized.

Step 8. Extracorporeal Resection and Anastomosis

- The pneumoperitoneum is evacuated and a 4- to 5-cm midline incision is made, centering on the Hasson trochar site at the level of the umbilicus.
- A small Alexis retractor is placed to protect the wound from infection and oncologic contamination. The colon is delivered into the operating field (**FIG 8A**). There should be no tension along mesenteric structures during the delivery of the specimen.
- The mesentery of the proximal and distal colon segment is taken in between clamps to the colonic wall. To ensure a well-vascularized anastomosis, the clamp is briefly taken off the marginal artery on the proximal colon side to ensure pulsatile flow.
- The proximal and distal margins are circumferentially cleared of excess fat and Kocher clamps are placed on the proximal and distal margins of the resection.

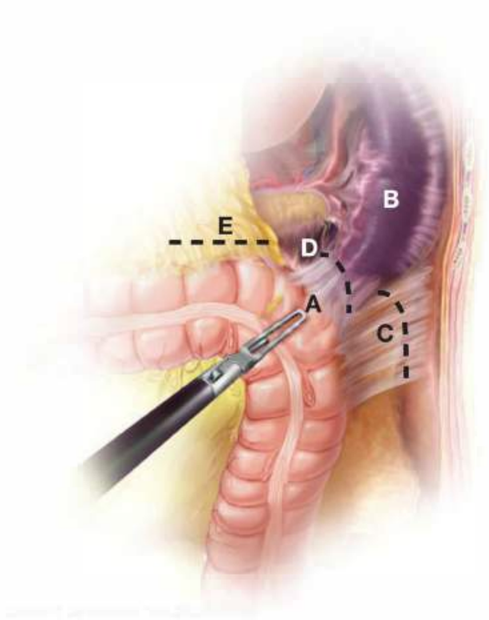


FIG 7 ● Mobilization of the splenic flexure. The phrenocolic *(C)*, splenocolic *(D)*, and gastrocolic *(E)* ligaments are transected. *A*, splenic flexure of the colon; *B*, spleen.

- A no. 10 blade scalpel is used to transect the proximal and distal colon and the specimen is passed off the field.
- Two Allis clamps are used to hold the proximal and distal colonic segments up. Using an Asepto and a poole sucker, the open colon ends are irrigated, suctioned, and cleaned of debris.
- The anastomosis is fashioned in a single layer with a running double armed 4-0 Maxon suture and placed back into the abdomen (**FIG 8B**).
- Once the anastomosis is delivered back into the abdominal cavity, the Alexis retractor is twisted and tied with umbilical tape around the Hasson port and the abdomen is reinsufflated to inspect the anastomosis (**FIG 8C**).
- The omentum is placed over the anastomosis. Closure of the mesenteric defect is not routinely performed.
- The 12-mm right lower quadrant port is closed with an inlet closure device, the 5-mm ports are taken out under direct visualization, and the abdomen is deinsufflated.

Step 9. Closure of Abdominal Wounds

- Gown and gloves are changed in an effort to prevent wound infections.
- Four clean towels are used to square off the surgical field.
- Separate closing instruments, suction, and Bovie tip are used.
- The abdominal fascia is closed with absorbable suture and the skin is closed with staples.

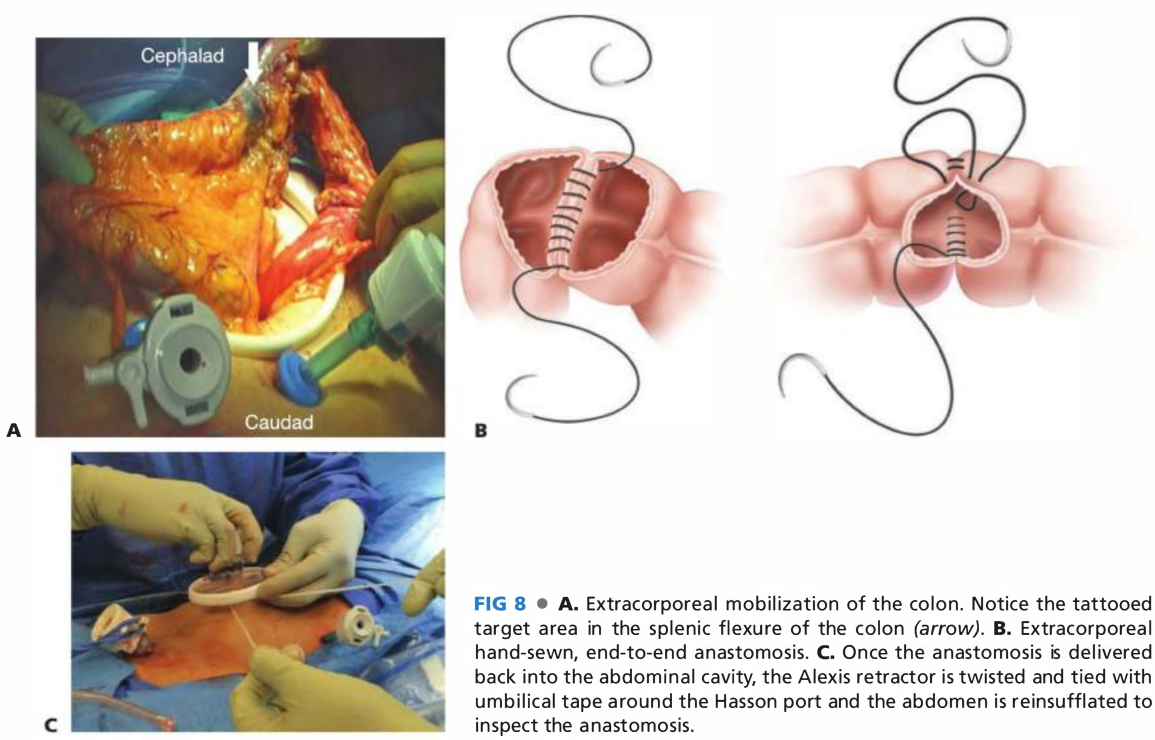


FIG 8 ● **A.** Extracorporeal mobilization of the colon. Notice the tattooed target area in the splenic flexure of the colon *(arrow)*. **B.** Extracorporeal hand-sewn, end-to-end anastomosis. **C.** Once the anastomosis is delivered back into the abdominal cavity, the Alexis retractor is twisted and tied with umbilical tape around the Hasson port and the abdomen is reinsufflated to inspect the anastomosis.

PEARLS AND PITFALLS

Preoperative imaging	■ Carefully review the CT scan as well as the colonoscopy report to determine whether the patient can be in a supine or lithotomy position. ■ Determine if ureteral stent placement will be necessary.
Positioning	■ Lithotomy position: Make sure that the legs are well padded to avoid injury to the lateral peroneal nerves.
Operative technique	■ The IMV at the ligament of Treitz is the "gateway" to the retroperitoneum. ■ Medial to lateral dissection of the retroperitoneal plane ■ Sweep ureter and gonadal vessels into the retroperitoneum. ■ Identify the letter T before IMA or left colic artery transection. ■ Facilitate splenic flexure takedown by placing a 5-mm left lower quadrant port and by standing in between the legs. ■ Make sure to free splenic flexure from all attachments to ensure full mobilization of the descending colon; this will ensure a tension-free anastomosis.
Pitfall: avoiding injury to the marginal artery	■ Once the IMV has been transected, the mesenteric bare area travels superiorly and medially about 1 cm from the lateral edge of duodenum until the middle colic is appreciated. Resist the temptation to continue toward the colon wall, resulting in injury to the marginal artery.
Pitfall: leaving retroperitoneal structures attached to the colonic mesentery	■ A common pitfall is to perform the retroperitoneal dissection one layer too deep, thereby leaving retroperitoneal structures (tail of the pancreas, left ureter, and gonadal vessels) attached to dorsal surface of the colonic mesentery. This could lead to serious injury of these structures while transecting the mesocolon. Additionally, this will significantly limit the mobility of the colon, which may result in anastomotic tension.
Pitfall: floppy descending or sigmoid colon	■ The lateral and splenic attachments are left for last. This allows the colon to be tethered up to the abdominal wall. If this colon still is not cooperative, place a 5-mm port in the right upper quadrant for the assistant to elevate the colon.
Pitfall: leaving the peritoneum of the lateral abdominal wall on the colon	■ Another location where it is easy to enter the wrong plane is during takedown of the lateral colon attachments. ■ The correct plane is immediately adjacent to the colon wall; stay medially during this phase of the dissection.

POSTOPERATIVE CARE

- An enhanced recovery after surgery (ERAS) pathway is used, which includes the following:
  - Deep vein thrombosis (DVT) prophylaxis with Lovenox starting in the morning of postoperative day (POD) 1
  - No additional antibiotics are required.
  - Pain control
    - Dilaudid patient-controlled anesthesia (PCA)
    - IV Tylenol scheduled q6h (first dose in the operating room [OR]); maximum dose: less than 4 g per day
    - IV Toradol scheduled q6h for 5 days if creatinine is normal, starting in the morning of POD 1
    - IV muscle relaxant (methocarbamol) scheduled q6h for 3 days
    - Discontinue PCA when patient tolerates oral intake well (usually late POD 1 or POD 2) and switch to Norco rather than Vicodin to decrease amount of acetaminophen administered.
  - Alvimopan (Entereg) is started preoperatively and continued twice a day until return of bowel function.
  - Only labs needed are hemoglobin/hematocrit (H/H) and basic metabolic panel (BMP) on POD 1 unless clinically indicated.
  - Diet
    - Patient leaves the OR without a nasogastric tube (NGT).
    - Okay for sips of clear liquids the evening of surgery
    - Clear liquids on POD 1 unless bloated
    - Advance diet to full liquid or soft diet on POD 2 unless bloated
    - Patient does not need to pass gas or have a bowel movement prior to advancing diet.
    - Be judicious with intravenous fluid (IVF).
  - Encourage early ambulation.
  - Foley: remove when patient begins walking, usually PODs 1 to 2.
  - Discharge: may discharge once patient has return of bowel function, usually PODs 3 to 4.

OUTCOMES

- Laparoscopic surgery leads to improvements in short-term outcomes, including a faster recovery, shorter hospital stay, and less pain.
- There is no difference in oncologic outcomes between laparoscopic and open surgery.

COMPLICATIONS

- Ureter injury: prevented by clear visualization of the retroperitoneal plane
- Sexual dysfunction (retrograde ejaculation) prevented by careful preservation of hypogastric sympathetic plexus located at the sacral promontory
- Wound infection: decreased incidence by careful attention to surgical technique
- DVT: prevented by initiating sequential compression device (SCD) therapy prior to anesthetic induction and timely initiation of pharmacologic prophylaxis.

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Chapter **18**

Left Hemicolectomy: Hand-Assisted Laparoscopic Technique

Steven A. Lee-Kong   Daniel L. Feingold

DEFINITION

- Left hemicolectomy is typically defined as resection of the splenic flexure of the colon with its mesentery including the left colic artery and the left branch of the middle colic artery. This operation is most commonly performed for neoplasia and is, in general terms, a mirror image of a right colectomy whereby the colon is mobilized and the mesentery is dissected out and transected, allowing exteriorization of the loop of colon. During left colectomy for cancer, the left side of the greater omentum is usually resected en bloc with the colon. The straight laparoscopic approach to splenic flexure lesions can be challenging, especially in cases with a large neoplasm, colonic obstruction, or difficult splenic flexure ("extreme" flexure). In these circumstances, the hand-assisted laparoscopic surgery (HALS) approach to left colectomy may prove advantageous over a pure laparoscopic approach as it restores tactile sensation and improves retraction and exposure.

PATIENT HISTORY AND PHYSICAL FINDINGS

- Prior surgical history can influence the approach to left colectomy
  - Prior colon resection
    - May affect remaining colonic blood supply and can influence the operative plan regarding what bowel segment will be used for the anastomosis
  - Extensive intraabdominal surgery
    - Extensive or dense adhesions may prohibit a minimally invasive approach.
    - Prior gastric or bariatric surgery can distort the anatomy and make for challenging dissection for left colectomy.
  - Abdominoplasty
    - May limit intraabdominal domain afforded by the pneumoperitoneum
- Morbid obesity or an abundance of intraabdominal adipose tissue may hinder a minimally invasive approach.

IMAGING AND OTHER DIAGNOSTIC STUDIES

- Contrast-enhanced cross-sectional imaging of the abdomen and pelvis is useful for planning the surgery in terms of accurate localization and in determining the site of the hand port. Imaging can also alert the surgeon of a potentially difficult splenic flexure takedown (extreme flexure, significant colon looping, bulky colon neoplasia adjacent to the spleen, etc.).
- Colonoscopy to evaluate the remaining colon. In addition, it allows to localize the target lesion with tattoos which is useful and facilitates a laparoscopic approach.

SURGICAL MANAGEMENT

Preoperative Planning

- Colonoscopy and pathology reports and relevant cross-sectional imaging should be reviewed.
- Intraoperative carbon dioxide (CO_2) colonoscopy should be available in the operating room for localization purposes (if necessary) as well as for assessment of the anastomosis, if needed.
- Mechanical bowel preparation facilitates intraoperative colonoscopy in cases where preoperative localization fails.
- In cases of neoplasia, the operative plan should be to perform a cancer operation regardless if the colonoscopy biopsies fail to demonstrate malignancy.

Positioning

- For HALS left colectomy, the authors prefer to use padded split-leg position with Ace wraps, securing the patient's legs to the operating room table (**FIG 1**). This allows the surgeon to stand between the patient's legs during the procedure. Split-leg positioning may be preferable to stirrups as the legs are maintained in a neutral position and pressure-related nerve injuries are minimized.
- The patient should be secured to the operating room table with a chest strap, as extreme positioning is often necessary.
- The right arm should be padded and tucked in a neutral position.

FIG 1 ● Patient positioning. We prefer a split-leg position to allow the surgeon to operate from between the legs and to minimize potential leg injuries.

ENTERING THE ABDOMEN AND INITIAL EXPOSURE

- A Pfannenstiel or lower midline incision is created for hand-port placement (**FIG 2**). A 5-mm camera port is placed in the supraumbilical midline and 5-mm working ports are placed in the right lower quadrant and left lower quadrant positions.
- In patients with prior abdominal surgery, laparoscopic access can be created by cut-down or Veress needle technique in a presumed safe location. This allows laparoscopic evaluation of abdominal wall adhesions, which can be lysed prior to creating the hand-port access. Alternatively, adhesions can be lysed in an open fashion through the hand-port incision; the surgeon's ability to perform adhesiolysis in this fashion may be limited. Inability to lyse these adhesions can jeopardize the laparoscopic approach.
- The patient is placed in steep Trendelenburg with the table tilted right side down.
- The greater omentum is draped over the transverse colon and liver. The small bowel is retracted out of the pelvis and toward the right upper quadrant of the abdomen, exposing the sigmoid and left colon mesentery (**FIG 3**).
  - A laparotomy pad placed intraabdominally through the hand port aides in the retraction of the small bowel and in maintaining exposure. This also facilitates cleaning the scope without having to remove the scope from the abdomen. To reduce the chance of a retained pad, a hemostat is placed on the surgeon's gown, signifying that a pad is in the belly. When the pad is removed (typically just prior to extraction), the hemostat is removed from the gown. If the surgeon goes to remove his or her gown with the hemostat still in place, the team is alerted that there may be a retained foreign body in the patient.
- A 30-degree angled scope is used at the discretion of the surgeon. Angled scopes enable the surgeon to look over the horizon (particularly useful in splenic flexure takedown) and improves laparoscopic access to the field by allowing the scope to be held away from the dissection.

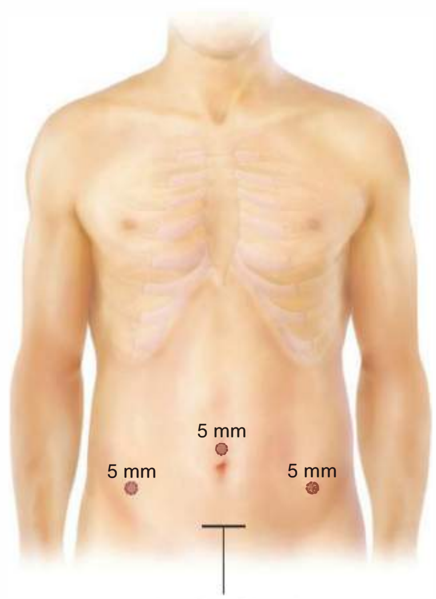

FIG 2 ● Ports, monitors, and team placement.

FIG 3 ● Left colon mesentery.

MESENTERIC DISSECTION, MEDIAL TO LATERAL

- Commonly, the sigmoid and its mesentery are mobilized in order to permit extraction and the creation of a tension-free anastomosis. In cases where this degree of mobilization is not required, these steps may be omitted.
- The surgeon stands at the patient's right hip and the assistant stands at the right shoulder holding the camera at the umbilicus. The inferior mesenteric artery (IMA) pedicle is elevated with the surgeon's right thumb and index finger (**FIG 4**) and is retracted toward the patient's left hip. The surgeon uses an energy device through the right lower quadrant port to dissect dorsal to the IMA and its superior hemorrhoidal terminal branch (**FIG 5**). The aortic bifurcation and common iliac arteries are appreciated prior to starting the dissection. The peritoneum beneath the pedicle is scored to the level of the sacral promontory.
- Palpating the right and left common iliac arteries located underneath the mesosigmoid and over the sacral promontory orients the surgeon (**FIG 6**).
- Care is taken to preserve the hypogastric nerves located dorsal to the superior hemorrhoidal vessels.

FIG 4 ● Grasping the IMA pedicle. The IMA and its terminal branch, the superior hemorrhoidal artery, are elevated off the retroperitoneum with the surgeon's right thumb and index finger.

- The retromesenteric plane is developed by sweeping the retroperitoneum down (dorsally) and elevating the mesentery (**FIG 6**). The plane is developed laterally toward the side wall, superiorly over Gerota's fascia and caudally toward the presacral space. As this is a relatively bloodless plane of dissection, bleeding is usually caused by injury to the overlaying mesentery or dissection into the floor of the space that is the retroperitoneum. Recognizing that you are not in the actual embryonic fusion plane allows you to adjust the dissection and reenter the correct plane.
- The left ureter and gonadal vessels are identified and preserved intact by sweeping these structures down into the retroperitoneum (**FIG 7**).

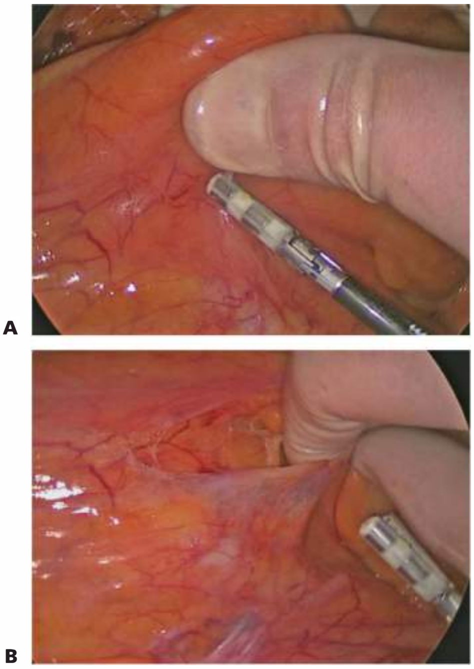

FIG 5 ● **A,B.** Scoring the peritoneum to enter the retromesenteric plane. The plane of dissection proceeds along the dorsal aspect of the superior hemorrhoidal vessels.

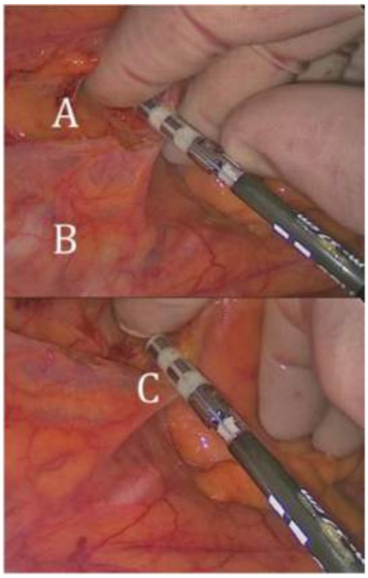

FIG 6 ● Palpating the right *(A)* and left *(B)* common iliac as well as the sacral promontory *(C)* helps orient the surgeon.

- With the hand supinated within the retromesenteric space, a mesenteric window is created between the main sigmoidal artery and the left colic artery. The takeoff of the left colic artery is then divided with the energy device (**FIG 8**) while ensuring the left ureter is preserved intact in the retroperitoneum. Tumor localization should be confirmed (by intraoperative colonoscopy, if needed) prior to vessel ligation.
- Once the left colic artery is transected, the retromesenteric space opens up, allowing further dissection in this plane laterally and cephalad. This dissection is carried along the plane located between the mesocolon and Gerota's fascia (**FIG 9**).
- The patient is then placed in slight reverse Trendelenburg position while the surgeon stands between the patient's legs and the assistant stands at the patient's right hip.

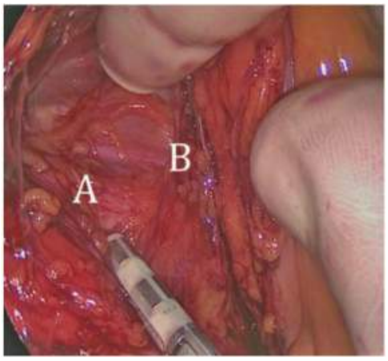

FIG 7 ● Retromesenteric dissection. The left ureter *(A)* and the left gonadal vessels *(B)* are identified and preserved intact in the retroperitoneum.

FIG 8 ● Dividing left colic artery.

- The assistant holds the camera and, using an atraumatic grasper through the right-sided port, retracts the left transverse colon cephalad. The surgeon orients himself by palpating the aorta and visualizing the ligament of Treitz (**FIG 10**). The surgeon, with his left hand in the abdomen and the energy device through the left-sided port, carefully enters the retromesenteric plane medial to the inferior mesenteric vein (IMV) by incising the peritoneum longitudinally along the medial aspect of the IMV (**FIG 11**). Care is taken to avoid injury to the small bowel in this dissection.

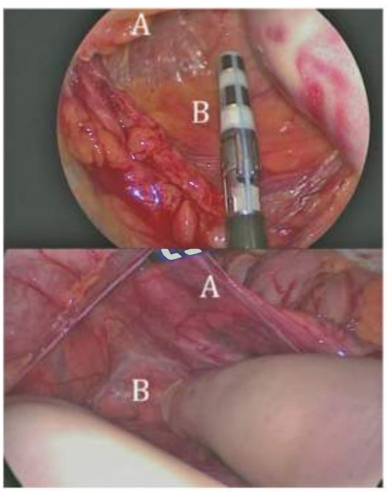

FIG 9 ● Further retromesenteric dissection. This dissection is carried along the plane located between the mesocolon *(A)* and Gerota's fascia *(B)*.

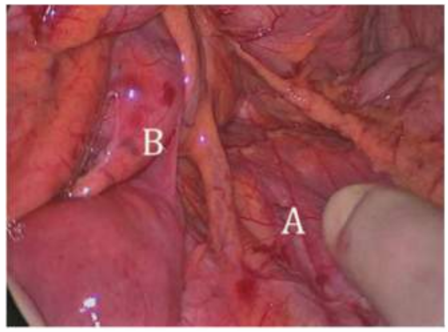

FIG 10 ● Medial to lateral dissection at the IMV. The surgeon orients himself by palpating the aorta *(A)* and visualizing the ligament of Treitz *(B)*.

  Taking down the ligament of Treitz and opening up the paraduodenal recess should be done with cold laparoscopic scissors to prevent thermal injury to the small bowel.
- The medial to lateral dissection at the IMV is the cephalad extension of the medial to lateral plane that had been already dissected at the level of the IMA. Elevating the colon mesentery off the retroperitoneum allows the two retromesenteric spaces to meet. When mobilizing the plane at the IMV, care should be taken not to enter the plane too deeply as this can injure the ureter or gonadal bundle.
- The IMV is then divided with the energy device at the cephalad extent of the dissection.
- The retromesenteric plane is then further developed cephalad to the inferior edge of the pancreas and laterally over the kidney to the splenic flexure.

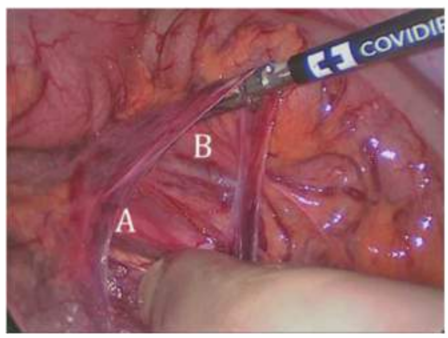

FIG 11 ● Medial to lateral dissection at the IMV. Care is taken to avoid injuring the left ureter *(A)* and gonadal vessels *(B)*.

SPLENIC FLEXURE MOBILIZATION

- The patient is placed in a steeper reverse Trendelenburg position; this delivers the plane of dissection closer to the hand port.
- The assistant retracts the greater omentum, and the surgeon's left hand applies countertraction to expose the bloodless plane between the omentum and the transverse colon (**FIG 12**). The omentum is released from the transverse colon and the lesser sac is entered at the midline. The dissection proceeds laterally, as far as possible, exposing the splenocolic ligament (**FIG 13**). The splenocolic ligament is then transected with the energy device.
- In cancer resections, the omentum adherent to the area of the cancer is resected en bloc. Care is taken to avoid injury to the short gastrics, stomach, pancreas, and spleen.

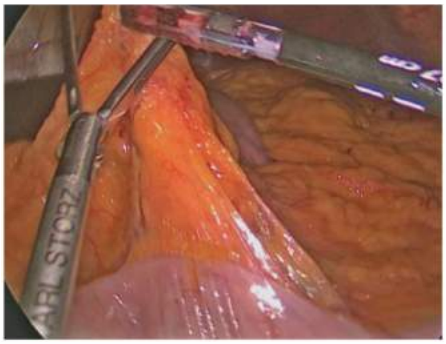

FIG 12 ● Splenic flexure mobilization. The assistant retracts the greater omentum while the surgeon retracts the transverse colon.

FIG 13 ● Mobilization of the splenic flexure: exposure of the splenocolic ligament. This ligament will be transected with the energy device.

LATERAL TO MEDIAL DISSECTION

- The descending colon has already been mobilized during the medial to lateral dissection of the mesocolon as described previously, and now the colon and is only tethered to the left gutter by the peritoneal attachments. Although the assistant retracts the colon medially by grasping an epiploic appendage, the surgeon releases the colon from the sidewall using the energy device (**FIG 14**). This dissection will immediately enter the retromesenteric dissection plane. Lateral dissection is continued superiorly until the lesser sac dissection is met and the splenic flexure is fully released.

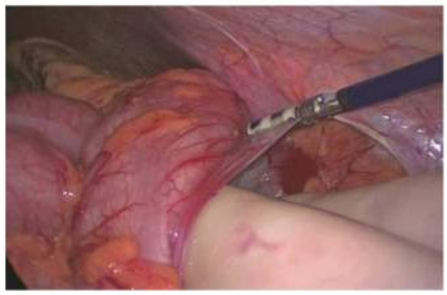

FIG 14 ● Lateral to medial dissection.

DISSECTION OF THE TRANSVERSE COLON MESENTERY

- The surgeon's supinated left hand underneath the mesentery exposes a clear space in the transverse mesocolon at the inferior border of the pancreas. Opening this mesenteric window facilitates the dissection to release the left transverse mesocolon from its retroperitoneal attachment (**FIG 15**). The transverse mesocolon is then transected with the energy device.
- The left branch of the middle colic artery is dissected out and divided at the base of the mesentery with the energy device. The anatomy of the middle colic artery is variable and more than one branch may need to be taken. The left colon is now fully mobilized (**FIG 16**).

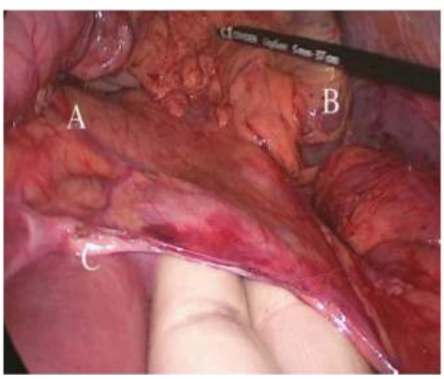

FIG 15 ● Dissection of the transverse colon mesentery. The transverse colon mesentery along the inferior border of the pancreas *(A)* between the spleen *(B)* and the ligament of Treitz *(C)* is exposed.

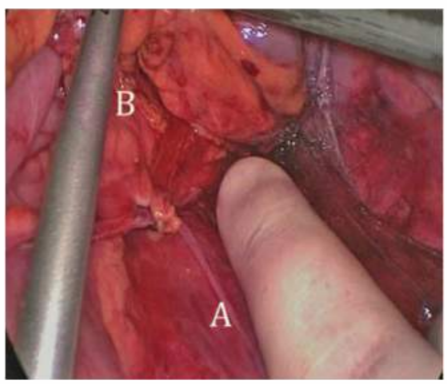

FIG 16 ● Full mobilization of the left colon is achieved. After complete mobilization of the left colon to the midline, Gerota's fascia *(A)* and the tail of the pancreas *(B)* can be visualized.

ASSESSMENT OF REACH

- Prior to exteriorization, the left upper quadrant is inspected and hemostasis is ensured. Each site of mesenteric vessel ligation is inspected as well.
- The intraabdominal laparotomy pad is extracted.
- The hand port is removed and, using a wound protector, the colon is exteriorized. Appropriate levels of transection are identified and the colon is divided with a linear stapler in open fashion, per usual. The specimen is oriented by a stitch to aide pathologic evaluation and is delivered off the field.
- Reach is assessed and no tension should be appreciated. If needed, the hand port can be replaced and further mobilization can be performed.

ANASTOMOSIS

- The anastomosis is created in stapled or hand-sewn fashion at the discretion of the surgeon (**FIG 17**).
- The authors advocate creating an omental pedicle laparoscopically (when possible) and draping this over the anastomosis.
- The mesenteric defect is broad and is not typically closed.

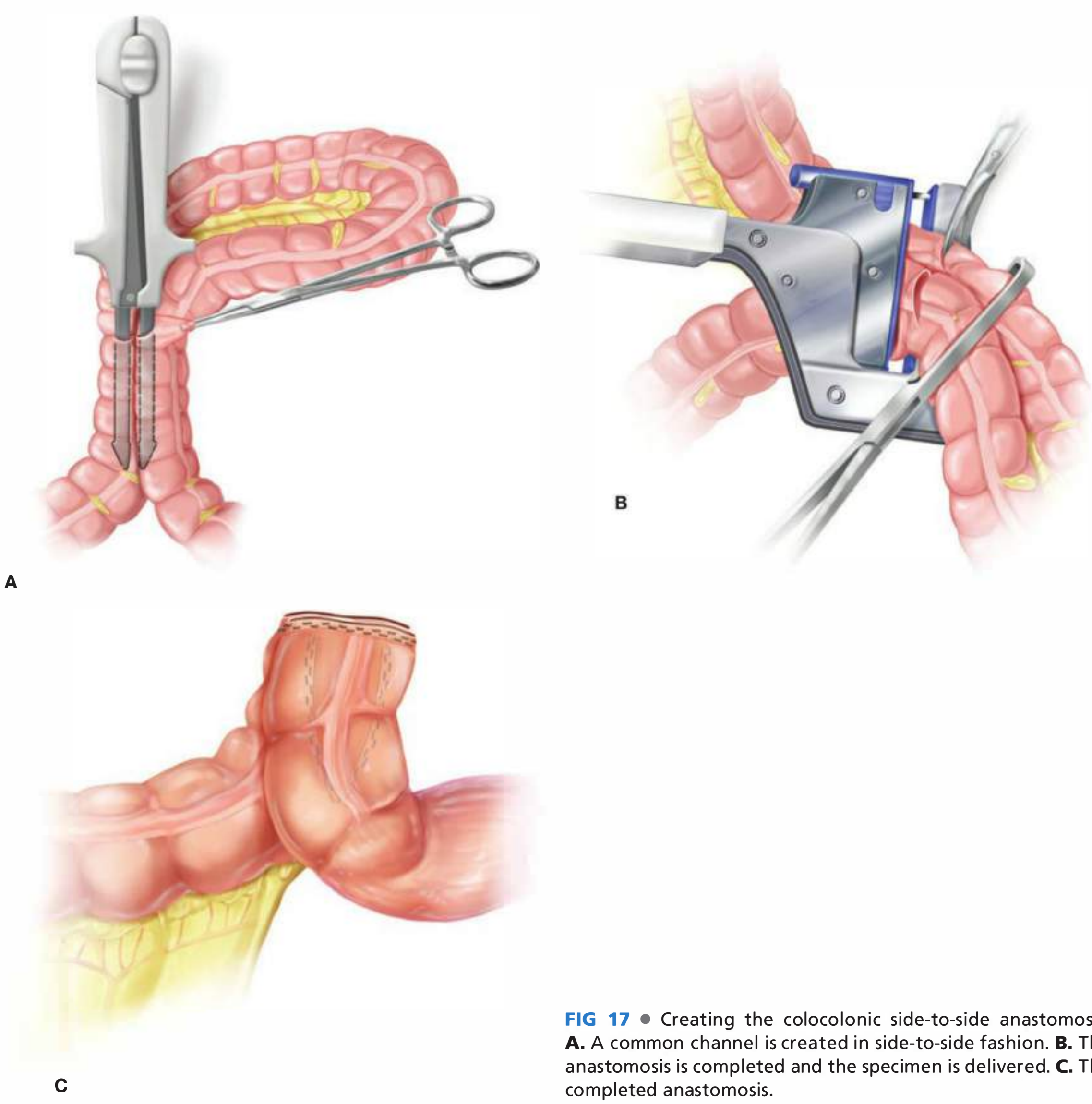

FIG 17 ● Creating the colocolonic side-to-side anastomosis. **A.** A common channel is created in side-to-side fashion. **B.** The anastomosis is completed and the specimen is delivered. **C.** The completed anastomosis.

PEARLS AND PITFALLS

Inadequate reach	Splenic flexure not completely released or transverse mesocolon not freed from inferior border of pancreas. The hepatic flexure may need to be released as well.
Inability to exteriorize the colon	Persistent attachments to the retroperitoneum or omentum need to be taken down.
Inability to identify left ureter	Retromesenteric dissection too deep into the retroperitoneum or the ureter is adherent to the mesenteric side of the dissection. Find the ureter at the level of the left colic artery instead of at the IMA.
Proximal colon ischemic after mesenteric division	Inadequate collateral colonic blood supply via the marginal artery requires further resection back to healthy colon.
Dissection not progressing	Place additional 5-mm working port(s) or convert to open procedure.
Poor access to the splenic flexure	Place patient in steeper reverse Trendelenburg and tilt the table left side up.
Splenic bleeding	Use the laparotomy pad to control the bleeding while the team prepares an energy device or absorbable hemostatic agents. Convert to open procedure if unable to achieve hemostasis.

POSTOPERATIVE CARE

- Remove the bladder catheter the morning after the operation to reduce the risk of urinary tract infections.
- Avoid immediate postoperative nasogastric tubes.
- Encourage early and progressive ambulation and pulmonary toilet.
- Use pharmacologic and mechanical deep vein thrombosis prophylaxis.
- Advance oral intake as patients tolerate rather than waiting for flatus or the first bowel movement.
- Maximize the use of nonnarcotic medications, when appropriate (ketorolac, acetaminophen, postprocedure transversus abdominis plane blocks) to help reduce narcotic use and minimize the incidence and duration of postoperative ileus.

OUTCOMES

- Minimally invasive colectomy is associated with shorter in-hospital convalescence and less narcotic use compared with open surgery.[1]
- For cancer resection, laparoscopic colectomy oncologic outcomes are similar to those of open resection.[1,2,3]
- Hand-assisted colectomy, as compared with straight laparoscopy, shortens operative times without increasing length of hospital stay or narcotic use.[4]

COMPLICATIONS

- Anastomotic dehiscence is a potential complication after any bowel anastomosis is created. This can be minimized by ensuring adequate blood supply and eliminating tension across the anastomosis.
- Extraction site wound infections can be minimized by using National Surgical Quality Improvement Program (NSQIP) approved protocols and wound protectors.

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Chapter **19**

Sigmoid Colectomy: Open Technique

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DEFINITION

- A sigmoidectomy is the resection of the sigmoid colon to the level of the rectosigmoid junction. The extent of the lymphadenectomy will be determined by the indication (benign vs. malignant disease).
- Focal segmental sigmoid resection for benign disease can be accomplished by dividing the vessels close to the bowel wall, without the need for a high pedicle transection. A complete sigmoidectomy (described in this chapter) includes transection of the inferior mesenteric artery (IMA) at its origin and resection of the proximal superior rectal artery (SRA) and sigmoidal branches.

DIFFERENTIAL DIAGNOSIS

- Indications for sigmoidectomy include the following:
  - Sigmoid colon polyps and cancer
  - Diverticular disease (i.e., complicated diverticulitis, perforation, fistulae, etc.)
- Other indications include sigmoid volvulus, ischemic or infectious colitis, and trauma.

PATIENT HISTORY AND PHYSICAL FINDINGS

- Most patients with early-stage colon cancer are asymptomatic, found on colonoscopy performed for screening purposes or secondary to a positive fecal occult blood test.
- Late-stage colon cancer can present with abdominal pain, unexplained weight loss, melena, iron deficiency anemia, or a change in bowel habits. Obstructive symptoms are typically secondary to circumferential tumors.
- Patients with uncomplicated diverticulitis report episodic pain in the left lower quadrant associated with fever, changes in bowel habits, and/or bloating.
- The spectrum of symptomatology for complex diverticulitis can be as benign as those for uncomplicated diverticulitis but can progress to localized or even generalized peritonitis.
- Patients with neoplastic or inflammatory erosion into adjacent organs, such as the bladder or vagina, can present with pneumaturia, fecaluria, or fecaloid vaginal discharge.
- A thorough family history of colon or rectal cancer, polyps, and/or other malignancies should be elicited.
- The physical examination should include the following:
  - Focused abdominal exam, including notation of abdominal scars
  - Digital rectal exam, focused on assessment of sphincter function
  - Rigid proctoscopy for all patients with sigmoid polyps or cancer reported by endoscopy to be within 20 cm from the anal verge. This will allow for confirmation of the site of the lesion, which oftentimes may not coincide with the endoscopy report. This information may alter the surgical and oncologic approach.
  - Rigid proctoscopy should not be performed in patients presenting with acute diverticulitis or perforation to avoid worsening of a microperforation by air insufflation.

IMAGING AND OTHER DIAGNOSTIC STUDIES

- Carcinoembryonic antigen (CEA): The baseline preoperative result and postsurgical control must be obtained as an assessment for complete tumor resection. On the other hand, the absolute presurgical value is an independent variable for survival.
- Abdominal computed axial tomography is the most sensitive and specific test for detection of intraabdominal metastases.
- Chest computed axial tomography is the most sensitive and specific test to detect mediastinal and lung metastases. It is also helpful in diverticulitis cases to evaluate for the extent of diverticular disease and for the possible presence of peridiverticular abscess, stricture, and/or fistula.
- Total colonoscopy: Regardless of the primary localization of the tumor, every patient should have a complete colonoscopy study whenever possible, because 2% to 9% of the patients may have synchronous tumors. The colonic enema with double contrast may be used in those patients in whom the colonoscopy is not possible.

SURGICAL MANAGEMENT

Preoperative Planning

- The patient should be mechanically bowel prepped the day before surgery with the GoLYTELY solution.
- The nil per os (NPO) status is then effective after midnight.
- The necessary radiologic and laboratory examination should be verified and reviewed accordingly.
- Patient should be consented appropriately for the procedure.
- We typically do not place preoperative stents for patients undergoing sigmoid colectomy for resolved diverticulitis. However, if there is any concern regarding potential difficulty in identification of the ureter, stenting should be considered.
- Appropriate intravenous antibiotic prophylaxis is given on induction.
- Consideration should be given to intravenous steroid supplementation if the patient is steroid dependent.
- Subcutaneous low-molecular-weight heparin is given on induction.
- A preoperative briefing with the entire surgical team is conducted. Items discussed include patient identification, type of surgery, type of anesthesia, expected events during the surgery, the need for blood components, prophylactic antibiotic, surgical devices availability, and potential adverse events and their prevention.

PATIENT POSITIONING AND OPERATING TEAM SETUP

- The patient should be placed in a standard supine position for induction of anesthesia.
- Following induction and securing of the endotracheal tube, a Foley catheter should be inserted.
- The patient is then placed in a low lithotomy position (**FIG 1**). Special care should be given to the positioning of the patient's legs in the stirrup devices; adequate padding and symmetrical positioning can minimize nerve injury.
- The arms should ideally be tucked at the sides with appropriate padding to afford the surgeons adequate space during the procedure and to prevent neurovascular injuries.
- Once the patient has been positioned and secured to the operating table, the rectum should be irrigated with saline solution using a piston syringe to evacuate remnant stool and bowel prep fluid.

FIG 1 ● Patient positioning. The patient is placed on a low lithotomy position, with the arms tucked to the side and the legs secured on Yellofin stirrups. Note that the thighs are parallel to the ground to prevent interference with the movement of the arms by the operating team. All pressure points are padded to prevent neurovascular injuries.

- The patient can then be cleaned and draped. The drape should have a cut-out section to allow for easy access to the perineum without disrupting the sterile field of the abdomen.
- The surgeon stands to the patient's right side, with his or her assistant standing to the patient's left side and with the scrub nurse standing to the surgeon's right side. A second assistant, if available, stands between the patient's legs (**FIG 2**).

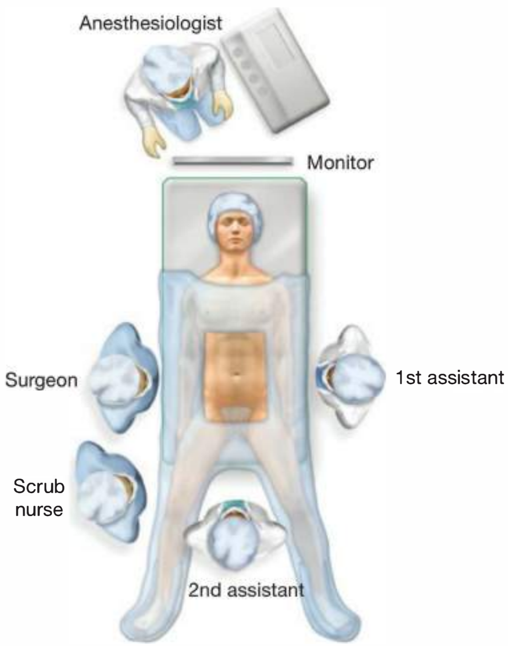


FIG 2 ● Operating team setup. The surgeon stands to the patient's right side, with his or her assistant standing to the patient's left side and with the scrub nurse standing to the surgeon's right side. A second assistant, if available, stands between the patient's legs.

LAPAROTOMY, INSPECTION, AND SURGICAL FIELD PREPARATION

- A midline incision from the umbilicus to the pubis is usually sufficient to begin the procedure. Additional access can be gained by extending the incision cranially toward the xiphoid process as necessary. Care should be taken to stay within the midline of the rectus sheath (linea alba) on opening.
- In patients with previous abdominal surgery, adherent bowel can complicate entry into the peritoneal cavity and meticulous dissection may be warranted. If possible, it might be easier to gain access into the abdomen by going above the previous scar where adhesions may be less tenuous.
- Upon entry into the peritoneal cavity, moist laparotomy pads placed around the wound edges can serve as wound protectors to reduce the likelihood of wound infection.
- A self-retaining retractor (e.g., a Balfour or Bookwalter retractor) can then be placed for adequate exposure.
- A careful and thorough examination of the abdominal cavity is critical. Evidence of metastatic disease or carcinomatosis must be appreciated before proceeding with the procedure. If present, these significantly impact both management and prognosis.
- The colon should be palpated in cases involving tumors to verify the position of the disease and assess the extent of resection. In procedures for diverticular disease, the state of the entire colon should be investigated, as this may impact the optimal scope of resection.
- Following inspection, if the decision is made to proceed, the small bowel should be eviscerated and packed to the right upper quadrant using a moist laparotomy pad or a moist towel to better facilitate exposure.

LATERAL TO MEDIAL MOBILIZATION OF THE LEFT COLON AND IDENTIFICATION OF THE LEFT URETER

- Once this has been confirmed, the supplying vessels and lymph basins should then be identified. Sigmoid colectomy usually entails resection of the sigmoid artery branches coming off of the IMA and the left colic artery with the accompanying lymph nodes that reside within that basin. The IMA or the left colic artery should be carefully identified along with the path of planned resection along the mesentery; the extent of the planned resection along the length of the sigmoid will dictate the degree to which the left colon must be mobilized.
- The patient is placed on a Trendelenburg position with the left side up to facilitate exposure.
- Mobilization of the colon is facilitated by retracting the sigmoid colon toward the midline.
- Using a combination of electrocautery and blunt dissection, release the lateral attachments of the sigmoid and descending colon by transecting the line of Toldt (FIG 3).
- Dissection along the line of Toldt should be largely bloodless, as this is an avascular plane. The dissection should then be extended both proximally along the descending colon toward the splenic flexure and also distally toward the rectosigmoid junction.
- The sigmoid and descending colon mesentery is separated from the retroperitoneum using a sharp lateral to medial dissection approach.
- At this point, care should be taken to identify the left ureter and gonadal vessels and ensure that they are kept intact in the retroperitoneum outside of the field of dissection (FIG 4A,B). In the lower abdomen, the left ureter is located medial to the gonadal vessels, close to the midline.
- Identification of the left ureter may be complicated in cases of diverticulitis where previous inflammation has created extensive adhesions. In such patients, preoperative placement of ureteric stents may be beneficial.

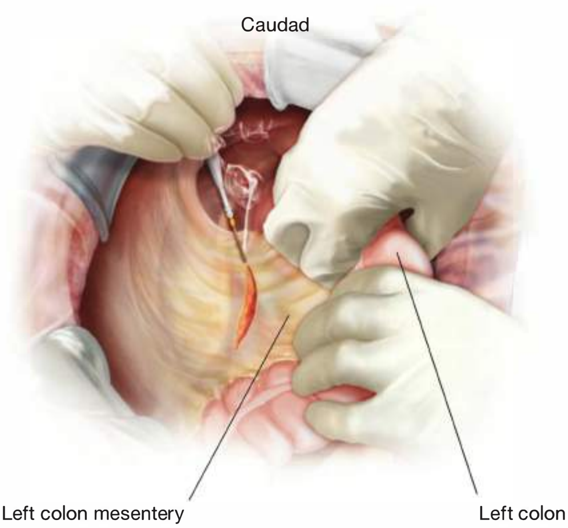


FIG 3 ● Lateral to medial mobilization of the left colon. With the sigmoid and descending colon retracted medially, the white line of Toldt is transected from the pelvic inlet to the splenic flexure.

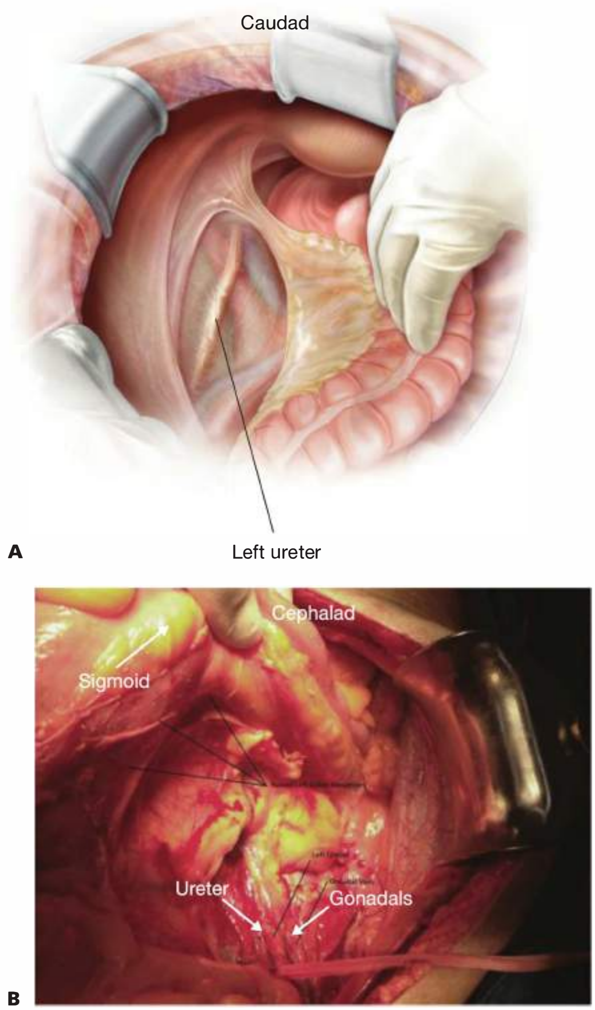


FIG 4 ● Exposure of the left ureter. The illustration **(A)** shows the view of the operative field from cephalad to caudad direction. The operative picture **(B)** shows a caudad to cephalad view of the field. In the lower abdomen, as the descending and sigmoid mesocolon are separated from the retroperitoneum by the lateral to medial dissection, the left ureter is located medial to the gonadal vessels, close to the midline.

MOBILIZATION OF THE SPLENIC FLEXURE

- Taking down the splenic flexure may be unnecessary on occasions with very redundant sigmoid but more often, it is required in order to achieve a tension-free anastomosis.
- This maneuver can be challenging, because the splenic flexure can have a very deep location in the left upper quadrant of the abdomen. Special attention should be afforded to this part of the operation, as troublesome bleeding from splenic capsular injury can be tricky. Splenic bleeding can usually be addressed using electrocautery, packing, or topical hemostatic agents.
- The lateral peritoneum sectioning is continued from the initial incision in a cephalic direction as far as possible, avoiding excessive traction of the splenic flexure in order to prevent splenic lacerations.
- The splenodiaphragmatic and splenocolic ligaments are transected with a monopolar scalpel or with a bipolar vessel-sealing device (**FIG 5**).
- The final approach to the splenic flexure should be complemented with another point of dissection that is initiated in the transverse colon to the left of the middle colic vessels. At this point, the gastrocolic ligament is transected, entering the lesser sac. The gastrocolic ligament is then transected from medial to lateral (**FIG 5**) with a monopolar scalpel or with a bipolar vessel-sealing device, until the lateral plane of dissection is reached.
- Finally, the attachments of the splenic flexure to the tail of the pancreas are divided with electrocautery. The left colon is now fully mobilized all the way to the midline.

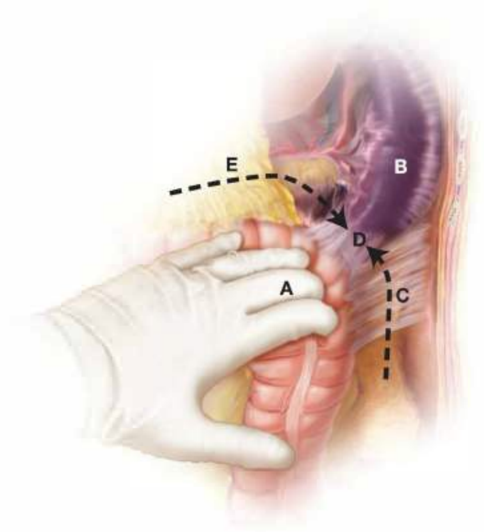
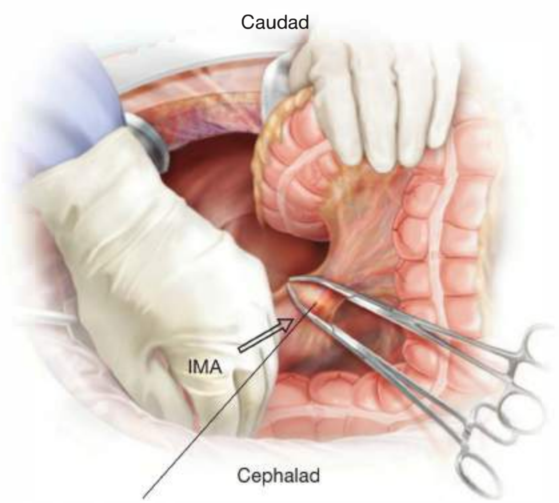
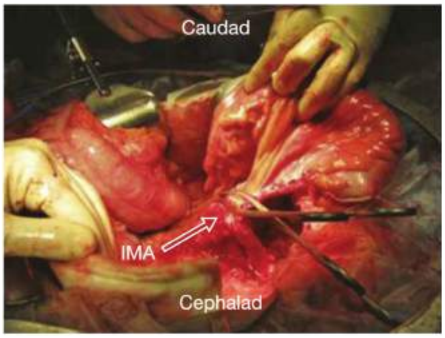


FIG 5 ● Splenic flexure mobilization. Mobilization of the splenic flexure. The surgeon retracts the splenic flexure of the colon *(A)* downward and medially, exposing the attachments of the splenic flexure to the spleen *(B)*. The phrenocolic *(C)* and splenocolic *(D)* ligaments are transected in an inferior to superior and lateral to medial direction. The gastrocolic ligament *(E)* is then transected in a medial to lateral direction until both planes of dissection meet and the splenic flexure is fully mobilized.

INFERIOR MESENTERIC ARTERY TRANSECTION

- With the assistant's two hands holding the proximal and distal sigmoid colon up, the root of the mesosigmoid colon is clearly visualized by the surgeon from the right side of the table. At the root of the mesentery, the arch of the superior hemorrhoidal vessels (SHV) can be seen and palpated.
- Placing the index finger behind the SHV arch allows the surgeon to incise with electrocautery the right surface of the peritoneum just under the dorsal surface of the SHV.
- This plane of dissection along the dorsal aspect of the SHV is carried distally over the promontory (leading into the presacral space) and proximally up to the origin of the IMA. The IMA is dissected circumferentially at its origin from the aorta.
- At this point, the colon mesentery is divided in between the sigmoid and descending colon with a vessel-sealing device, starting from the antimesenteric border and extending toward the origin of the IMA. The marginal arcade is transected along this dissection line close to the colon wall at the proposed anastomosis level.
- The IMA is then ligated between Sarot clamps, incised, and doubly ligated with braided 2-0 suture (**FIG 6A,B**). High IMA ligation allows for an excellent lymph node harvest.



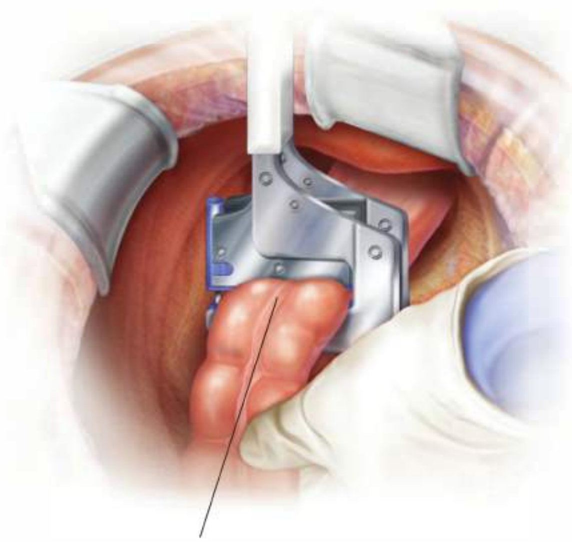


B

FIG 6 ● **A,B.** IMA transection. With the assistant holding the sigmoid colon up, the IMA is transected between clamps and will subsequently be ligated with heavy silk sutures.

COLON TRANSECTION

- Following mobilization of the left colon, the sigmoid colon can then be resected.
- We prefer to use the GIA staplers with 60-mm blue cartridges (3.1 mm) for the proximal transection. The proximal transection is performed between the sigmoidal and left colic vessel distribution, between the sigmoid and descending colon segments.
- For the distal transection, we typically employ the 90-mm transabdominal (TA) stapler to complete the resection. The distal transection is performed just distal to the rectosigmoid junction (FIG 7), which can be identified by the splaying of the tinea coli. The remaining specimen mesenteric attachments are transected with a vessel-sealing device.
- For diverticular disease, the extent of the proximal transection is variable, as it depends on the extent of diverticular disease. The distal transection, however, must always be distal to the rectosigmoid junction to ensure that there are no diverticular elements distal to the anastomosis.
- Once this part of the operation has been successfully completed, the specimen can be removed from the operative field and sent to the pathologist.



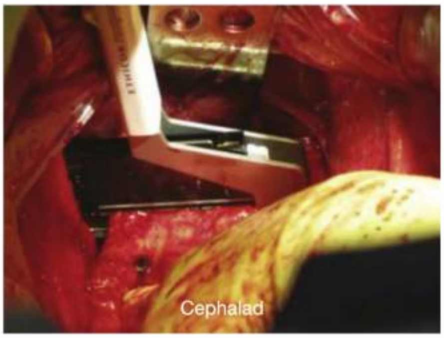


FIG 7 ● Distal specimen transection. The distal transection is performed with a 90-mm TA stapler just distal to the rectosigmoid junction, which can be identified by the splaying of the tinea coli.

ANASTOMOSIS

- There are two options for restoring intestinal continuity—hand-sewn versus stapled anastomosis. We favor a stapled anastomosis whenever possible.
- If a partial (subtotal) sigmoidectomy is all that is needed (as is the case sometimes in diverticulitis cases), then it may be feasible to perform a GIA stapled side-to-side colocolonic anastomosis in contiguity before transecting the specimen (**FIG 8A**). The anastomosis is then completed (and the specimen transected) with a TA stapler (**FIG 8B**).
- More commonly, however, when the entire sigmoid colon is removed, performing a colorectal anastomosis is best achieved by an end-to-end colorectal anastomosis using an end-to-end anastomosis (EEA) stapling device (**FIG 9**).
- The size of the stapler selected should be dictated by the caliber of the colon and rectum. If possible, a 28- to 29-Fr size is desirable to reduce the incidence of anastomotic strictures.
- The anvil of the stapler is placed in descending limb/colon via a colotomy and secured using a purse-string nonabsorbable suture, preferably a 3-0 nylon.
- One surgeon then moves to the patient's perineum and inserts the stapler into the rectum. The anal canal should be digitally dilated with lubricated fingers before inserting the EEA stapler.
- The anvil is then approximated with stapler under the guidance of the abdominal surgeon and is then fired.
- The perineal surgeon must then inspect the "donuts" from the stapler to ensure continuity; discontinuity must raise suspicion for an inadequate anastomosis and should warrant further inspection and possible interrogation of the anastomosis. We do not routinely test the anastomosis, but this may be achieved via transrectal instillation of methylene blue dye and/or air (**FIG 10**).
- Hand-sewn anastomosis is less common in the modern era, but it is a skill that should reside within the armamentarium of every general surgeon.
- We prefer to perform a double-layered closure starting with 3-0 Vicryl sutures full-thickness through the colon and rectal walls in a running fashion. This is followed by 3-0 Vicryl Lembert sutures through the serosa of the colon and adventitia of the rectum to buttress the anastomosis.
- In patients with a narrow pelvis, maneuvering may be difficult. Interrupted sutures should also be used to reinforce areas of potential leak or inadequate anastomosis following stapling. The main danger would be overzealous placement of sutures, leading to ischemia at the anastomotic tissue.
- The role of diverting colostomy or ileostomy has declined in recent years. These are rarely performed, except for cases where the integrity of the anastomosis is in question. This may include patients with positive leak tests on table or patients with risk factors for anastomotic breakdown such as steroid use or severe malnutrition. In patients whom a diverting ostomy is deemed prudent, we prefer a loop ileostomy owing to the relative ease with which these can be reversed later on.

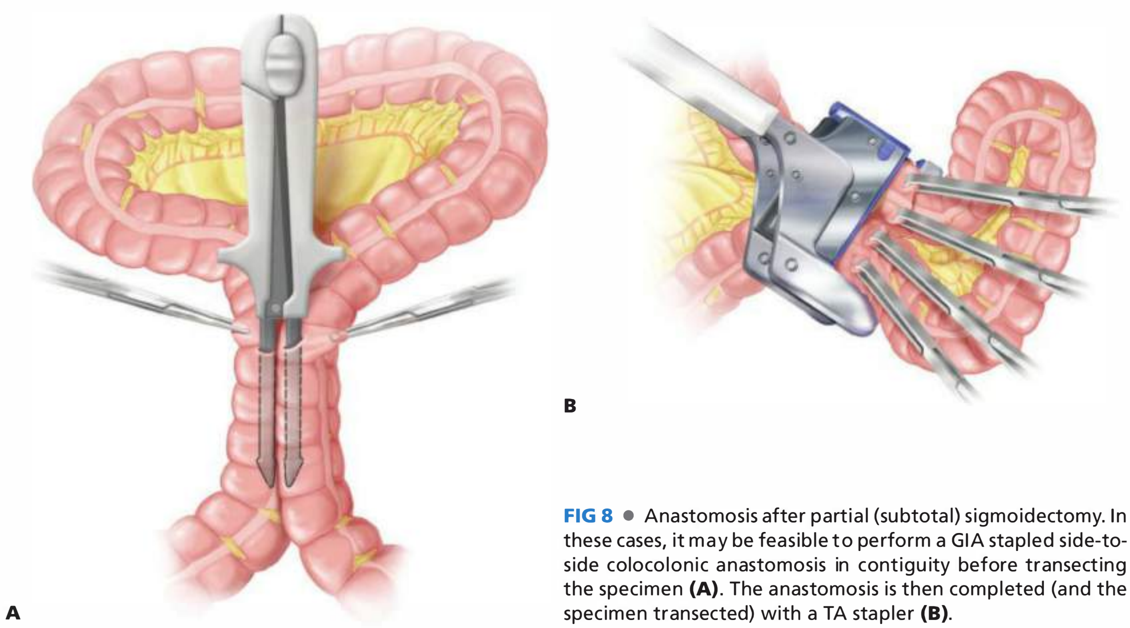


FIG 8 ● Anastomosis after partial (subtotal) sigmoidectomy. In these cases, it may be feasible to perform a GIA stapled side-to-side colocolonic anastomosis in contiguity before transecting the specimen **(A)**. The anastomosis is then completed (and the specimen transected) with a TA stapler **(B)**.

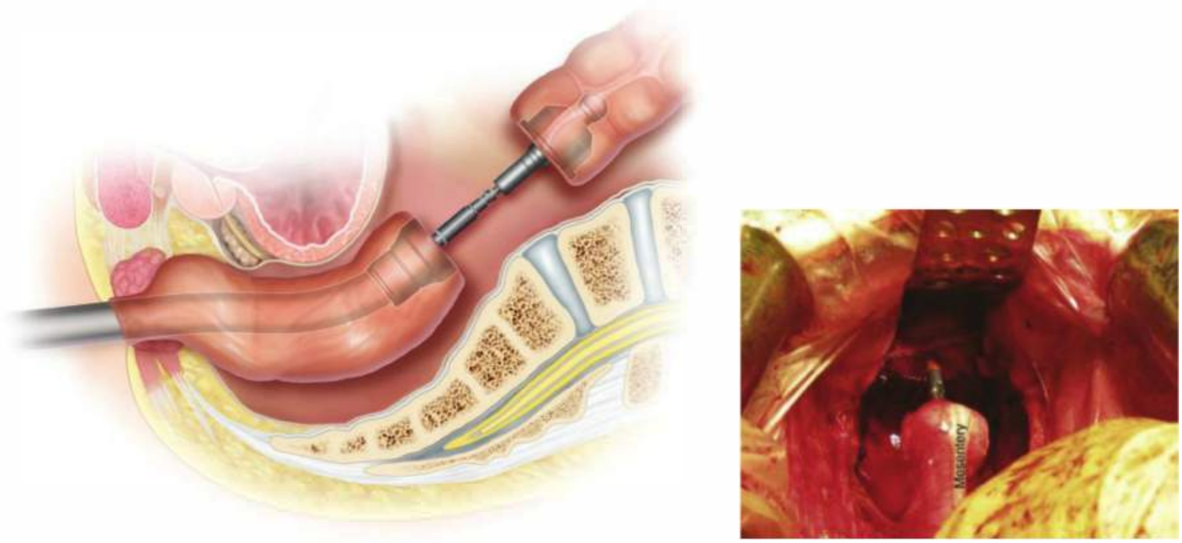


FIG 9 ● Anastomosis after a full sigmoid resection. An end-to-end EEA 29-Fr stapled anastomosis is performed.

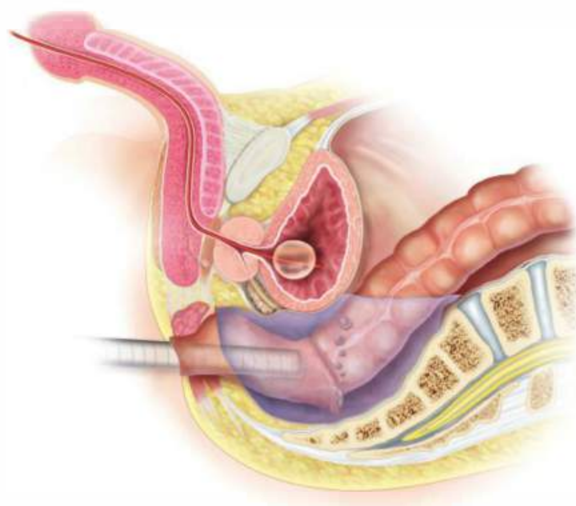


FIG 10 ● The anastomosis is then tested under water. The presence of air bubbles would indicate an anastomotic disruption, which necessitates a revision of the anastomosis.

CLOSURE

- Once intestinal continuity has been restored, a final inspection of the abdomen is usually sufficient before closure.
- All packs should be removed and counted and hemostasis should be complete before fascial closure.
- The fascia is best reapproximated using a running, double-stranded size 0 polydioxanone (PDS) suture.
- The skin can then be closed using skin staples.
- Dry dressings are adequate, although newer vacuum dressings are becoming popular owing to the preponderance for wound infections following colon surgery. We, however, still use the dry dressing and wound infection has not been a problem in our practice.

PEARLS AND PITFALLS

Localizing the target lesion	■ Preoperative colonoscopic tattooing greatly aids in the localization of the tumor intraoperatively. ■ If not available, on-table colonoscopy may be necessary.
Patient position	■ An improper position with hip flexion will make it difficult to maneuver during the whole procedure. Make sure the patient's thighs are parallel to the ground.
Identification of the left ureter	■ Identification of the left ureter is critical prior to vascular transection. ■ In difficult cases, stenting may help identify the ureter. ■ Stents do not decrease ureteral injury but aid in the intraoperative identification of the injury when it happens.
Splenic flexure mobilization	■ May not be necessary in cases with a very redundant sigmoid colon. ■ In most case, it is required to ensure a tension-free anastomosis.
Anastomosis	■ A tension-free anastomosis is the most critical element to prevent an anastomotic leak. ■ It is also paramount to preserve the proximal colonic blood supply intact (the marginal artery of Drummond) in order to have a healthy anastomosis.

POSTOPERATIVE CARE

- The Foley catheter is left in situ for 24 hours to assess fluid status and also because of the increase likelihood of urinary retention following surgery in the pelvis.
- A nasogastric tube is not routinely employed.
- The patient should be monitored closely until fully awake and stable.
- Clear fluids can be started on the evening of surgery.
- Early ambulation is essential.
- Pain control with patient-controlled analgesia or epidural analgesia is required.
- Antibiotics should be discontinued within 24 hours as per protocol.
- Pharmacologic venous thrombosis prophylaxis is instituted according to guidelines.

OUTCOMES

- The patient's prognosis depends on the tumor staging, which is determined by the histopathologic study of the specimen (pTNM).
- Many patients will require adjuvant chemotherapy according to the tumor stage.

COMPLICATIONS

- Wound infections
- Incisional hernias
- Urinary/sexual dysfunction: important to preserve hypogastric nerves and parasympathetic ganglia intact
- Ureteral injury: critical to identify the left ureter prior to IMA transection
- Anastomosis leak: It is critical to construct a well-vascularized, tension-free anastomosis.
- Deep vein thrombosis (DVT): lower risk with use of adequate DVT prophylaxis
- Cardiac and pulmonary complications
- Pelvic abscess: reduced incidence with placement of an omental pedicle flap in the pelvis
- Perineal wound breakdown is a notorious problem, especially in high-risk patients.

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Chapter 20 Sigmoid Colectomy: Laparoscopic Technique

Arden M. Morris

DEFINITION

- Laparoscopic sigmoid colectomy is a laparoscopic procedure that involves complete or partial removal of the sigmoid colon most often with a primary anastomosis, which can be performed intra- or extracorporeally.

DIFFERENTIAL DIAGNOSIS

- Laparoscopic sigmoid colectomy is most often performed to treat colon cancer or diverticulitis but may also be performed to treat a benign neoplasm, which cannot be resected endoscopically, Crohn's or other fistulizing disease, intussusception, sigmoid volvulus, or other obstructive, inflammatory, or infectious conditions.

PATIENT HISTORY AND PHYSICAL FINDINGS

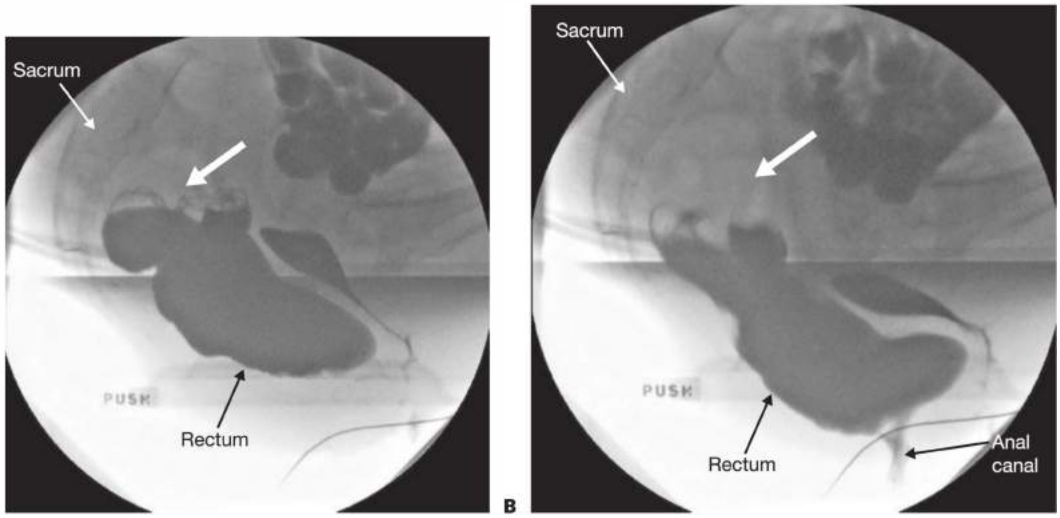
- A complete history should be tailored to the patient's primary diagnosis and should include a description of constitutional symptoms (nausea/vomiting, anorexia, weight loss or gain, fever, diaphoresis, fatigue), pain (site, quality, timing, inciting and relieving factors), dietary and bowel habits (constipation, diarrhea, frequency, continence, obstructive symptoms, bleeding), urinary habits, and sexual function.
- Physical exam includes a description of the presence and quality of distension, tenderness, guarding (voluntary or involuntary), rebound, and organomegaly. It is important to check carefully for evidence of a mass. For the sigmoid colon, this should be specifically checked by using one hand to elevate the left flank and the other hand to palpate the left lower quadrant between the iliac spine and the infraumbilical midline abdomen. The presence of involuntary guarding during this maneuver may indicate inflammation of the sigmoid colon consistent with acute or smoldering diverticulitis.
- A digital rectal exam must be performed preoperatively. The exam should include digital palpation of the coccyx, ischial tuberosities, and levators. The exam should include an assessment of sensation (anal wink), anal sphincter tone, and voluntary contraction (normal vs. diminished squeeze and normal relaxation vs. paradoxical puborectalis contraction with bearing down).

FIG 1 ● Axial CT scan of the pelvis with diverticulitis and extraluminal gas *(arrows)*.

IMAGING AND OTHER DIAGNOSTIC STUDIES

- There are many options for preoperative diagnostic imaging. For suspected diverticulitis and/or other inflammatory or fistulizing disease, abdominal/pelvis computed tomography (CT) is the most effective means for diagnosis and operative planning. In addition, CT documentation of the presence of diverticulitis is particularly important in the event that the patient's symptoms do not abate postoperatively.
- For neoplastic disease, chest/abdomen/pelvis CT should be performed to identify possible metastases to identify the extent of the tumor if possible.
- Although CT with oral and rectal contrast is useful for both intra- and extraluminal assessment (**FIG 1**), a fluoroscopic examination with barium or water-soluble contrast enema is also useful to assess the bowel lumen especially if colonoscopy cannot be performed (**FIG 2**).
- In the case of rectal prolapse, defecography exam preoperatively can provide additional information about the extent of sigmoid colon intussusception and the presence of an enterocele or rectocele (**FIG 3**).
- Full colonoscopy should be performed preoperatively to assess the proximal colon and to tattoo the colon proximally and distally to neoplastic lesions (**FIG 4**).

FIG 2 ● Water-soluble contrast enema displaying a sigmoid volvulus *(block arrow)*. Notice the "omega loop" configuration of the sigmoid volvulus pointing to the right upper quadrant of the abdomen and the "bird's beak" narrowing at the entrance of the pelvis *(dashed arrow)*.



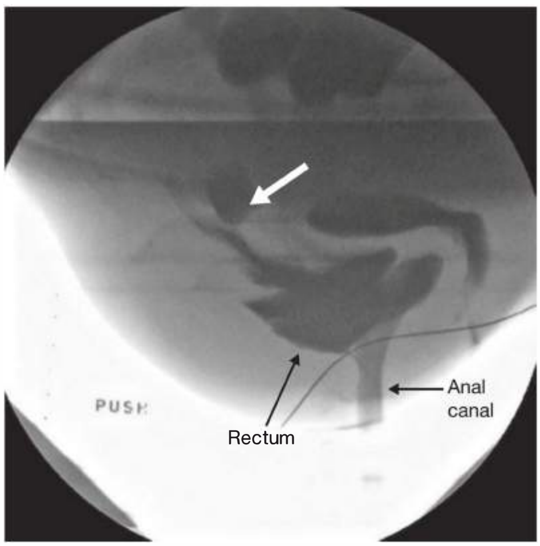


FIG 3 ● **A–C.** Defecography displaying redundant sigmoid progressively intussuscepting into the rectum *(block arrows)* and thereby causing obstructed defecation.

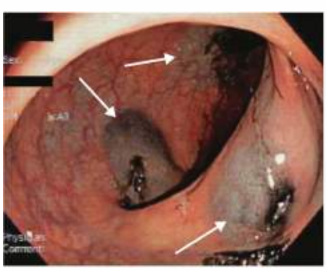


FIG 4 ● Colonoscopy with submucosal injection of India ink *(arrows)* to mark the area of concern prior to operation. The colon is injected in three separate locations distal to the target lesion in order to maximize intraoperative localization of the target lesion.

SURGICAL MANAGEMENT

Preoperative Planning

- Although the use of a full mechanical bowel preparation continues to be debated, at a minimum the sigmoid and rectum should be cleansed of stool using enemas the night before and morning of surgery in order to drive an anastomotic stapler through the rectum for reattachment. If a complete mechanical bowel preparation is undertaken, oral antibiotics should be included.
- Although use of laparoscopy has reduced risk of wound infections among patients undergoing colon surgery, risk of deep-space organ infections remains. Broad-spectrum intravenous antibiotics should be given within 30 minutes prior to the abdominal incision. Intraoperatively, antibiotic redosing should be discussed by the surgeon and anesthesiologist for any operation that lasts 4 hours or longer.

- Risk of deep venous thrombosis is increased among patients with a diagnosis or cancer or inflammatory bowel disease, patients who undergo abdominal or pelvic surgery, and those who have prolonged operations. Patients who undergo laparoscopic sigmoid colectomy fulfill several of these criteria and therefore are at substantially increased risk of venous thrombosis. To reduce this risk, sequential compression devices should be applied to bilateral lower extremities and initiated *preinduction*, when they are most effective at countering the effects of periinduction venous pooling. After induction, 5,000 units of heparin should be delivered subcutaneously.

Patient Positioning

- After endotracheal general anesthesia has been induced, the patient is placed in a split-leg or dorsal lithotomy position and secured in a beanbag, with careful attention to padding the extremities, tucking the right arm at the side, and lowering the thighs to be parallel to the floor if possible. If the hips are flexed, the thighs are higher than the abdomen and can hinder the laparoscopic dissection (**FIG 5**).
- Tape the patient across the chest over a towel to secure him or her to the operating room (OR) table.
- A urinary catheter is placed to decompress the bladder and assist with monitoring urine output during the operation. If the normal anatomic location of the left ureter has been compromised by previous surgery or by an inflammatory condition such as diverticulitis, which can shorten the mesentery and pull the ureter medially, then placement of a ureteral stent or a lighted ureteral stent should be considered.

FIG 5 ● Patient positioning. The patient is placed on a low lithotomy position with the legs on Yellofin stirrups. The thighs are positioned parallel to the ground to avoid conflict with the surgeon's arms. The patient is placed on a beanbag with both arms tucked and taped to the table over a towel. All pressure points are padded to prevent neurovascular injuries.

- An orogastric tube is placed to decompress the stomach.
- If the mechanical bowel preparation or preoperative enemas are inadequate, the surgeon should perform a rigid sigmoidoscopy to clear the rectum of stool after endotracheal general anesthesia has been induced.
- Most hospitals in the United States now require a robust time-out that includes a verbal statement of the patient's identification, diagnosis, medications and allergies, the planned procedure, and positioning, as well as the names and roles of the operating team and a list of necessary equipment and potential problems.

TECHNIQUES

PORT PLACEMENT AND OPERATING TEAM SETUP

- The surgeon stands to the patient's right side, with the scrub nurse next to him or her. The assistant stands to the left side of the table (**FIG 6**). Two monitors, facing the surgeon and the assistant, are used.
- A 12-mm umbilical incision is created sharply and extended to the level of the fascia. The fascia is elevated with 2-0 Vicryl tacking sutures and then opened sharply. The Hasson port is then placed within the peritoneal cavity and tacking sutures are pulled up and clamped. This will be used as the camera port.
- Insufflation with carbon dioxide (CO_2) at high flow is initiated to an appropriate pressure of approximately 14 mmHg.
- After inspection of the abdominal cavity with the laparoscope, three additional 5-mm working ports are placed under visualization in the right upper, right lower, and left lower quadrants of the abdomen (**FIG 7**).

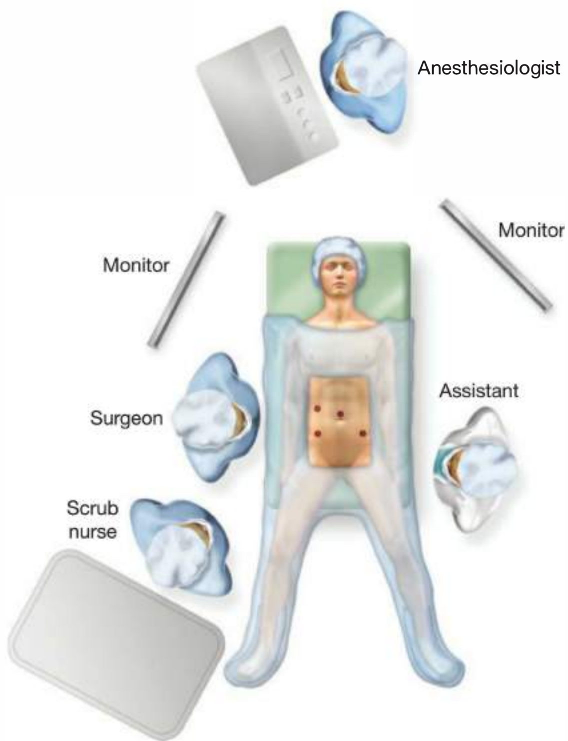


FIG 6 ● Operating team setup. The surgeon stands to the patient's right side, with the scrub nurse next to him or her. The assistant stands to the left side of the table. Two monitors, facing the surgeon and the assistant, are used.

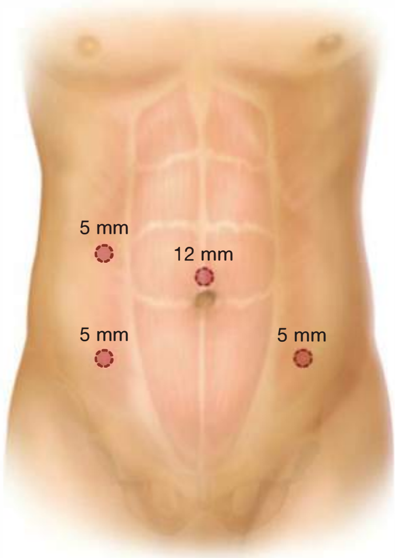


FIG 7 ● Port placement. A 12-mm camera port is inserted supraumbilically using a Hasson technique. After insufflation of the pneumoperitoneum, three additional 5-mm working ports are placed under visualization in the right upper, right lower, and left lower quadrants of the abdomen.

INFERIOR MESENTERIC ARTERY TRANSECTION

- The sigmoid colon is inspected and, if necessary, adhesions are lysed. The omentum and small intestine are retracted into the right upper quadrant and the operating table is rotated into Trendelenburg and right side down positions as needed for bowel retraction.
- The sigmoid colon is grasped broadly with a bowel grasper and elevated toward the anterior abdominal wall to expose the sacral promontory and the medial peritoneal fold (**FIG 8**). The peritoneum is incised below (dorsal) the inferior mesenteric artery (IMA) and its terminal branch, the superior hemorrhoidal artery (SHA).
- The dissection is continued from medial to lateral, beginning the separation of the mesocolon and the retroperitoneum, exposing the left ureter and gonadal vessels, which are identified and preserved intact in the retroperitoneum (**FIG 9**).
- The IMA is dissected circumferentially. Lifting up on the IMA and its terminal branches, the SHA and the left colic artery, will form what appears to be a letter "T" (**FIG 10**).
- The IMA is then transected at its origin off the aorta with a vascular load stapler (**FIG 11**) or an energy device.
- The mesentery of the colon is then transected with an energy device, from the IMA stump up to the colon wall, at the level of the planned proximal transection (typically between the sigmoid and descending colon).

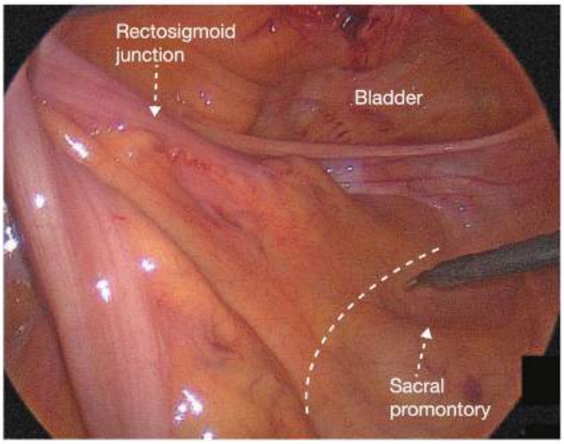


FIG 8 ● Vascular pedicle dissection. The sigmoid colon is pulled toward the anterior abdominal wall, tenting out the base of its mesentery peritoneum at the sacral promontory. The peritoneum is incised along the root of the mesocolon *(dotted line)*, dorsal to the IMA/SHA arteries, across the promontory, and toward the right posterolateral cul-de-sac.

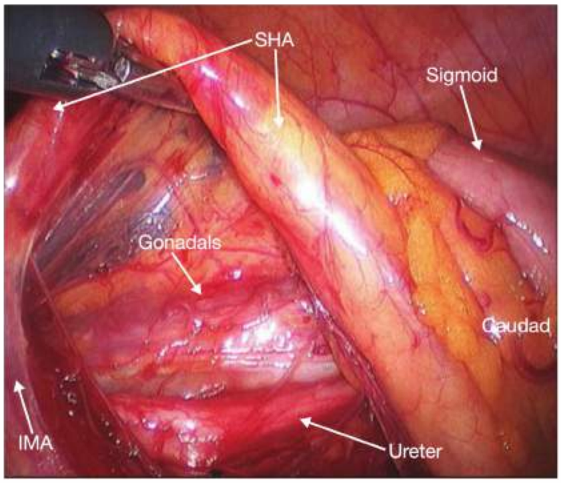


FIG 9 ● Identification of the ureter. With the SHA, distal to its origin of the IMA, tented up toward the anterior abdominal wall, the mesosigmoid is separated from the retroperitoneum. This exposes the left ureter and gonadal vessels, which are identified and preserved intact in the retroperitoneum.

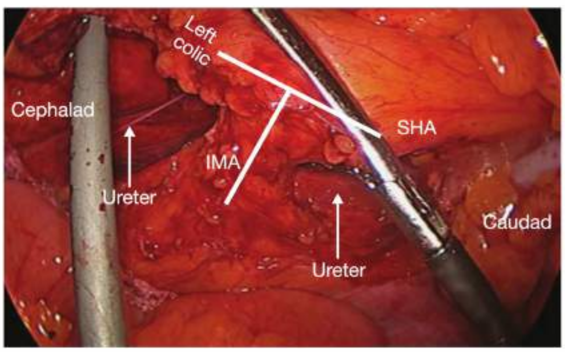


FIG 10 ● The IMA is dissected circumferentially. Lifting up on the IMA and its terminal branches, the SHA and the left colic artery will form what appears to be a letter "T." The ureter can be seen safely preserved in the retroperitoneum.

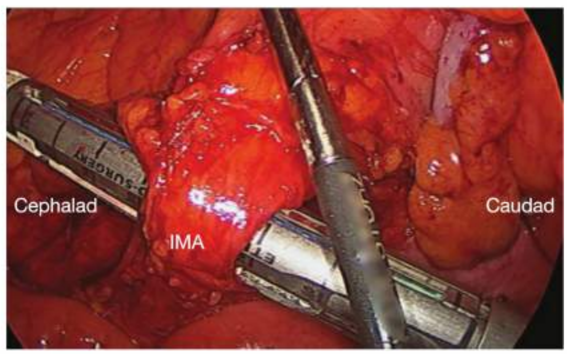


FIG 11 ● IMA transection. The IMA is then transected at its origin off the aorta with a vascular load stapler.

MEDIAL TO LATERAL MOBILIZATION

- The sigmoid and descending mesocolon are dissected off the retroperitoneum via a medial to lateral approach (**FIG 12**).
- With the assistant helping hold the mesocolon up, the surgeon gently dissects along the transition between the two fat planes (Gerota's fascia in the retroperitoneum, dorsally, and the mesocolon, ventrally).
- This dissection is carried laterally to the lateral abdominal wall, inferiorly to the level of the pelvic inlet and superiorly until you separate the tail of the pancreas from the posterior aspect of the splenic flexure. Completion of this step will greatly facilitate all subsequent steps of this operation.
- The left ureter and gonadal vessels should be identified and preserved intact in the retroperitoneum.

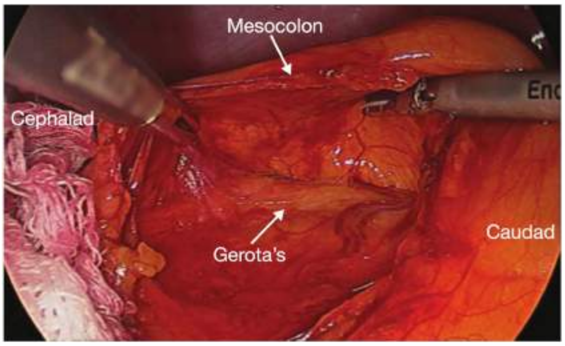


FIG 12 ● Medial to lateral mobilization. The sigmoid and descending mesocolon are dissected off the retroperitoneum via a medial to lateral dissection approach. With the assistant helping hold the mesocolon up, the surgeon gently dissects with an energy device along the transition between the two fat planes (Gerota's fascia in the retroperitoneum, dorsally, and the mesocolon, ventrally). This dissection is carried laterally to the lateral abdominal wall, inferiorly to the level of the pelvic inlet, and superiorly until you separate the tail of the pancreas from the posterior aspect of the splenic flexure. Completion of this step will greatly facilitate all subsequent steps of this operation.

DIVISION OF THE LATERAL PERITONEAL ATTACHMENTS AND MOBILIZATION OF THE SPLENIC FLEXURE

- After completing the medial to lateral portion of the descending colon mobilization from the sacral promontory to the splenic flexure and over Gerota's fascia, the lateral sigmoid colon retroperitoneal attachments are divided with scissors (**FIG 13**) and/or an energy device.
- The splenic flexure is now encountered. Full mobilization of the splenic flexure (**FIG 14**) is often needed in order to ensure a tension-free anastomosis.
- The patient is placed on a reverse Trendelenburg position, helping bring the splenic flexure into view.
- The surgeon and the assistant retract the splenic flexure inferiorly and medially, exposing the splenocolic and phrenocolic ligaments. These ligaments are then transected with a 5-mm energy device (**FIG 15**) in an inferior to superior and lateral to medial fashion.
- At this point, it is often easier to start the transection of the gastrocolic ligament medially, entering the lesser sac and proceeding with the transection of the gastrocolic ligament in a medial to lateral dissection (**FIG 14**) until the lateral dissection plane around the splenic flexure is encountered.
- The splenic flexure and descending colon are now completely free of any attachments and fully mobilized toward the midline.
- Mobilization of the splenic flexure is greatly facilitated by having completed the medial to lateral mobilization of the splenic flexure in the previous step.

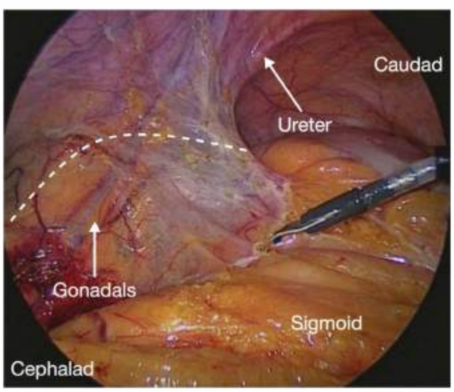


FIG 13 ● Lateral sigmoid colon mobilization. The lateral retroperitoneal attachments of the sigmoid colon are divided *(dotted line)*, readily entering the previous medial to lateral dissection plane. The left ureter and gonadal vessels are visualized in the retroperitoneum.

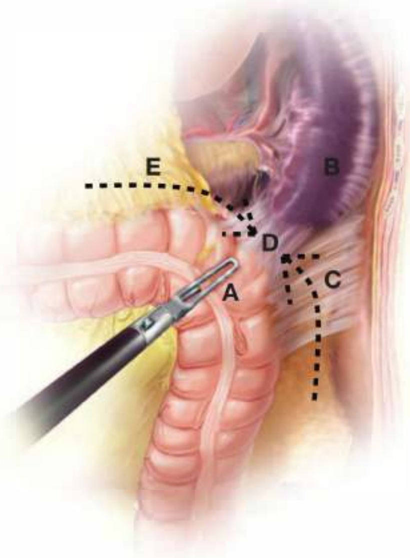


FIG 14 ● Mobilization of the splenic flexure. The surgeon retracts the splenic flexure of the colon *(A)* downward and medially, exposing the attachments of the flexure to the spleen *(B)*. The phrenocolic *(C)* and splenocolic *(D)* ligaments are transected in an inferior to superior and lateral to medial direction. The gastrocolic ligament *(E)* is transected in a medial to lateral direction until both planes of dissection meet and the splenic flexure is fully mobilized.

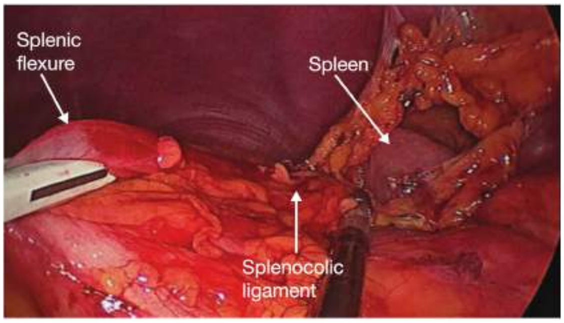


FIG 15 ● Mobilization of the splenic flexure: transection of the splenocolic ligament.

DIVISION OF THE SIGMOID COLON

- An endostapler is inserted into the 12-mm port and used to divide the sigmoid colon distal to the rectosigmoid junction (**FIG 16**), which can be identified by the splaying of the tinea coli.

FIG 16 ● Distal transection. An endostapler is inserted into the 12-mm port and used to divide the sigmoid colon distal to the rectosigmoid junction.

- The abdomen is desufflated, the umbilical port is extended to a 4-cm incision, and a wound protector is placed.
- The sigmoid colon is grasped at its transected distal end and pulled through the 4-cm incision to an appropriate location on the descending colon for the proximal side of the anastomosis.
- If an end-to-end colorectal anastomosis will be constructed, a bowel clamp and purse-string device are applied to the descending colon, which is divided to permit removal of the sigmoid colon. The anvil for a size 31-mm end-to-end anastomosis (EEA) stapler is placed in the descending colon and the purse string is drawn up snugly and tied.
- If a side-to-end anastomosis will be constructed, the descending colon is transected between clamps; the anvil of the EEA stapler device is inserted through the open distal end of the colon and the anvil (with a spear attached to it) is delivered through the antimesenteric aspect of the descending colon approximately 5 cm from the opened distal end. The distal end is closed with a linear stapler.
- The sigmoid colon is removed from the field.

CREATING AND TESTING THE ANASTOMOSIS

- The colon end with the anvil in place is dropped back into the abdomen and the fascial incision is closed. Insufflation with CO_2 is reinitiated.
- With laparoscopic visualization, an EEA stapler is inserted through the anal canal and into the rectum. When the stapler reaches the proximal-most portion of the rectum, the spike is advanced through the rectal wall adjacent to the staple line.
- A grasper is used to remove the spike from the stapler shaft. The spike must be carefully placed in a uniform location in order to avoid losing it within the peritoneal cavity. Using graspers, the spike and anvil are then married (**FIG 17A**) and the EEA stapler is closed and deployed (**FIG 17B**). The stapler is then removed from the anal canal and the anastomotic donuts are inspected. Two intact donuts should be observed. The spike is removed from the abdomen.
- To test for leakage, the anastomosis is covered with sterile saline and the proximal colon is gently compressed. A rigid or flexible sigmoidoscope is inserted through the anal canal and into the rectum, insufflating the rectum with air until it escapes the anal canal. The staple line is carefully inspected for evidence of air bubbles (**FIG 18**). When no air bubbles are seen, the rectum is desufflated and the sigmoidoscope is removed. Air bubbles would indicate an anastomotic leak and would necessitate either revision of the anastomosis and/or performance of a proximal diverting ostomy, depending on the severity of the leak as well as on patient and operative circumstances.

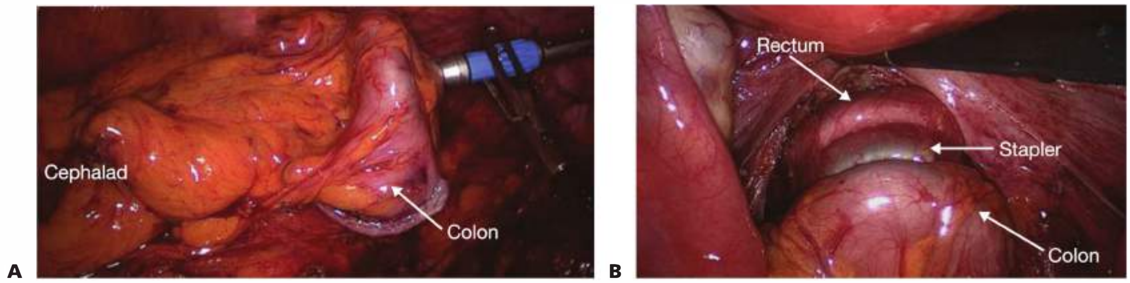


FIG 17 ● Intracorporeal stapled anastomosis: A side-to-end stapled EEA is constructed. Using graspers, the spike (rectal side) and anvil (colon side) are married (**A**) and the EEA stapler is closed and deployed (**B**), creating the anastomosis.

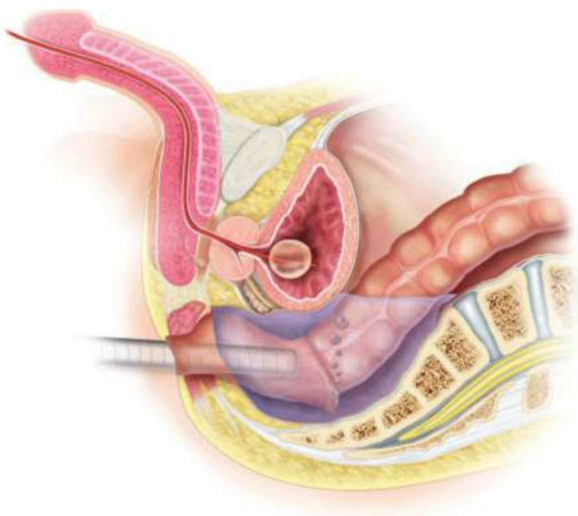


FIG 18 ● Air leak test. The completed colorectal anastomosis is tested under water. Air bubbles identified during insufflation of the anastomosis indicate an anastomotic leak.

WOUND CLOSURE

- Port sites are closed at the skin in the preferred manner.
- The umbilical fascia closure is inspected and completed if necessary. Subcutaneous tissue is irrigated with sterile saline and skin is closed as desired.

PEARLS AND PITFALLS

Preoperative planning	■ For any neoplastic lesion, use of preoperative colonoscopic tattoo can help to avoid resecting the incorrect colon segment. ■ This practice is particularly important for laparoscopic resection as the colon cannot be palpated prior to the first division.
IMA division	■ The nerve plexus adjacent to the IMA takeoff is associated with sexual function in males. Therefore, the dissection should proceed directly beneath the pedicle and extend laterally. ■ Patients should be informed preoperatively that even with great care, it is possible to injure the nerves, which may lead to impaired sexual function.

Anastomosis	▪ In some cases, mobilization for a tension-free anastomosis will be facilitated with extra port placement. For example, an additional suprapubic 5-mm port can greatly assist visualization during the mesenteric dissection toward the splenic flexure. ▪ If the descending colon is in spasm or if it is difficult to insert a size 31-mm stapler anvil, the bowel can be relaxed with administration of 0.5 to 1 mg intravenous glucagon in the absence of hypotension. ▪ Careful attention to the location of spike placement is of utmost importance. The most common site for placement is the left gutter just distal to dissection. The spike should be removed from the abdomen prior to the air leak test.
Avoiding ureteral injury	▪ The ureters must be carefully visualized after the initial mesentery division and again during division of the lateral peritoneal attachments. If there is a concern for ureteral injury, intravenous indigo carmine should be administered, followed by a search for extravasation of blue dye.

POSTOPERATIVE CARE

- The orogastric tube and any ureteral stents should be removed prior to awakening the patient from anesthesia. Within 24 hours of surgery, the urinary catheter should be removed.
- Persuasive evidence indicates that an enhanced recovery program of limited intraoperative intravenous fluids, early postoperative ambulation, early feeding, and minimization of narcotic pain medication can lead to a more rapid recovery and earlier discharge. Such early discharge has not been associated with increased risk for readmissions.

OUTCOMES

- Functional outcomes after laparoscopic sigmoid colectomy may include reduced pain and spasms prior to bowel movements if the patient suffered from an obstructive or inflammatory diagnosis.
- Although many patients report defecatory urgency and increased frequency in the 30-day postoperative period, in most cases the urgency resolves and frequency declines after 4 to 6 weeks.

COMPLICATIONS

- Peroneal nerve injury (positioning)
- Ureteral injury
- Postoperative bleeding
- Wound infection
- Anastomotic leak
- Anastomotic stenosis
- Sexual dysfunction
- Bowel dysfunction (urgency and frequency)

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Chapter **21**

Hand-Assisted Laparoscopic Sigmoidectomy

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DEFINITION

- A sigmoidectomy is the resection of the sigmoid colon to the level of the rectosigmoid junction. The extent of the lymphadenectomy will be determined by the indication (benign vs. malignant disease).
- Focal segmental sigmoid resection for benign disease can be accomplished by dividing the vessels close to the bowel wall, without the need for a high pedicle transection. A complete sigmoidectomy (described in this chapter) includes transection of the inferior mesenteric artery (IMA) at its origin and resection of the proximal superior hemorrhoidal artery (SHA) and sigmoidal branches.
- A hand-assisted laparoscopic (HAL) sigmoidectomy approach uses a hand access port to aid with the dissection and resection. This approach increases the use of minimally invasive surgery, reduces conversion rates, and decreases operative times while maintaining all the short-term outcome advantages when compared to conventional laparoscopic surgery.

DIFFERENTIAL DIAGNOSIS

- Indications for sigmoidectomy include the following:
  - Sigmoid colon polyps and cancer
  - Diverticular disease (i.e., complicated diverticulitis, perforation, fistulae, etc.)
  - Other indications include sigmoid volvulus, ischemic or infectious colitis, and trauma.

PATIENT HISTORY AND PHYSICAL FINDINGS

- Patients with sigmoid pathology can be asymptomatic, with abnormalities found during screening colonoscopy.
- The most common symptoms are bleeding (occult/anemia or overt), obstruction, and pain.
- The initial history should include the following:
  - Time course of presenting symptoms, including bleeding, constipation, and pain
  - Presence/absence of rectal incontinence
  - History of sexual function (erection and ejaculation for males, dyspareunia for females)
  - Information regarding associated urologic symptoms such as recurrent urinary tract infections, dysuria, pneumaturia and/or fecaluria, which suggest a possible fistula with the urinary tract
  - Presence of systemic symptoms such as fever and weight loss
  - Previous surgical history, specifically regarding abdominal and/or pelvic surgery
  - Personal and/or family history of prior colon cancer/polyps, inflammatory bowel disease, diverticular disease
- The ***physical exam*** should include the following:
  - Focused abdominal exam, including notation of abdominal scars
  - Digital rectal exam, focused on assessment of sphincter function
  - Rigid proctoscopy, for all patients with sigmoid polyps or cancer reported by endoscopy to be within 20 cm from the anal verge. This will allow for confirmation of the site of the lesion, which oftentimes may not coincide with the endoscopy report. This information may alter the surgical and oncologic approach.
  - Rigid proctoscopy should not be performed in patients presenting with acute diverticulitis or perforation to avoid worsening of a microperforation by air insufflation.

IMAGING AND OTHER DIAGNOSTIC STUDIES

- A complete colonoscopy should be performed to rule out synchronous disease.
- For cancer and/or polyps, a tattoo must be placed just distal to the lesion at three different points within the circumference to allow for intraoperative localization of the target.
- A computed tomography (CT) of the abdomen and pelvis is obtained to rule out adjacent organ involvement, to evaluate for extraluminal complications (e.g., abscess, fistula), and to rule out metastatic disease in patients with cancer. A CT of the chest completes the metastatic workup.
- A carcinoembryonic antigen (CEA) level is obtained in all cancer cases.

SURGICAL MANAGEMENT

Preoperative Planning

- An informed consent, including discussion of the need for a possible ostomy, is obtained.
- We do not routinely ask patients to complete a formal bowel preparation. Fleet enemas are prescribed to facilitate the performance of the anastomosis.
- All patients should receive preoperative prophylactic antibiotics, following published guidelines. We administer 1 to 2 g of ertapenem within 1 hour of surgical incision.
- Pharmacologic deep vein thrombosis (DVT) prophylaxis should be given to patients perioperatively, based on current recommendations and guidelines.

Patient Positioning and Operating Room Setup

- Proper patient position and operating room (OR) setup is critical for successful performance of minimally invasive surgery (**FIG 1**).
- The patient is placed in a modified lithotomy position using Yellofin stirrups with the heels firmly planted in the stirrups.
- Pressure-bearing areas in the calf and lateral legs are padded to prevent DVT and lateral peroneal nerve injury.
- The patient's toes, knee, and contralateral shoulder are aligned.
- The thighs are placed parallel to the ground to prevent conflict with the surgeon's arms.
- The patient's buttocks are placed at the edge of the table to allow for smoother introduction of the end-to-end anastomosis (EEA) stapler at time of reconstruction.

FIG 1 ● Patient and OR setup. The patient is placed in a modified lithotomy position with the thighs parallel to the floor and the arms tucked. The patient is secured to the OR bed using a chest tape-over-towel technique.

- Both arms are tucked at the sides, with padding added to protect against nerve injuries.
- The patient is taped to the table across the chest over towels to avoid slipping.
- All laparoscopic elements (CO_2 line, camera, light cord) exit through the right upper side. All energy device cords exit through the upper left side. This allows for a clutter-free working space for the operative team.

Team Positioning and Draping

- The patient is prepped with chlorhexidine and draped to facilitate easy access to the perineum.
- The surgeon stands at the patient's right lower side, with the assistant to his or her left side and the scrub nurse to his or her right side (FIG 2).
- Two monitors are placed in front of the team at eye level on the patient's left side.

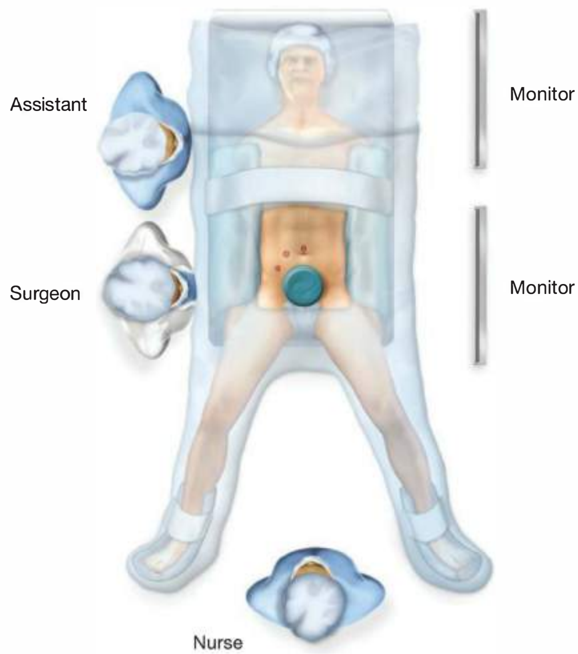

FIG 2 ● Team and monitor setup. The surgeon stands at the patient's right lower side with the assistant to his or her left and the scrub nurse to his or her right. The monitors are placed in front of the team at eye level.

PORT PLACEMENT

- Insert the GelPort through a 5- to 6-cm Pfannenstiel incision. This incision will be also used for specimen extraction. It results in better cosmesis, lowers the incidence of wound infections and hernias, and allows for more working space between the hand and the instruments.
- Ports: Insert a 5-mm working port in the right upper quadrant (RUQ), a 12-mm working port in the right lower quadrant, and a 5-mm camera port above the umbilicus. These three ports are triangulated, with the camera port at the apex of the triangle. This setup avoids conflict between instruments and camera and prevents disorientation (avoids "working on a mirror") (FIG 3).

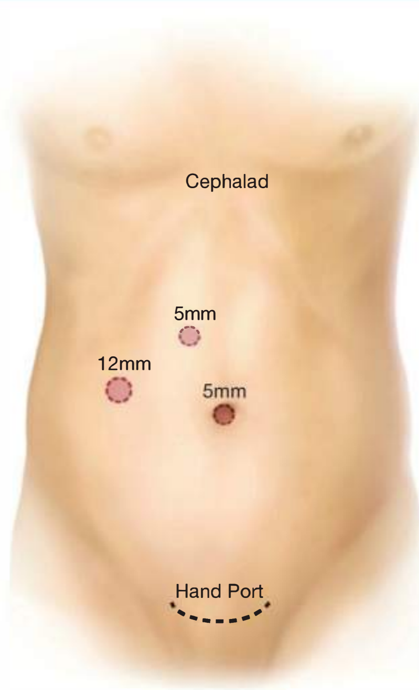

FIG 3 ● Port placement. The hand port is inserted through a 6-cm Pfannenstiel incision at the projected extraction site. A 5-mm camera port is inserted supraumbilically. A 5-mm and a 12-mm working port are inserted in the right upper and right lower quadrants, respectively.

OPERATIVE STEPS

- Our HAL sigmoidectomy operation is highly standardized and consists of nine steps:
  - Transection of the inferior mesenteric vein (IMV)
  - Transection of the IMA
  - Medial to lateral dissection of the descending mesocolon
  - Sigmoid colon mobilization off the pelvic inlet
  - Descending colon mobilization
  - Mobilization of the splenic flexure
  - Intracorporeal distal transection
  - Extracorporeal proximal transection
  - Intracorporeal anastomosis

Step 1. Transection of the Inferior Mesenteric Vein

- This is the critical "point of entry" in this operation. We favor it over starting at the IMA level due to the IMV's constancy in location, the ease of its visualization by the ligament of Treitz, and the absence of structures that can be harmed around it (no iliac vessels or left ureter nearby). This will be the only time during the operation when a virgin tissue plane is entered. Every step will set up the following ones, opening the tissue planes sequentially.
- The patient is placed on a steep Trendelenburg position with the left side up. Using the right hand, move the small bowel into the RUQ and the transverse colon and omentum into the upper abdomen. If necessary, place a laparotomy pad to hold the bowel out of the field of view, especially in obese patients. This pad can also be used to dry up the field and to clean the scope tip intracorporeally. Make sure the circulating nurse notes the laparotomy pad in the abdomen on the white board.
- Identify the critical anatomy: IMV, ligament of Treitz, and left colic artery (FIG 4).
- If there are attachments between the duodenum/root of mesentery and mesocolon, transect them with laparoscopic scissors. This will allow for adequate exposure of midline structures.

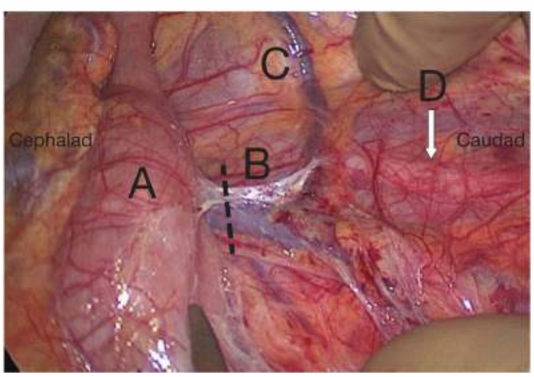

FIG 4 ● Step 1: Key anatomy. Ligament of Treitz *(A)*. IMV *(B)*. Left colic artery *(C)* as it separates from the IMV and goes toward the splenic flexure of the colon. The left ureter *(D)* is located far from the IMV transection point *(dotted lines)*.

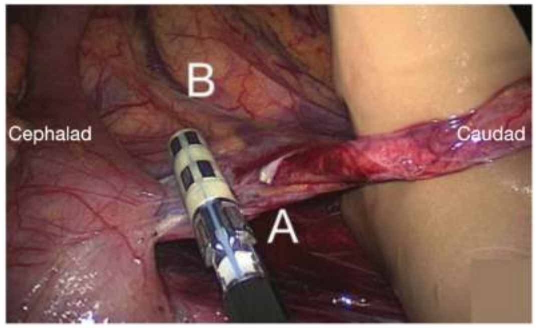

FIG 5 ● Step 1: The surgeon holds the IMV *(A)* anteriorly with his or her right hand and transects it cephalad of the left colic artery *(B)* with a 5-mm energy device.

- Pick up the IMV with the right hand. Incise the peritoneum under the IMV and dissect in front of Gerota's fascia with endoscopic scissors, starting at the level of the ligament of Treitz. Proceed with the dissection caudally towards the IMA. The assistant provides upward countertraction with a grasper.
- Transect the IMV (FIG 5) cephalad of left colic artery, which moves away from the IMV and toward the splenic flexure of the colon, with the 5-mm energy device, thus preserving intact the left-sided marginal arterial arcade, and preserving the blood supply to the anastomosis.

Step 2. Transection of the Inferior Mesenteric Artery

- Identify the critical anatomy: the "letter T" formed between the IMA and its left colic and superior SHA terminal branches (FIG 6).

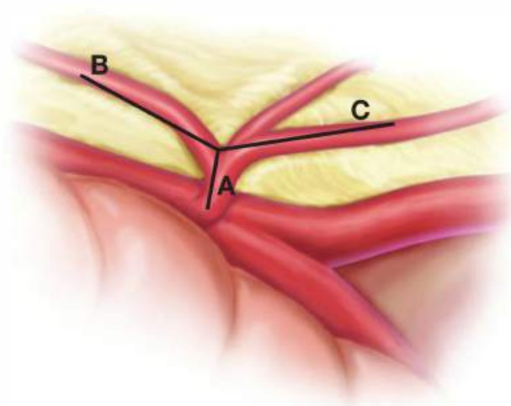

FIG 6 ● Step 2: Critical anatomy. Identify the letter T formed between the IMA *(A)* and its left colic artery *(B)* and SHA *(C)* terminal branches.

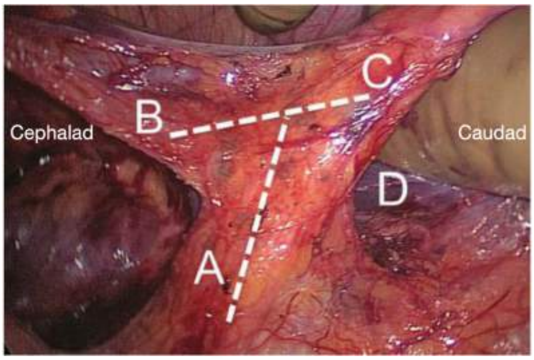

FIG 7 ● Step 2: The letter T dissected: IMA *(A)*, left colic artery *(B)*, and SHA *(C)*. Notice the left ureter *(D)* in the retroperitoneum. The IMA takeoff is just cephalad from the aortic bifurcation *(dotted lines)*. The thumb and index finger are lifting the SHA off the groove located anterior to the right common iliac artery.

- Using the hand, the aorta is identified and tracked down to the level of its bifurcation. The IMA will originate 1 to 2 cm proximal to this level.
- Holding the SHA up with the right hand, dissect the plane along the palpable groove between the SHA and the left iliac artery using laparoscopic scissors. After scoring the peritoneum under the SHA, use a 5-mm energy device to dissect (by gently pushing downward toward the retroperitoneum) along the avascular plane located between the meso-descending colon, anteriorly, and the retroperitoneum, posteriorly. This avascular plane can be identified by the transition between the two distinctive fat planes.
- Preserve the sympathetic nerve trunk intact in the retroperitoneum. Identify the left ureter, located in front of the left iliac artery and psoas muscle and medial to the gonadal vessels, before transecting any structure.
- You can now visualize the dissected letter "T" (**FIG 7**). Dissect with your thumb and index finger around and behind the IMA and transect the IMA at its origin with a vascular load stapler (**FIG 8**, *dotted line*) or energy device. This ensures excellent lymph node harvest and great exposure for step 3.

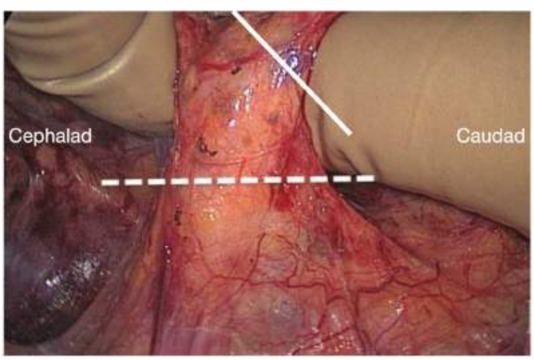

FIG 8 ● Step 2: The IMA is now completely encircled and will be transected at its origin *(dotted line)* with a stapler or energy device. Alternatively, the vascular transection can be done at the takeoff of the SHA and sigmoidal vessels *(solid line)*, preserving the IMA and left colic vessels intact and ensuring prograde blood flow into the descending colon.

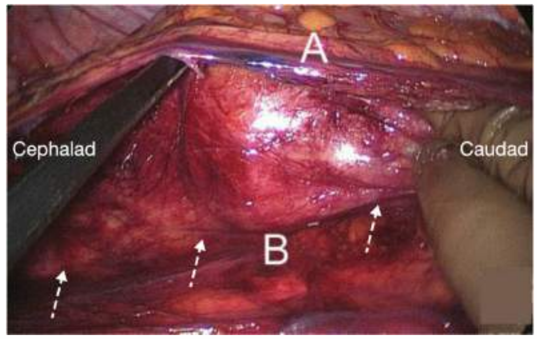

FIG 9 ● Step 3: Medial to lateral dissection of the descending mesocolon. The surgeon's hand is holding the descending mesocolon and colon anteriorly *(A)*, separating them from Gerota's fascia and other retroperitoneal structures *(B)*. The dissection proceeds along the transition between the two distinct fat planes *(arrows)*.

- Alternatively, the vascular transection can be done at the takeoff of the SHA and sigmoidal vessels (**FIG 8**, *solid line*), preserving the IMA and left colic intact and ensuring prograde blood flow into the descending colon segment that will be eventually used for the anastomosis. The drawback is that this makes the medial to lateral dissection step somewhat more challenging, because the IMA will keep the mesocolon tethered to the retroperitoneum.

Step 3. Medial to Lateral Dissection of the Descending Mesocolon

- The surgeon's right hand and the assistant's grasper hold the descending mesocolon up, creating a working space between the mesocolon and the retroperitoneum (**FIG 9**). The plane between the mesocolon and Gerota's fascia, readily identified by the transition between the two fat planes, is dissected by gently pushing it downward with the 5-mm energy device.
- Dissect caudally toward the pelvic inlet; this will greatly facilitate performance of step 4.
- Dissect laterally until you reach the lateral abdominal wall; this will greatly facilitate performance of step 5.
- Dissect cephalad, under the splenic flexure of the colon, until reaching the inferior border of the pancreas. This is critical for an easy mobilization of the splenic flexure during step 6.

Step 4. Sigmoid Colon Mobilization off the Pelvic Inlet

- The surgeon pulls the sigmoid colon medially, exposing the lateral sigmoid colon attachments (**FIG 10A**). Transect the attachments between the sigmoid and the pelvic inlet with laparoscopic scissors in your left hand, staying medially, close to the sigmoid and mesosigmoid, to avoid injuring the ureter/gonadal vessels.
- Dissect caudally until reaching the entrance to the left pelvic inlet.
- The left ureter and gonadal vessels, dissected in step 3, should be visible (**FIG 10B**).

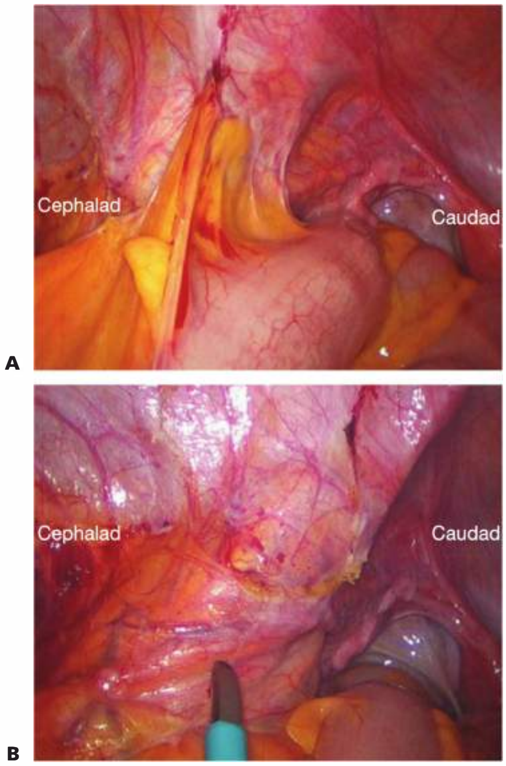

FIG 10 ● Step 4. Panel **(A)**: Medial traction on the sigmoid exposes its lateral attachments to the pelvic inlet. Panel **(B)**: After the sigmoid mobilization is completed, the left ureter is visualized as it crosses over the left iliac artery.

Step 5. Descending Colon Mobilization

- Retract the descending colon medially with your left hand. Transect the white line of Toldt up to the splenic flexure using endoscopic scissors. You should readily enter the retroperitoneal dissection plane dissected during step 3 (**FIG 11**).

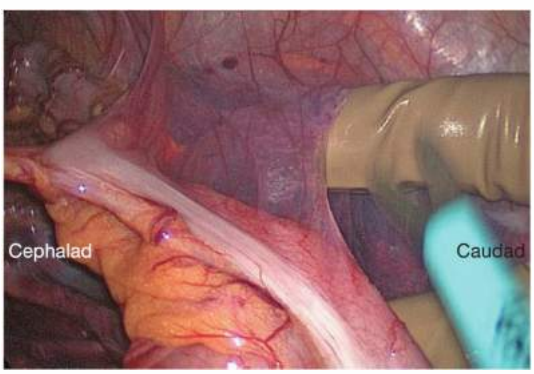

FIG 11 ● Step 5: Transection of the lateral descending colon attachments. Notice that the hand has entered the retroperitoneal dissection plane previously dissected during step 3.

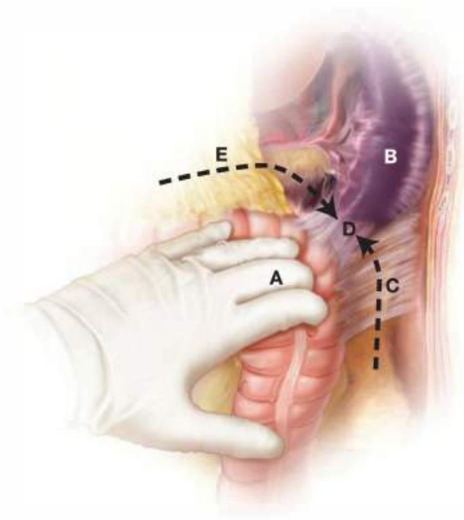

FIG 12 ● Step 6: Mobilization of the splenic flexure. The surgeon retracts the splenic flexure of the colon *(A)* downward and medially, exposing the attachments of the flexure to the spleen *(B)*. The phrenocolic *(C)* and splenocolic *(D)* ligaments are transected in an inferior to superior and lateral to medial direction. The gastrocolic ligament *(E)* is transected in a medial to lateral direction, until both planes of dissection meet and the splenic flexure is fully mobilized.

Step 6. Splenic Flexure Mobilization

- Place the patient on reverse Trendelenburg position with the left side up to help displace the splenic flexure down out of the left upper quadrant.
- We use a two-way approach to the splenic flexure mobilization, with an upward lateral dissection and a medial to lateral dissection meeting around the splenic flexure (**FIG 12**).
- Now, turn your attention medially. With the assistant pulling the transverse colon downward with a grasper, the surgeon lifts the stomach up with his or her left hand and transects the gastrocolic ligament in between the stomach and transverse colon using a 5-mm energy device through the RUQ port site (**FIG 13A**). This allows for entrance into the lesser sac and provides for an excellent view of the splenic flexure.
- Transect the gastrocolic ligament (from medial to lateral) with the 5-mm energy device, staying close to the transverse colon and avoiding the spleen. Proceed laterally toward the splenic flexure.
- Because the medial to lateral dissection performed in step 3 completely separated the splenic flexure of the colon from the retroperitoneum, the surgeon can now slide his or her right hand under the splenic flexure, connecting the two planes of dissection around the flexure, with the index finger "hooked" under the splenocolic ligament. This allows for an easy transection of the splenocolic ligament with an energy device (**FIG 13B**). The left colon should be now fully mobilized to the midline.

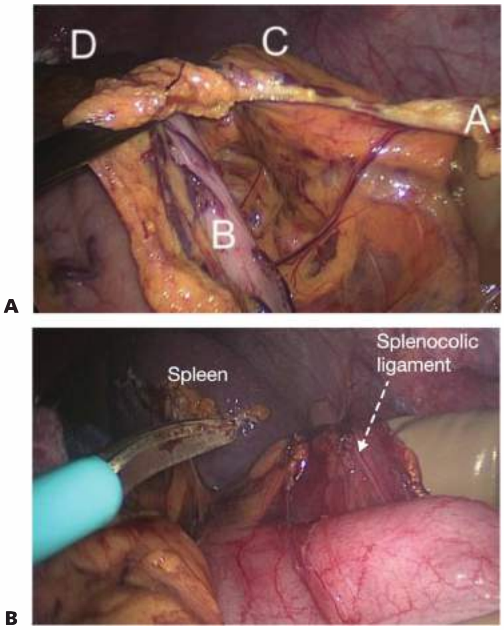

FIG 13 ● Step 6: Mobilization of the splenic flexure. Panel **(A)**: The partially transected gastrocolic ligament is visible between the transverse colon *(A)* and the stomach *(B)*. Notice the excellent view of the lesser sac laterally toward the splenic flexure of the colon *(C)* and the spleen *(D)*. Panel **(B)**: The surgeon is "hugging" the splenic flexure with his or her right hand and is "hooking" his or her index finger under the splenocolic ligament, allowing for an excellent exposure and transection of this ligament with an energy device.

Step 7. Intracorporeal Distal Transection

- Dissect the rectosigmoid junction circumferentially. The rectosigmoid junction can be identified by the splaying of the teniae coli. Transect the upper mesorectum with the 5-mm energy device at the level of the projected distal bowel transection.
- While pulling on the sigmoid upward with the left hand, transect the bowel intracorporeally just distal to the rectosigmoid junction with a linear Endo GIA stapler device (**FIG 14**).
- At this point, transect the mesocolon between the sigmoid and left colic vessels with the 5-mm energy device. Start at the stapled IMA stump on the specimen side, and move up toward the colon wall, transecting the left colic artery (at its origin, off the IMA stump) and the marginal artery (close to the colon wall).

Step 8. Extracorporeal Proximal Transection

- Deliver the sigmoid and descending colon through the Pfannenstiel incision site with the Alexis wound protector in place to protect the wound from oncologic/infectious contamination.
- There should be absolutely no tension during the extraction of the specimen. Otherwise, mesenteric tears that could lead to troublesome bleeding may occur. If there is tension during the extraction phase, completely mobilize the splenic flexure if you have not done so already.

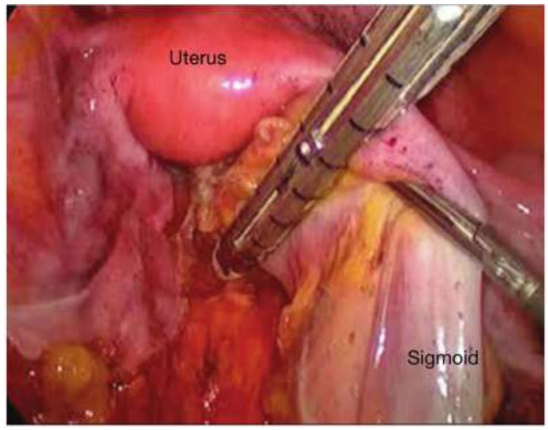

FIG 14 ● Step 7. The intracorporeal distal transection is performed with a linear stapler just distal to the rectosigmoid junction.

- Transect the colon between Kocher clamps between the sigmoidal and left colic vessel distribution, at the point where the mesocolon was previously transected intracorporeally during the previous step. Send the specimen to the pathologist for evaluation.
- Now place the anvil of a 29-mm EEA stapler device into the descending colon and exteriorize it through the antimesenteric border with the spike approximately 5 cm proximal to the open end of the colon. Close the distal end of the descending colon with a linear stapler cartridge.
- Reintroduce the descending colon with the anvil in place into the abdomen in preparation for the anastomosis. Close the hand access port and reinsufflate the pneumoperitoneum.

Step 9. Intracorporeal Colorectal Anastomosis

- You are now ready to perform the intracorporeal side-to-end colorectal anastomosis (**FIG 15**).
- The assistant introduces the 29-mm EEA stapler device into the rectum and opens the spear through the rectal stump, anterior to the staple line, under direct laparoscopic visualization.
- Making sure the mesentery is facing medially and that there are no twists in the bowel, the two ends of the stapler are brought together and the stapler is closed, while avoiding any additional tissue to slip in between the two ends. Once fully closed, the stapler is fired and the EEA carefully pulled back out of the rectum.
- To ensure that the anastomosis is intact, we check for the two donuts to be complete and subsequently test the anastomosis by insufflating it under water, ensuring that it is airtight (**FIG 16**).

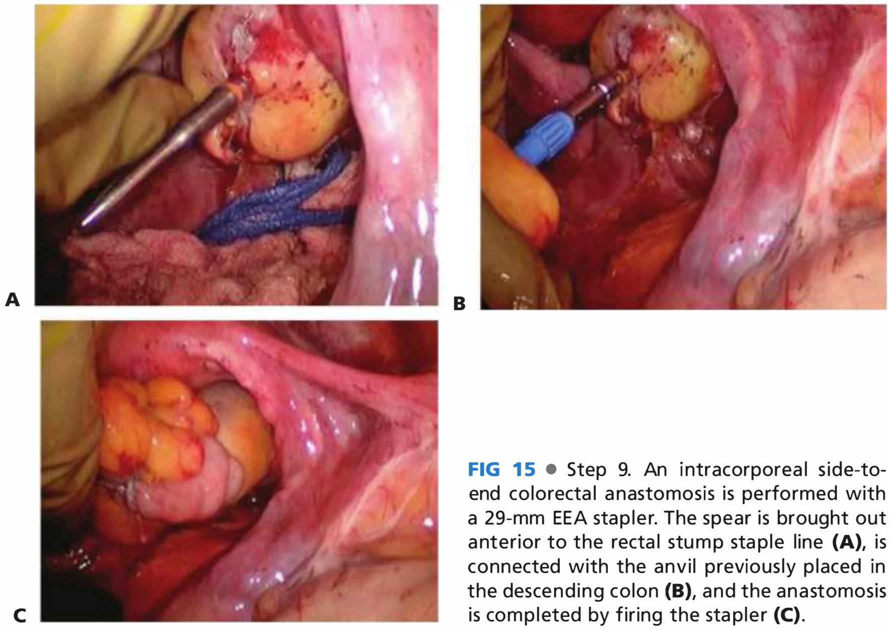

FIG 15 ● Step 9. An intracorporeal side-to-end colorectal anastomosis is performed with a 29-mm EEA stapler. The spear is brought out anterior to the rectal stump staple line **(A)**, is connected with the anvil previously placed in the descending colon **(B)**, and the anastomosis is completed by firing the stapler **(C)**.

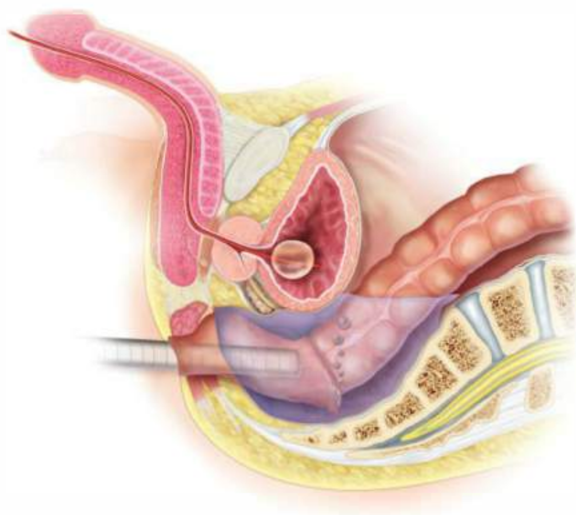

FIG 16 ● The completed colorectal anastomosis is tested under water. Air bubbles identified during insufflation of the anastomosis indicate an anastomotic leak.

WOUND CLOSURE

- The Pfannenstiel incision is closed using no. 1 polydioxanone (PDS) suture in a running fashion. All skin incisions are closed with 4-0 PDS subcuticular sutures. Dermabond is applied to seal off all wounds.
- We do not routinely use drains for this operation.

PEARLS AND PITFALLS

Indications	■ For benign cases, a segmental sigmoid resection, with vascular transection close to the bowel wall, may be enough. ■ For malignant cases, a complete sigmoidectomy, with a high vascular pedicle transection is necessary to ensure adequate lymphadenectomy.
Positioning	■ Secure the patient to the table while protecting all pressure-bearing areas. ■ Make sure that all anesthesia lines and monitors are working appropriately after positioning the patient; there will be limited access to the arms during the procedure. ■ Avoid unnecessary clutter of cables/lines; open up the working space for the operating team.
Port placement	■ Triangulate all ports. ■ Place the hand access port in a Pfannenstiel location.
Vascular transection	■ Transection of the IMV is the *safest* point of entry for this operation. ■ A high IMA transection facilitates the medial to lateral dissection and ensures an excellent lymphadenectomy. ■ It is essential to identify the left ureter above prior to IMA transection.
Mesenteric dissection	■ A complete medial to lateral dissection of the mesentery is critical to facilitate all subsequent steps of this operation.
Distal transection	■ The distal transection is easier to perform intracorporeally than extracorporeally. ■ The distal transection is performed just distal to the rectosigmoid junction, identified by the splaying of the teniae coli.
Intracorporeal anastomosis	■ Make sure the anastomosis is tension-free and that both ends are adequately perfused. ■ Always test the integrity of the anastomosis and be ready to repair or redo it if a leak is identified.

POSTOPERATIVE CARE

- Fast-track or enhanced recovery after surgery (ERAS) programs have shown to expedite postoperative recovery and to minimize postoperative complications following colon surgery. No postoperative antibiotics are used. DVT prophylaxis with heparin products is used routinely.
- We do not use a nasogastric tube.
- Remove the Foley catheter on the first postoperative day.
- Encourage early ambulation, minimize postoperative use of narcotics and promote early feeding as tolerated.
- Patients usually meet criteria for discharge on postoperative days 3 to 4.

OUTCOMES

- The outcomes following HAL sigmoidectomy are excellent.
- HAL colectomy is associated with all the short-term outcome benefits of conventional laparoscopic surgery over open surgery, including less postoperative pain, earlier return of bowel function, and shorter length of stay.
- HAL colectomy is associated with a higher usage rate and a lower rate of conversion to an open approach (2% to 6% vs. 20% to 25%) when compared to conventional laparoscopic colectomy.
- Postoperative complications are equivalent for HAL and conventional laparoscopic sigmoid colectomy.
- HAL sigmoidectomy for cancer yields similar long-term oncologic outcomes compared to open surgery.

COMPLICATIONS

- Surgical site infection
- Anastomotic leak
- Postoperative bleeding
- Postoperative small bowel obstruction
- Urinary retention
- Dehiscence/hernia
- Medical complications: DVT/pulmonary embolism (PE), urinary tract infection, myocardial infarction, and so forth

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Chapter 22

Sigmoid Colectomy: Single-Incision Laparoscopic Surgery Technique

Rodrigo Pedraza Eric M. Haas

DEFINITION

- Single-incision laparoscopic sigmoidectomy is a minimally invasive technique in which a sigmoid colectomy is performed laparoscopically through a single-port device. The entirety of the procedure is accomplished using one sole incision through which all the laparoscopic instruments are placed.
- Reduced port single-incision laparoscopic sigmoidectomy is a modified technique in which the single-port device is placed through a Pfannenstiel incision and an additional port is placed through the umbilicus. This technique is also called "single plus one" sigmoidectomy[1] and is used to facilitate operative exposure, avoid instrument conflict, and benefit from the Pfannenstiel incision—diminished infection, dehiscence, and hernia rates.

PATIENT HISTORY AND PHYSICAL FINDINGS

- Single-incision laparoscopic sigmoidectomy is safe and feasible for essentially all benign and malignant sigmoid diseases requiring resection.[2–4] The most common indications include diverticular disease, cancer, and polyps.
- Patients with diverticular disease typically present with recurrent episodes of diverticulitis or complications such as perforation or obstruction. Left lower quadrant pain and tenderness are commonly encountered and may be accompanied with nausea, vomiting, and fever. Lower gastrointestinal (GI) bleeding is rarely present.
- Cancer and polyps of the sigmoid colon are frequently diagnosed incidentally during screening colonoscopy. Those with large polyps or malignancy may present with hematochezia, bowel obstruction, perforation, or lower abdominal or pelvic pain.
- Single-incision laparoscopic sigmoidectomy is contraindicated in patients who cannot tolerate major abdominal surgical procedures, such as those with severe hemodynamic instability, recent myocardial infarction, or severe thromboembolic event.
- History of prior abdominal surgery may lead to a prolonged procedure due to extensive lysis of adhesions; nonetheless, it is not an absolute contraindication to the use of the single-incision approach.
- The procedure may be performed in patients with high body mass index (BMI). However, the high complexity and high conversion rates make this a less ideal scenario for single-incision sigmoidectomy. In patients with high BMI, conventional multiport or hand-assisted laparoscopic technique may be more suitable.
- Large, bulky tumors may require further incision lengthening during the procedure, losing pneumoperitoneum, thus hindering the ability to complete the case with the single-incision technique. Nevertheless, some single-port devices allow incision lengthening without compromising the pneumoperitoneum.
- Surgeons without experience with single-incision colectomy may encounter technical difficulties. Before offering this approach, competency with conventional multiport and/or hand-assisted laparoscopic techniques is recommended. Additionally, it is suggested that the surgeon becomes proficient in single-incision sigmoidectomy in those with benign disease prior to performing oncologic resections.

IMAGING AND OTHER DIAGNOSTIC STUDIES

- Regardless of the procedure indication, all patients necessitate appropriate preoperative evaluation with endoscopic and radiologic studies.
- For patients with diverticular disease, colonoscopy or flexible sigmoidoscopy is warranted to assess the length of the affected bowel, to determine resection levels, and to confirm the diagnosis. Furthermore, a computed tomography (CT) scan of the abdomen and pelvis is mandatory to evaluate the severity of the pericolonic disease. Some patients with severe active disease demonstrated on the CT scan may benefit from a course of antibiotics or even abscess drainage prior to the procedure.
- If the indication for the sigmoidectomy is a colonic polyp or malignancy, endoscopic tattooing of the lesion is required to ensure proper location during the laparoscopic procedure (**FIG 1**).

A  B

FIG 1 ● Tattooing the lesion in at least three quadrants of the bowel wall during colonoscopy (panel **A**) facilitates proper location of the pathology during the laparoscopic approach (panel **B**).

- For malignant cases, a complete oncologic workup is mandatory. A multidisciplinary approach involving surgeon and medical oncologist is preferable. Lymph node and distant organ involvement are evaluated with the CT scan of the abdomen and pelvis and positron emission tomography (PET) scan. Patients with lower tumors in the rectosigmoid junction may need magnetic resonance imaging (MRI) to evaluate tumor local progression into the pelvis and lymph node status.

SURGICAL MANAGEMENT

Preoperative Planning

- Bowel preparation is traditionally achieved through a polyethylene glycol–based laxative solution and oral antibiotics. This practice has recently been called into question. An accepted alternative is the use of a modified bowel preparation with preoperative enema to clear out the distal stool.
- In the operating room and under anesthesia, rigid proctosigmoidoscopy is recommended to ensure the level of the lesion is above the rectum and to ensure that the bowel is clean of fecal matter.
- For noncontaminated cases, prophylactic antibiotics are administered according to the Surgical Care Improvement Project (SCIP) measures.
- If the cases involve active infection such as those with recurrent diverticulitis or perforation, broad-spectrum antimicrobials with gram-negative and anaerobe bacterial coverage are chosen.

Positioning

- The patient is placed in a modified lithotomy position with both arms tucked at the patient's side. The patient is secured with adhesive tape over the chest, without compromising chest expansion (**FIG 2**). Antislip rubber pads may be used to further secure the patient to the operating room table. It is imperative to ensure proper and secured positioning, as later in the procedure, Trendelenburg position will be required.
- The optimal modified lithotomy position is achieved with a 25- to 30-degree thigh flexion and with moderate thigh abduction (**FIG 2**). This positioning allows adequate surgeon maneuverability, avoiding conflict with the patient's thighs while affording proper perineal access.
- For abdominal entry, laparoscopic exploration, and lysis of adhesions, the patient is in supine position. In this portion of the procedure, the surgeon and assistant are located on the right and left side, respectively.
- Thereafter, the patient is placed in Trendelenburg position with the left side elevated. The surgeon and assistant are located on the right side of the patient with the laparoscopic monitor on the left (**FIG 3**).

FIG 2 • Patient positioning. The patient is placed in a modified lithotomy, 25- to 30-degree thigh flexion, and with moderate thigh abduction to allow adequate surgeon maneuverability, avoiding conflict with the patient's thighs while affording proper perineal access. It is imperative to further secure the patient to the table—we use adhesive tape over the chest, avoiding compromising chest expansion.

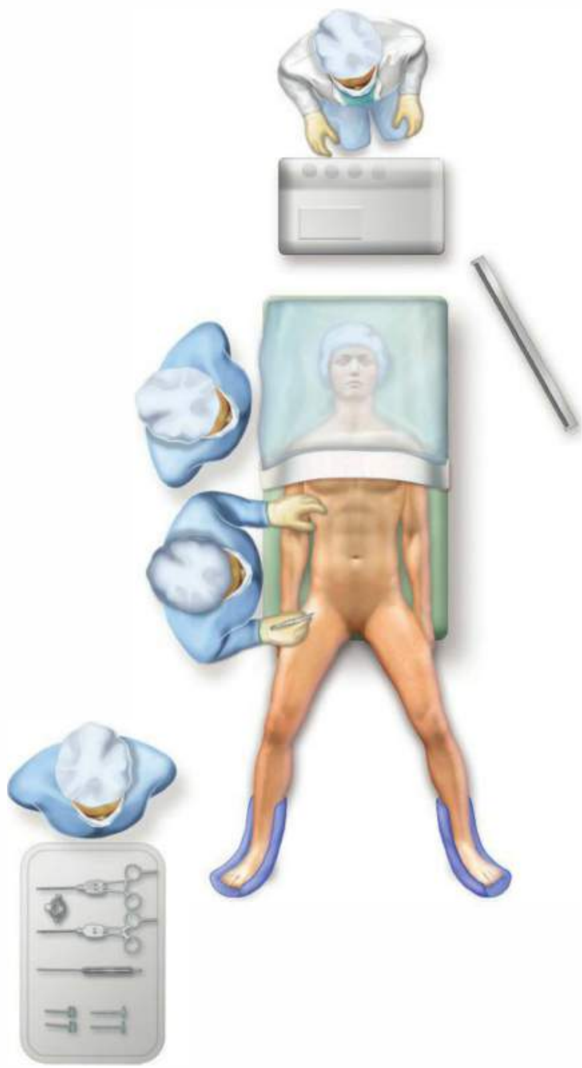


FIG 3 • Operative room patient/surgeon configuration for single-incision laparoscopic sigmoid colectomy.

INCISION AND PORT PLACEMENT

- Typically, a 2.5-cm vertical umbilical skin incision is performed (**FIG 4**). The umbilical stump is divided, affording fascial lengthening to 4 cm without modifying the skin incision (**FIG 4**). Following entry into the abdominal cavity, the single-port device is placed.
- An alternative approach is the abdominal entry using a 4-cm Pfannenstiel incision (**FIG 5**). This modification improves cosmetic outcomes while decreasing wound infection and hernia rates. This approach is challenging, as the instruments are in close proximity with the target operative field, limiting maneuverability. Thus, when this approach is used, we favor a single plus one technique using a Pfannenstiel incision with an additional 5-mm incision for the camera in order to avoid instrument conflict (**FIG 5**).
- Prior to port placement, a surgical sponge may be introduced into the abdominal cavity to facilitate retraction later in the procedure.

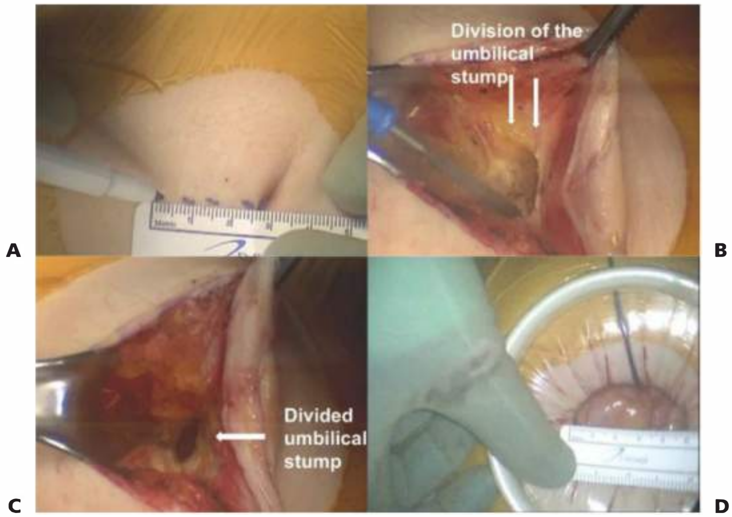


FIG 4 ● Umbilical incision. **A.** The skin incision is 2.5 cm in length, but after division of the umbilical stump (**B** and **C**), the fascial incision size is lengthened to 4 cm **(D)**.

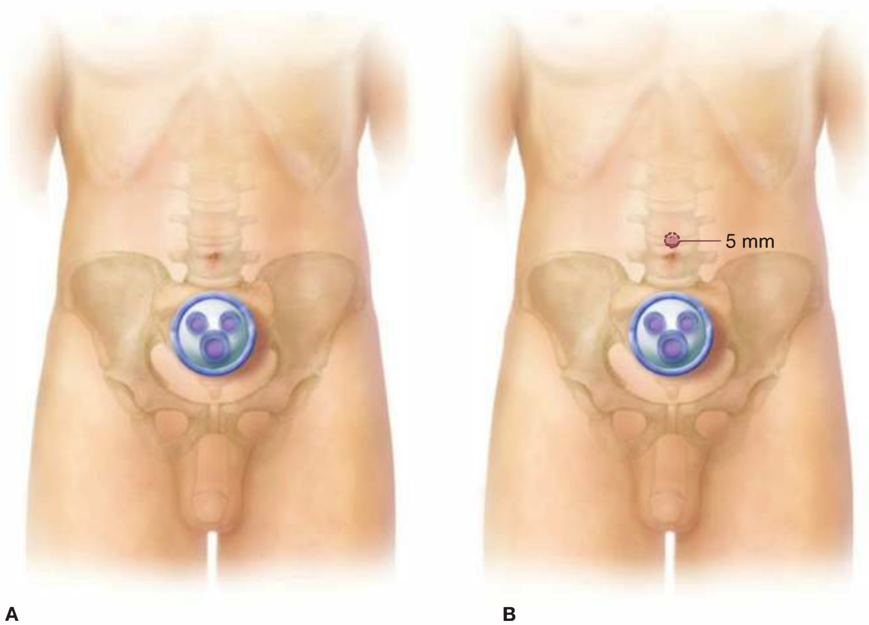


FIG 5 ● **A.** Pfannenstiel incision port configuration for single-incision laparoscopic sigmoid colectomy. **B.** "Single plus one" technique: The addition of a 5-mm camera port in the umbilicus facilitates steps during the procedure and minimizes instrument and surgeon/assistant conflict.

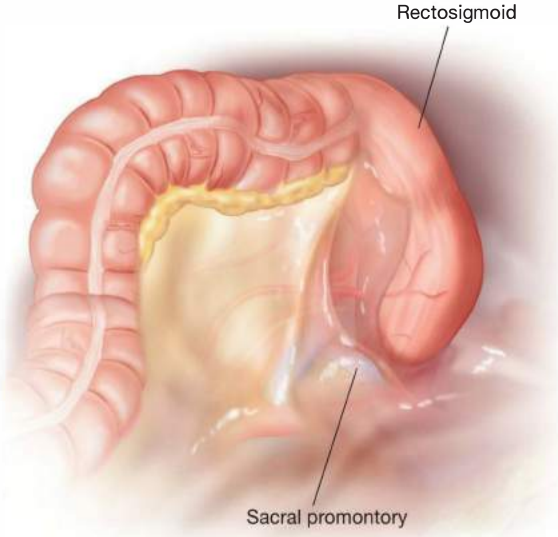
- Port placement varies depending on the single-port device used. Once the port is placed, pneumoperitoneum is created and the laparoscopic camera and instruments are introduced.
- A 30-degree camera and traditional straight laparoscopic instruments are used. Alternatively, articulated instruments may be employed.
- In order to afford maximal operative reach and to avoid internal and external instrument conflict, bariatric and standard length instruments may be used simultaneously. Moreover, a right-angle light cord adaptor may be used to further decrease conflict.

EXPLORATION AND LYSIS OF ADHESIONS

- The abdominal cavity is thoroughly examined to assess the disease process and, in oncologic cases, to evaluate the presence of metastatic disease.
- If required, lysis of adhesions may be safely performed laparoscopically.

DEVELOPMENT OF THE PRESACRAL PLANE

- With the patient in Trendelenburg position and the left side elevated, the small bowel loops are retracted superiorly and to the right to expose the target operative field. The surgical sponge facilitates small bowel retraction.
- The sigmoid and rectosigmoid junction are identified and retracted anteriorly and laterally (FIG 6).
- The sacral promontory is identified and the peritoneum is incised medially with either a monopolar or bipolar energy device (FIG 6). An avascular presacral plane is created and further developed using blunt and sharp dissection with a bipolar tissue-sealing device (FIG 6). During this dissection, anatomic landmarks include the sacral promontory, superior rectal artery, left ureter, left gonadal vein, and left iliac vein. The concept of single-incision triangulation is used. In this technique, one instrument elevates the tissue anteriorly while the other—from the surgeon's dominant hand—performs dissection in a "hand-over-fist fashion."
- The dissection plane is developed without excessive deep dissection to avoid pelvic plexus injury. Furthermore, it is imperative to identify and to preserve the left ureter.
- Once the presacral plane is fully developed, attention is then drawn to the identification of the left colic artery.



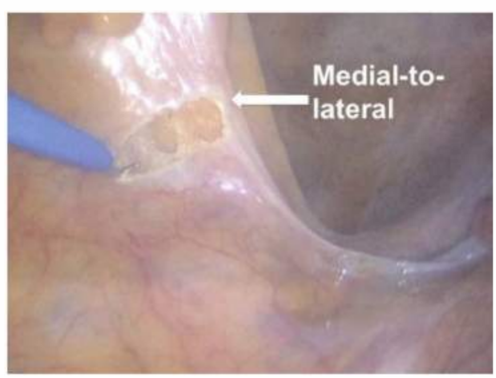


FIG 6 ● Presacral plane development. **A.** The rectosigmoid is retracted laterally and anteriorly; the sacral promontory is identified as landmark prior to the peritoneal incision. **B.** The peritoneum is incised in a medial-to-lateral fashion. *(continued)*

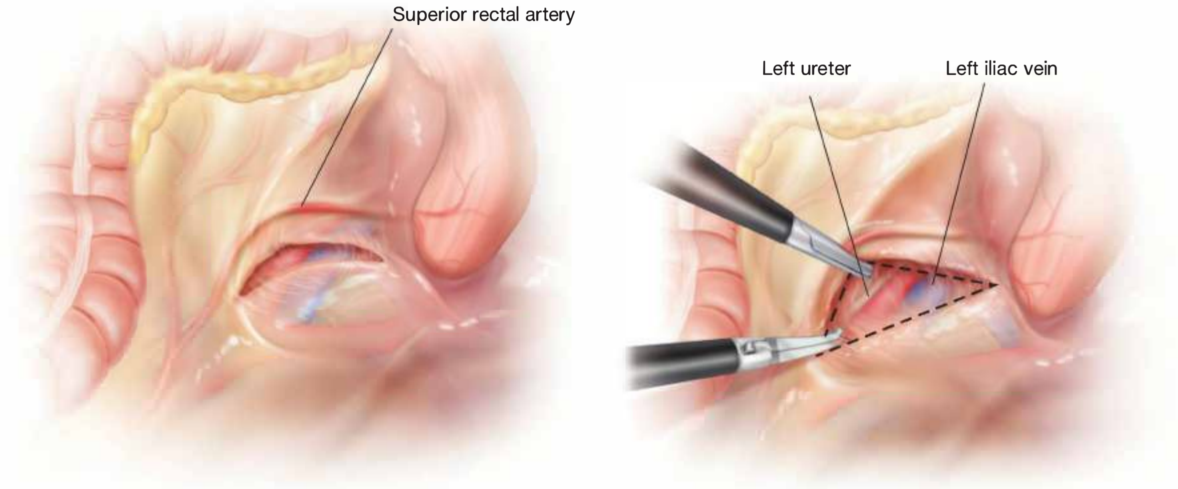


FIG 6 ● *(continued)* **C.** The presacral dissection continues and the superior rectal artery is identified. **D.** The plane is further developed using a triangulation technique with one instrument elevating the tissue while the other instruments carrying out the dissection. Additional critical structures are identified and preserved, including the left ureter and left iliac vein.

DEVELOPMENT OF THE RETROPERITONEAL PLANE

- Once identified, the left colic artery is grasped and elevated. A peritoneal incision is made medial to the vessel and the retroperitoneal plane is created using either a monopolar or bipolar energy device (**FIG 7**).
- The retroperitoneal plane is further developed, making use of the triangulation technique described previously. The dissection is carried out anterior to Gerota's fascia, along the inferior border of the pancreas, and moving laterally toward the white line of Toldt. The superior portion of the left ureter is identified and preserved.

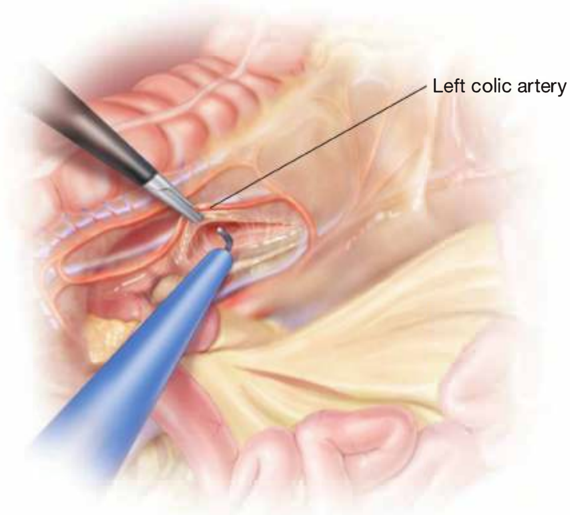


FIG 7 ● The left colic artery is grasped and elevated. A peritoneal incision is made medial to the vessel and the retroperitoneal plane is created and further developed using a triangulation technique. The dissection is carried out anterior to Gerota's fascia and toward the white line of Toldt.

HIGH VASCULAR DIVISION—THE EAGLE SIGN

- At this point, the left colic and superior rectal arteries are isolated and elevated to readily identify the inferior mesenteric artery (IMA). This maneuver results in the exposure of the "eagle sign." The "body" of the "eagle" is the IMA, the superior "wing" the left colic artery, and the inferior wing the superior rectal artery (**FIG 8**). The identification of this sign facilitates appropriate vascular identification and division. The IMA is now safely divided at its origin with a bipolar energy device or linear stapler. The inferior mesenteric vein is then identified and divided. In those with benign disease, a high ligation technique is not required and division takes place at the level of the superior rectal artery.

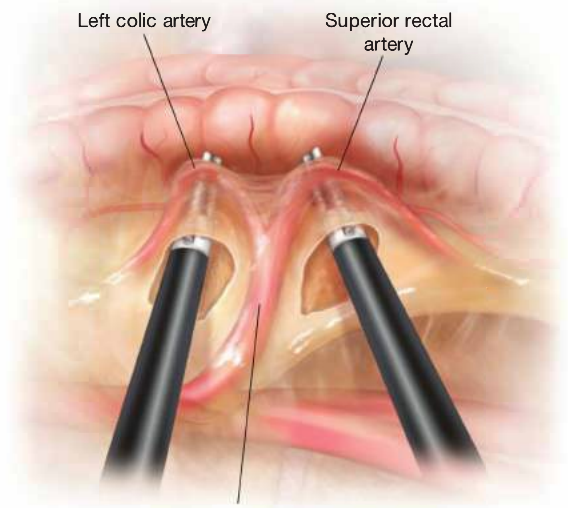


FIG 8 ● **A.** The eagle sign: The body of the eagle is the inferior mesenteric artery (IMA), the superior wing the left colic artery, and the inferior wing the superior rectal artery. **B.** The IMA is now safely divided at its origin with a bipolar energy device or linear stapler.

LATERAL ATTACHMENTS AND SPLENIC FLEXURE TAKEDOWN

- Some cases may require splenic flexure mobilization to afford a tension-free anastomosis. This is achieved by detaching the gastrocolic ligament at the level of the distal transverse colon, allowing entry to the lesser sac. At this level, the splenocolic ligament is readily taken down, affording a complete splenic flexure mobilization.
- The lateral attachments of the descending colon are taken down from the pelvic brim to the splenic flexure. The descending colon is grasped and retracted medially while the attachments are released with a bipolar tissue-sealing device (**FIG 9**).
- In order to fully mobilize the left colon, additional rectosigmoid pelvic attachments are taken down. This also achieves proper upper rectum mobilization, which is beneficial for the specimen division.

FIG 9 ● Lateral-to-medial dissection. The lateral attachments of the sigmoid and descending colon are taken down in an inferior-to-superior direction from the pelvic brim to the splenic flexure, which is readily mobilized if required.

BOWEL DIVISION

- The rectosigmoid is flipped in a medial-to-lateral direction and its mesentery is divided (**FIG 10**). A window is created in the mesentery through which the linear stapler will be placed. The rectosigmoid is then placed in normal anatomic position and it is divided tangentially using a laparoscopic linear stapler.
- The instruments and single-port device are removed and the specimen is exteriorized. The level of the proximal division is chosen and the bowel is divided extracorporeally (**FIG 10**).

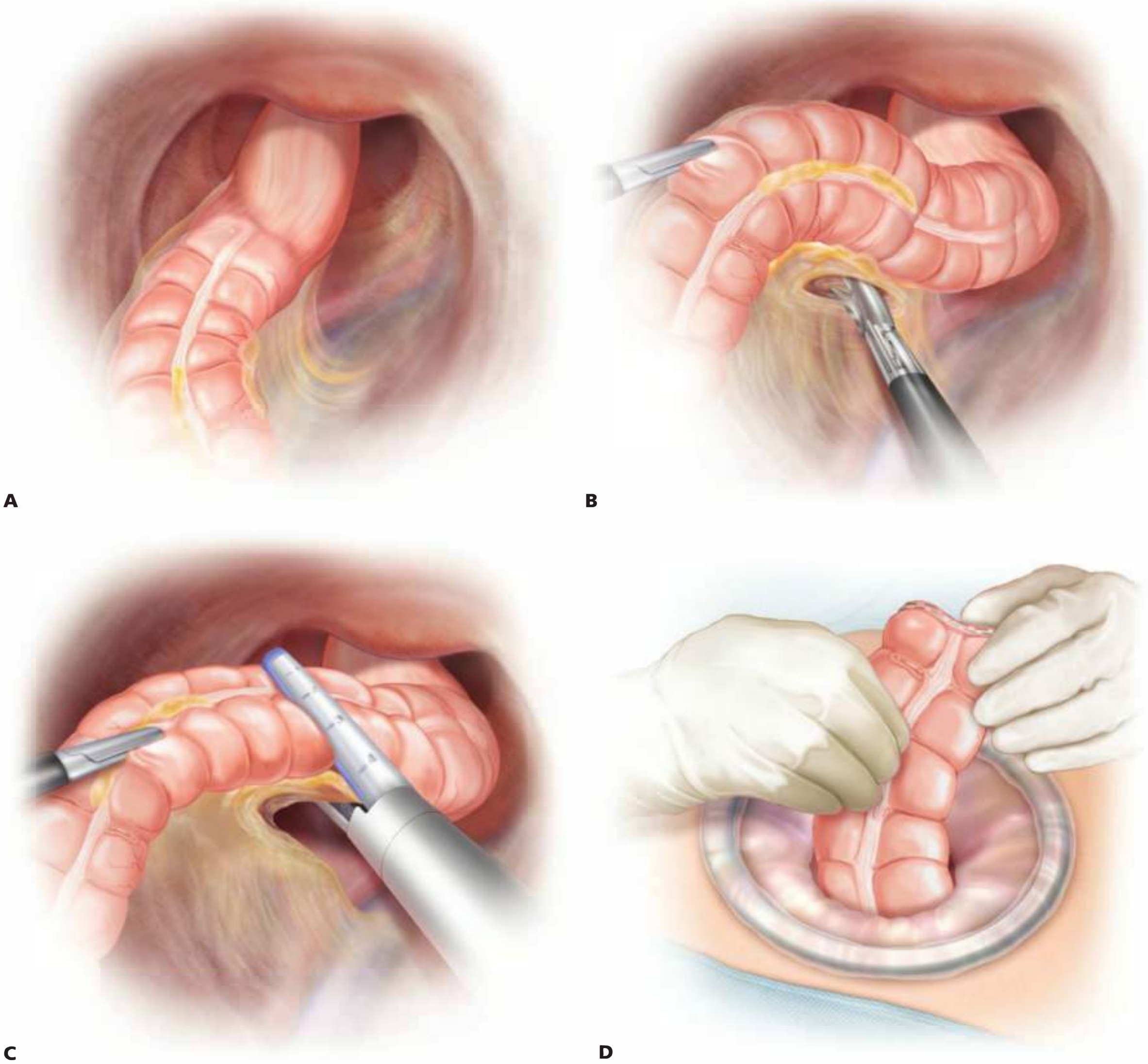
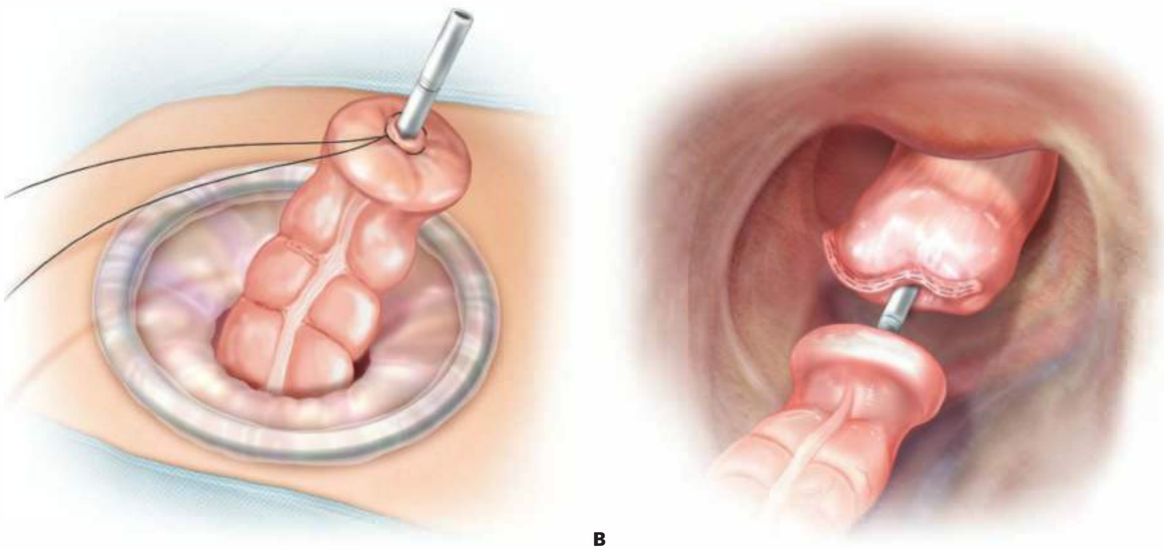


FIG 10 ● **A.** The rectosigmoid is fully mobilized and ready for division. **B.** A window is created in the mesentery to introduce the stapler in preparation for specimen division. **C.** Rectosigmoid division with a linear stapler. **D.** Extracorporeal mobilization of the bowel for proximal division and preparation for bowel anastomosis.

ESTABLISHMENT OF BOWEL CONTINUITY

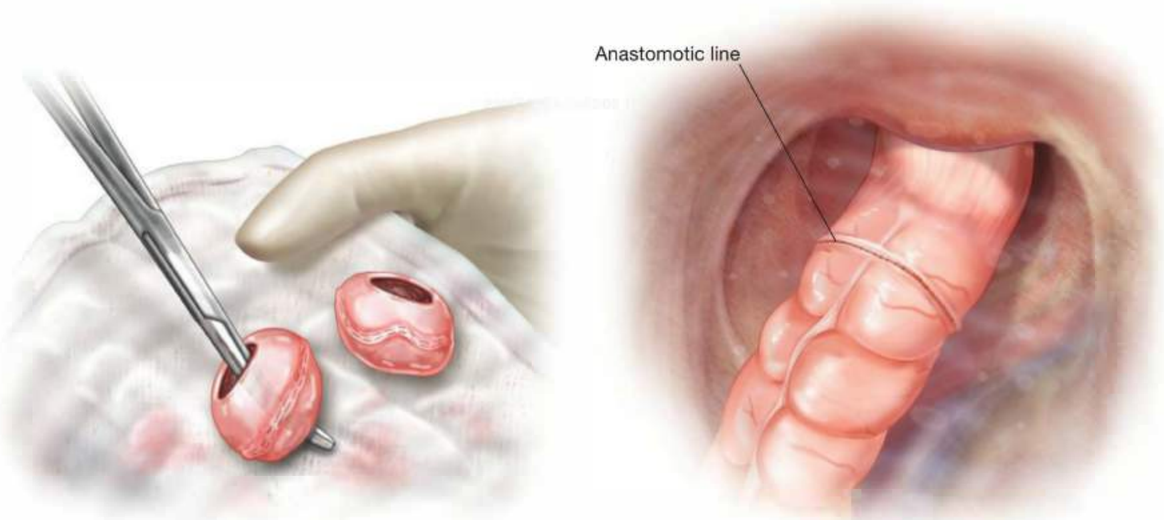
- An end-to-end anastomosis is performed with a circular stapler in a traditional fashion.
- We prefer to use a circular stapling device of 29-mm size. Smaller sizes are prone to result in stricture formation and should be avoided, and larger sizes may result in tearing of the bowel wall.
- The anvil of the stapler is introduced into the proximal bowel and is secured with a purse-string suture (FIG 11). The bowel is introduced back into the peritoneal cavity and the pneumoperitoneum is reestablished.
- The assistant inserts the stapler handle transanally and advances it to the level of the staple line.
- The anvil and the handle of the stapler are aligned and the stapler is closed under direct laparoscopic visualization (FIG 11). Before performing the anastomosis, it is important to ensure that the bowel is not twisted. Once proper bowel alignment is corroborated, the stapler is fired and then removed transanally.



A B

FIG 11 ● End-to-end colorectal anastomosis. **A.** The anvil of the stapler is introduced and secured into the proximal bowel with a purse-string suture. **B.** After the bowel is reintroduced into the abdomen, the anvil and the handle of the stapler are aligned and the stapler is closed under direct laparoscopic visualization.

- Confirmation of a proper anastomosis is performed in three stages. Proctoscopy is performed to visualize the integrity and viability of the anastomosis. The anastomotic rings (donuts) are examined to ensure they are intact circumferentially (**FIG 12**). Finally, an air insufflation test is then performed to confirm that the anastomosis is airtight (**FIG 12**). If the anastomosis is found to be inadequate, modifications may be required as well as consideration of diversion of the fecal stream, depending on the characteristics of the individual case.



A B

FIG 12 ● Anastomotic confirmation. **A.** The anastomotic rings are inspected to confirm that they are intact. **B.** An air insufflation test is performed to confirm the absence of anastomotic leak.

BOWEL DIVERSION

- For cases in which it is unsafe to perform a primary end-to-end colorectal anastomosis, sigmoid resection with end colostomy or, alternatively, anastomosis with a protective loop ileostomy may be performed.

TECHNICAL ALTERNATIVES

- Single-incision laparoscopic sigmoidectomy may be also performed with a lateral-to-medial dissection approach.
- We favor the medial-to-lateral approach because it allows identification of critical structures such as the left ureter, facilitating its preservation. Furthermore, we believe that is a more "natural" approach, as the instruments are located in the midline, simplifying the procedure.
- For the lateral-to-medial approach, the procedure initiates with the release of the lateral attachments of the descending colon, establishment of the retroperitoneal plane, followed by vascular identification and division. Once the sigmoid/left colon is mobilized, the extracorporealization, bowel division, and anastomosis are performed as described previously.

PEARLS AND PITFALLS

Indications	■ Sigmoid diverticulitis, colon cancer, large colon polyps, inflammatory bowel disease
Preoperative evaluation	■ Colonoscopy with lesion tattooing for polyps and cancer ■ Abdominopelvic CT scan ■ PET scan selectively
Incision	■ 2.5-cm umbilical or 4-cm Pfannenstiel ■ Single plus one technique: 4-cm Pfannenstiel and 5-mm umbilical port for camera port
Technique	■ Medial-to-lateral dissection. Early identification and preservation of the left ureter. ■ Vascular dissection to visualize the eagle sign and high IMA ligation in malignancy ■ Specimen division with end-to-end anastomosis with 29-mm circular stapler ■ Proper anastomosis confirmed with proctoscopy, evaluation of anastomotic rings, and air insufflation test
Postoperative care	■ Patients benefit from the use of a fast-track perioperative protocol.

POSTOPERATIVE CARE

- Postoperative care following minimally invasive colorectal surgery is enhanced with use of a standardized fast-track protocol.[5]
- Orogastric or nasogastric tube is avoided, and diet is resumed with clear liquids 8 to 12 hours after the procedure and advanced with resumption of bowel activity.
- Bladder catheter is removed on postoperative day 1.
- Ambulation is achieved the first night of surgery.
- Postoperative analgesia is accomplished with a combined modality to reduce opioid use. Local infiltration with a long-acting anesthesia can be accomplished with liposomal bupivacaine. Intravenous acetaminophen and nonsteroidal antiinflammatory drugs can be given in a staggered fashion. Use of opioid can be limited to breakthrough pain, and alvimopan can be used to eliminate the effects of opioids in the GI tract.

OUTCOMES

- Most patients following sigmoid colectomy managed with a fast-track perioperative protocol have an average length of hospital stay of 3 days.[2,4]
- Complications may warrant longer hospital stays and should be managed on an individual basis.
- Hernia rates can be reduced by use of the Pfannenstiel incision versus the umbilical incision.
- Those with malignancies should be placed on oncologic surveillance protocols.

COMPLICATIONS

- Vascular injury with intraperitoneal bleeding
- Ureteral injury
- Sexual and/or urinary dysfunction secondary to autonomic nerve injury

- Prolonged postoperative ileus
- Wound complications (e.g., hematoma, seroma, infection, and dehiscence)
- Anastomotic dehiscence
- Intraabdominal abscess
- Hernia formation

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Chapter 23

Surgical Management of Complicated Diverticulitis: Perforation and Colovesical Fistula

Scott E. Regenbogen

DEFINITION

- Diverticulitis is acute or chronic inflammation and/or infection caused by perforation of a colonic diverticulum. Acute, simple diverticulitis results from localized, contained contamination, without features of complex disease, and is typically amenable to medical therapy alone.
- Complicated diverticulitis includes free perforation with peritonitis, abscess formation, fistula, or stricture and will typically require operation. Chronic or recurrent diverticulitis may be an indication for resection if the episodes are frequent, incur substantial morbidity, or fail to resolve with medical therapy.

DIFFERENTIAL DIAGNOSIS

- Diverticulitis is often a clinical diagnosis. The syndrome of left lower quadrant pain, fever, and abdominal tenderness may also be consistent with irritable bowel syndrome, gastroenteritis, stercoral perforation, appendicitis, inflammatory bowel disease, urinary tract infection, aortic dissection or aneurysmal rupture, nephrolithiasis, pelvic inflammatory disease, ovarian torsion, and a variety of other causes of acute abdominal pain.
- When diverticulitis is identified on computed tomography (CT) of the abdomen as segmental colon inflammation associated with diverticulosis, it must be distinguished from other causes of segmental colitis, including perforated neoplasm, ischemia, and Crohn's disease. Details of clinical history, family history of colorectal cancer, and previous colon evaluation are helpful in excluding the latter two.
- Except in the emergency setting, malignancy must be excluded, either by endoscopic evaluation or other means, because the principles of oncologic resection, including wide lymphadenectomy and en bloc resection, are typically violated in surgery for benign diverticular disease.

PATIENT HISTORY AND PHYSICAL FINDINGS

- Patients with diverticulitis typically present with abdominal pain and fever. Because more than 90% of diverticulitis occurs in the sigmoid colon, the symptoms will typically localize to the left lower quadrant.
- Free perforation may present as generalized peritonitis and/or sepsis.
- In the presence of colovesical fistula, the patient may have irritative urinary symptoms or even pneumaturia or fecaluria, and there may be air or enteral contrast visible in the bladder. Occasionally, patients with colovesical fistula may not report a preceding episode of acute diverticulitis; rather, their initial presentation may be with symptoms of the fistula itself. Passage of urine per rectum is not common with colovesical fistulae from diverticulitis.
- The clinical history should focus on the presence or absence of repeated episodes and symptoms suggesting fistulizing disease—gas or stool in the urine or per vagina.
- In consideration of the differential diagnosis, the examiner should elicit any history consistent with inflammatory bowel disease or ischemic colitis and assess the patient's risk factors for colorectal cancer (age, personal and family history of cancer or polyps, and whether any previous colorectal cancer screening evaluations have been performed).
- Physical examination in the acute setting will reveal localized or generalized abdominal tenderness. Focal guarding in the left lower quadrant is typical. Diffuse rebound tenderness suggests generalized peritonitis from free feculent perforation or purulent peritonitis from abscess rupture. Abdominal wall erythema may suggest incipient colocutaneous fistula. In the chronic setting, patients may have fullness or a palpable mass.
- Traditional recommendations for elective colon resection after two episodes of uncomplicated diverticulitis have generally been abandoned. Instead, elective colectomy is recommended on a case-by-case basis, depending on age, comorbidity, severity and frequency of attacks, and the success of medical therapy.
- Elective resection is often advised after recovery from an episode of complicated diverticulitis managed with medical therapy and/or percutaneous drainage.
- Urgent operation may be indicated for free perforation with sepsis.

IMAGING AND OTHER DIAGNOSTIC STUDIES

- Typical findings on CT scan of the abdomen include segmental colonic inflammation and pericolonic fat stranding within an area of diverticulosis. There may be extraluminal air or fluid or a contained abscess. Intravenous and oral contrast administration is helpful, although not essential. Rectal contrast is generally unnecessary, except to help with delineating a fistula.
- CT is the most sensitive test for diagnosing colovesical fistula (**FIG 1**). Other options include contrast enema (**FIG 2**), CT or fluoroscopic cystography, cystoscopy, colonoscopy, or oral administration of undigested material (e.g., charcoal, poppy seeds) to be observed for in the urine. In some cases, colovesical fistula may be a clinical diagnosis based on the presence of pneumaturia and/or fecaluria alone.

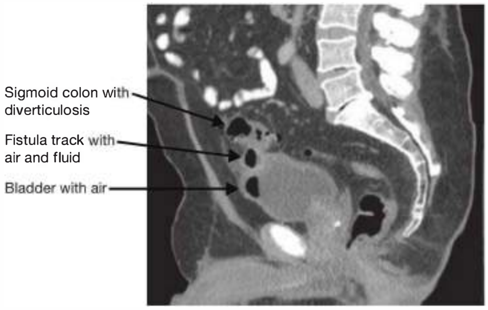


FIG 1 ● Sagittal CT image demonstrating sigmoid diverticulitis with a fistula track and air in the bladder consistent with colovesical fistula.

FIG 3 ● Colonoscopic image of colonic diverticulosis.

- Colonoscopy (**FIG 3**) is advisable for evaluation of diverticulitis and colovesical fistula in order to exclude a perforated malignancy, which can have similar clinical presentation and radiographic appearance. The presence of malignancy would warrant an oncologic mesenteric lymphadenectomy and en bloc resection of involved bladder wall, whereas the fistula may simply be divided in cases with benign inflammatory etiology.

SURGICAL MANAGEMENT

Preoperative Planning

- When patients present with diffuse peritonitis and sepsis, urgent operation may be required. Broad-spectrum antibiotics should be administered and the patient should be well resuscitated with intravenous fluid prior to surgery.
- Every effort should be made before surgery to mark acceptable sites on the abdominal skin for stoma creation bilaterally. Consideration may be given to placement of ureteral stents preoperatively if it can be performed without undue delay.
- Decision making should be centered on the patient's clinical condition, the severity of pelvic sepsis, the suitability for colorectal anastomosis, and the ability to safely resect the inflammatory segment.
- Options for surgical approach in the emergency setting include
  - Proximal diversion without resection
  - Resection with end colostomy and rectal stump closure (Hartmann procedure)
  - Resection with primary anastomosis, with or without diverting loop ileostomy
  - Laparoscopic lavage and drainage
- Complete colonoscopy in the elective setting should be performed in order to exclude a perforated malignancy that presented as perforated diverticulitis or synchronous malignancy.
- Cystoscopy and urine cytology may be considered in cases of colovesical fistula if there is suspicion for a primary bladder malignancy.
- Consideration should be given to prophylactic placement of ureteral catheter(s) to assist with identification of the ureter, if it appears to be involved with the inflammatory segment.
- Laparoscopic approaches to complex diverticular disease and colovesical fistula are appropriate in hemodynamically stable patients among surgeons with adequate laparoscopic colorectal surgery skills and training. Hand-assisted and straight laparoscopic techniques have similar short- and long-term reported outcomes.
- If inflammation is severe and there is intention to perform a Hartmann procedure with end colostomy or a colorectal anastomosis with diverting loop ileostomy, the patient should undergo preoperative evaluation and counseling by an enterostomal therapist, including marking suitable locations for a stoma on the abdomen, either unilaterally or bilaterally, if the operative plan will depend on intraoperative findings.
- Mechanical bowel preparation with or without oral antibiotics is a controversial topic. There is no definitive evidence for or against bowel preparation. However, if there is intention to use a circular end-to-end stapling device placed per anus, mechanical bowel preparation or rectal enema should be administered to clear stool from the rectum. If a colorectal anastomosis and diverting loop ileostomy is planned, mechanical bowel preparation is recommended to avoid leaving a column of stool between the ileostomy and the downstream anastomosis.

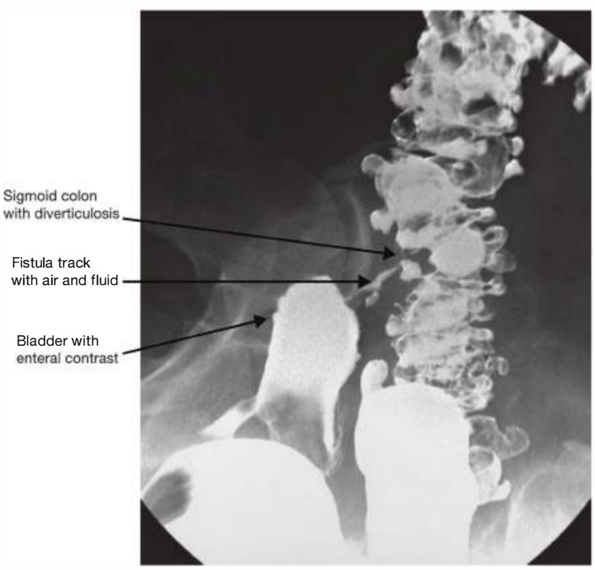


FIG 2 ● Barium enema demonstrating sigmoid diverticulosis with a fistula track and contrast filling the bladder.

- Prophylactic antibiotics to cover skin flora, enteric gram negatives, and anaerobic bacteria should be administered before making the incision.
- Appropriate pharmacologic and/or mechanical prophylaxis for venous thromboembolism is recommended.

Positioning

- The patient is placed in modified lithotomy position (**FIG 4A**) or supine with legs abducted on a split-leg table (**FIG 4B**) to provide access to the anus.
- If a laparoscopic approach is used, consideration may be given to a position-assisting device, such as a beanbag, to prevent the patient from sliding during extreme positioning changes.
- If stoma markings were performed preoperatively, these should be redrawn with a marker that will remain visible after skin preparation.

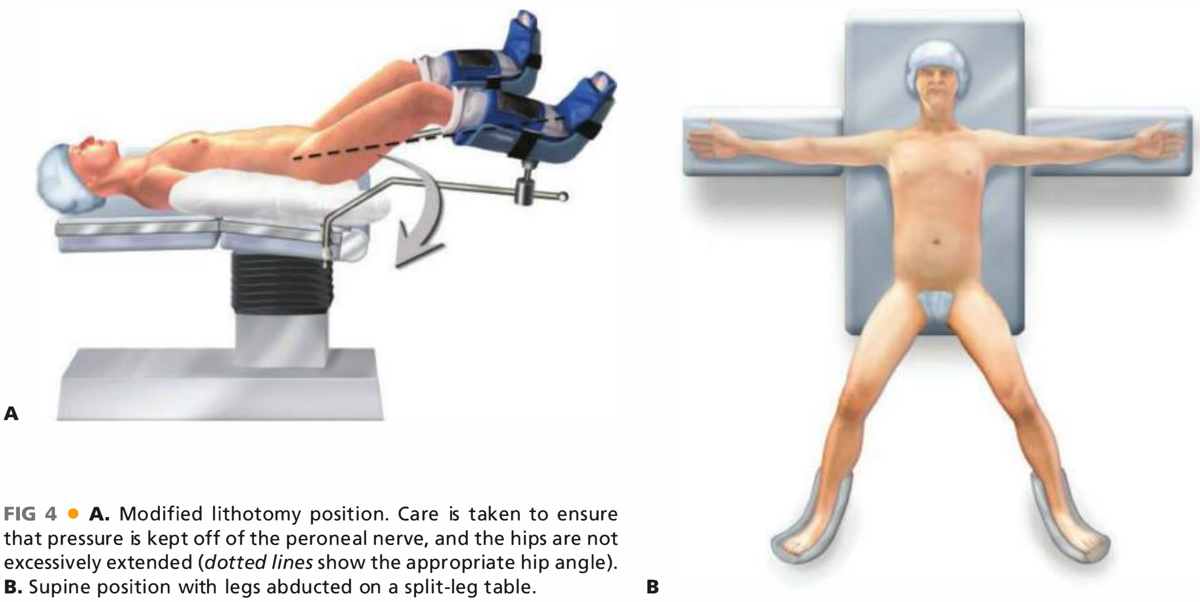


FIG 4 ● **A.** Modified lithotomy position. Care is taken to ensure that pressure is kept off of the peroneal nerve, and the hips are not excessively extended (*dotted lines* show the appropriate hip angle). **B.** Supine position with legs abducted on a split-leg table.

LAPAROSCOPIC ELECTIVE SIGMOID COLECTOMY, BLADDER REPAIR

Abdominal Access and Port Placement

- The abdomen may be accessed via a percutaneous Veress needle or an open Hasson cannula technique.
- Typical port placement is depicted in **FIG 5**. A 12-mm camera port is placed at the umbilicus. Three working ports are inserted, including a 5-mm port in the right upper quadrant, a 12-mm port in the right lower quadrant (preferably at a potential diverting loop ileostomy site), and a 5-mm port in the left lower quadrant (preferably at a potential colostomy site).

Isolation and Division of the Inferior Mesenteric Artery Pedicle

- In order to gain access to the proximal inferior mesenteric artery (IMA), the gastrocolic omentum is elevated over the transverse colon, into the upper abdomen, with the patient in steep Trendelenburg position, with the operating table tilted toward the right. The small bowel is brought to the right upper quadrant and out of the pelvis.
- Elevation of the rectosigmoid mesentery with a grasper through the left lower quadrant port toward the left lower quadrant, demonstrates the IMA as a ridge in the sigmoid colon mesentery and exposes a plane between the mesentery and the retroperitoneum on the medial peritoneal fold of the mesentery. With cautery attached to Endo Shears brought through the right lower quadrant port, a long incision is made in the medial peritoneal fold of the mesentery along a clear space seen between the IMA and the retroperitoneum (**FIG 6**).
- Through this incision, the left ureter, gonadal vessels, and retroperitoneal tissues are identified and dissected down off of the vessel and the mesentery (**FIG 7A**). If the left iliac artery and/or left psoas muscle are exposed, the plane of dissection must be brought more anteriorly. The left ureter is identified definitively by visualizing peristalsis.
- Once the left ureter has been identified and protected in the retroperitoneum, the IMA is encircled. The IMA and its terminal branches, the left colic artery, and the superior hemorrhoidal artery form what appears to be a "letter T," facilitating the identification of these critical vascular structures (**FIG 7B**). The IMA is then divided.

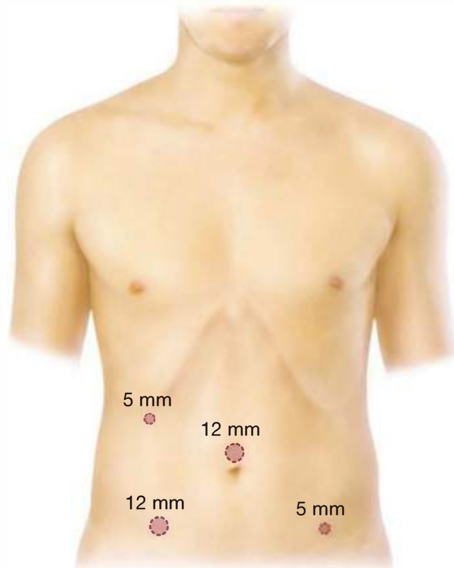


FIG 5 ● Laparoscopic port placement for sigmoid colectomy. A 12-mm camera port is placed at the umbilicus. Three working ports are inserted, including a 5-mm port in the right upper quadrant, a 12-mm port in the right lower quadrant (preferably at a potential diverting loop ileostomy site), and a 5-mm port in the left lower quadrant (preferably at a potential colostomy site).

I prefer a bipolar vessel-sealing device (**FIG 8A**) but choices include vascular clips, endoscopic staplers (**FIG 8B**), or endoloops. When using an energy device for division, it is advisable to have endoloops available in the room as a backup to control bleeding from the divided pedicle in case of device failure.

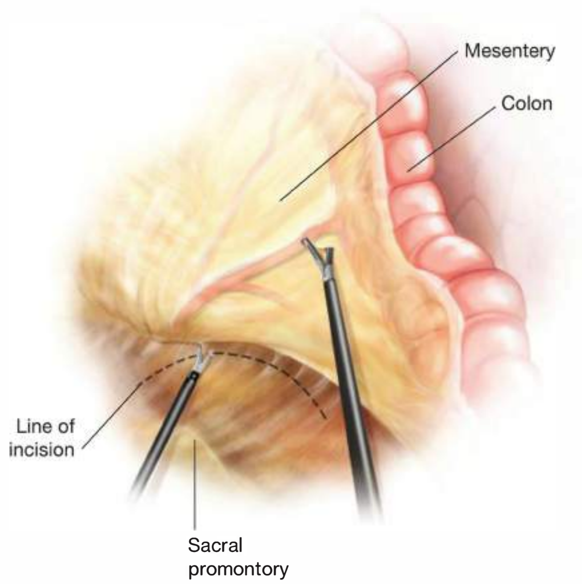
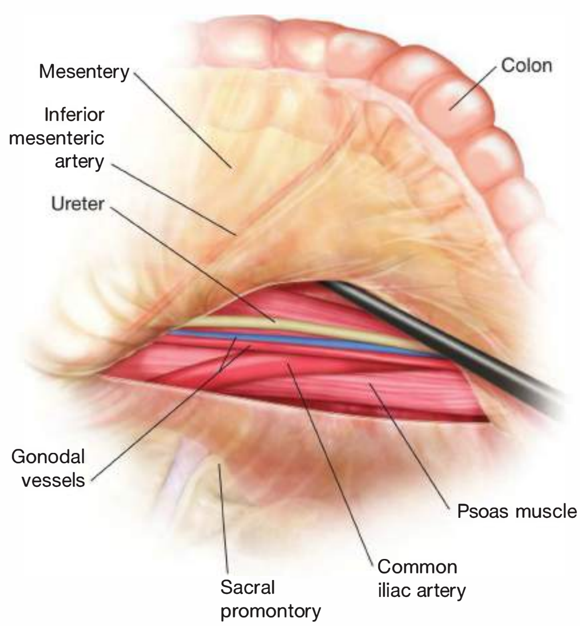


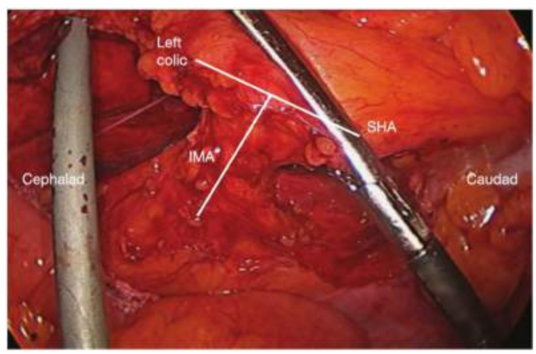
FIG 6 ● The sigmoid colon is elevated, placing tension on the IMA pedicle, and an incision is made in the medial peritoneal fold dorsal to the IMA *(dotted line)*.

Mobilization of the Descending Colon and Splenic Flexure

- The "medial-to-lateral" dissection of the mesocolon is performed by elevating the divided vascular pedicle, identifying the line of separation between the posterior side of the colon mesentery ventrally and Gerota's fascia overlying the kidney and retroperitoneum dorsally

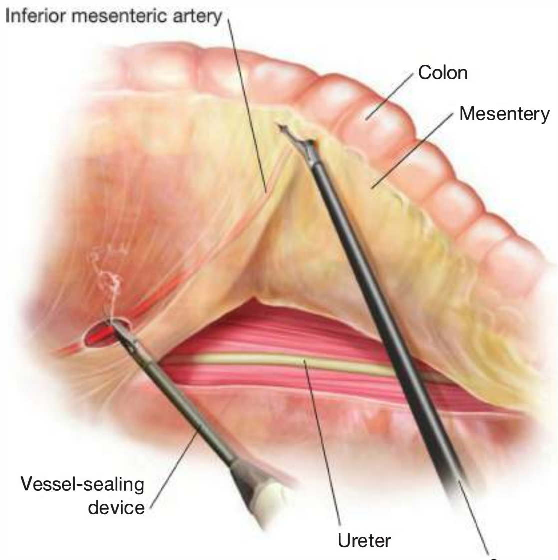


A



B

FIG 7 ● **A.** The mesenteric vessels are isolated by sweeping the retroperitoneal tissues, including the left ureter and gonadal vessels, posteriorly off the mesentery of the sigmoid colon. The left ureter is identified as it crosses under the colon mesentery and is protected in the retroperitoneum. **B.** The IMA and its terminal branches, the left colic artery, and the superior hemorrhoidal artery (SHA) form what appears to be a "letter T," facilitating the identification of these critical vascular structures.



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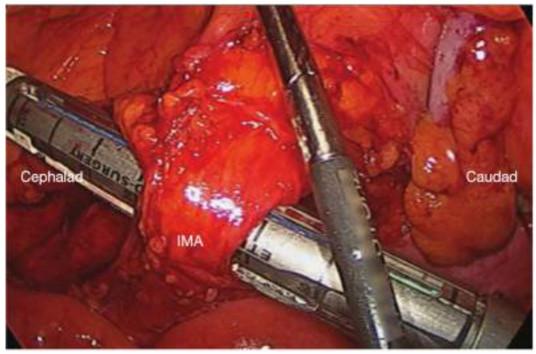
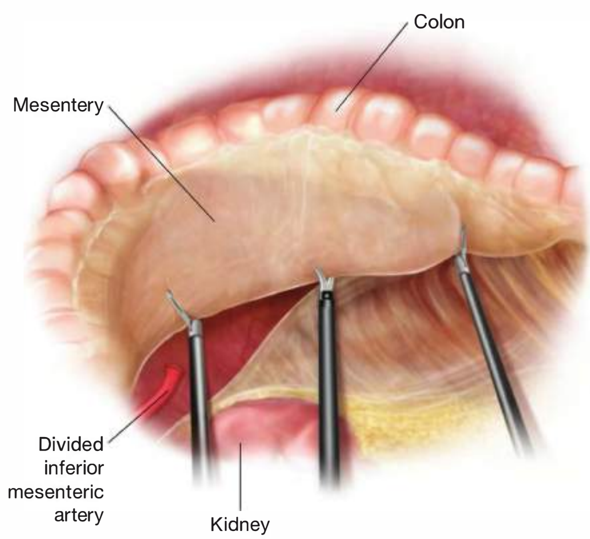


B

FIG 8 ● The IMA is encircled at its base and divided with a **(A)** bipolar vessel-sealing device or **(B)** endoscopic stapler, ensuring that the ureter is not ensnared during the division.

(**FIG 9A,B**). The retroperitoneal tissues are swept down (dorsally) with a combination of cautery and blunt dissection. This dissection continues laterally to the abdominal side wall and superiorly to the inferior border of the pancreas and the superior edge of the distal transverse colon and splenic flexure. This will greatly facilitate the mobilization of the splenic flexure later during the case.

- The lateral dissection is then performed by retracting the colon medially and dividing the white line of Toldt from the pelvic brim to the splenic flexure (**FIG 10**). As the dissection continues superiorly, the patient's position is gradually altered, going from steep Trendelenburg toward slight reverse Trendelenburg position. The rightward tilt is maintained. If the medial dissection has been performed completely, there should be only a single tissue layer to divide before meeting the medial plane of dissection.
- At this point, the splenic flexure is mobilized. It is often helpful to access the lesser sac first by transecting the gastrocolic ligament with a tissue-sealing device from the distal transverse colon (**FIG 10**). The splenic flexure is then fully mobilized by transecting the splenocolic and phrenocolic ligaments superolateral to the colon with



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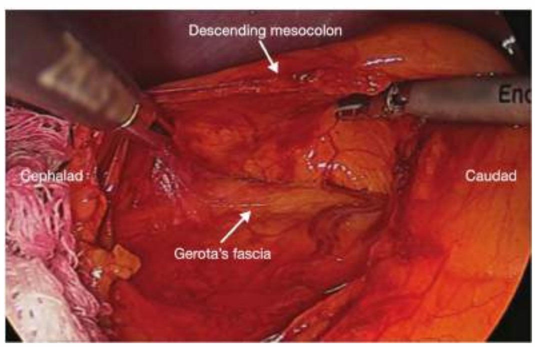

B

FIG 9 ● **A,B.** A medial-to-lateral dissection of the mesocolon is performed by elevating the divided vascular pedicle and sweeping the Gerota's fascia and retroperitoneal tissues dorsally, laterally to the abdominal wall, and superiorly to the tail of the pancreas and posterior to the splenic flexure of the colon.

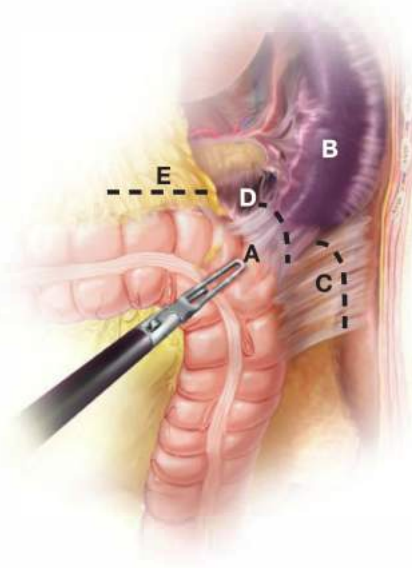

FIG 10 ● Mobilization of the splenic flexure. The phrenocolic *(C)*, splenocolic *(D)*, and gastrocolic ligaments *(E)* are transected in order to separate the splenic flexure *(A)* from the spleen *(B)*.

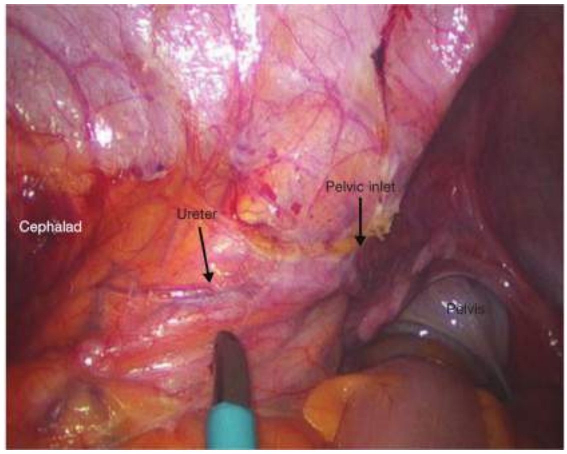

FIG 11 ● Mobilization of the sigmoid of the pelvic inlet. The left ureter can be seen crossing the left common iliac artery at the level of the left pelvic inlet.

cautery or a tissue-sealing device (**FIG 10**). To check for adequate length, healthy descending colon above the area of inflammation should be able to reach to the pelvis without any tension.

Mobilization of the Rectosigmoid, Separation, and Repair of the Fistula

- The sigmoid colon typically has attachments to the left sidewall at the pelvic inlet. These can be incised with cautery after the ureter has been reidentified, crossing the left common iliac artery at the level of the left pelvic inlet (**FIG 11**). Peritoneal incisions down each side of the rectosigmoid to the level of the upper rectum will allow identification of the upper mesorectum.
- The fistula is divided with a combination of sharp dissection and cautery. If it cannot be safely achieved laparoscopically, the extraction incision may be made at this time and separation accomplished by finger fracture.
- Once the colon and bladder are separated, the bladder may be repaired with one or two layers of absorbable suture material if a full-thickness defect is exposed. The closure can be leak tested by irrigation through the urinary catheter with methylene blue dye to enhance visualization of a potential urinary leak.
- A closed suction drain may be left in the pelvis if the bladder repair is extensive; but often, the actual hole in the bladder is quite difficult to identify definitively and drainage is not required for most cases.
- The upper rectum is then divided distal to the coalescence of the teniae coli by bluntly creating a window between rectum and mesorectum. The mesorectum is divided at this level using a tissue-sealing device. The upper rectum is then transected either with an endoscopic stapler via the right lower quadrant port site or through the extraction incision.

Extraction Incision, Colon Division, and Anastomosis

- The specimen may be extracted through a lower abdominal incision of choice. I prefer a small Pfannenstiel incision with a transverse curvilinear fascial incision.
- The specimen is exteriorized through the extraction incision.
- Before division of the bowel, I prefer to clamp the marginal artery distally, then divide it sharply within the mesentery, at a point on the descending colon proximal to the area of inflammation, just beyond the intended point of division. The presence of arterial bleeding from the proximal end indicates adequate blood supply for the future anastomosis.
- The colon is then divided, either with a linear stapler or a purse-string application device.
- A 31-Fr anvil of an end-to-end anastomosis (EEA) device is sewn into the divided end of the colon, and care should be taken to be sure that the mesentery is not twisted as the anvil is brought to the pelvis.
- The handle of the stapler is advanced transanally, up to the rectal staple line, and an end-to-end stapled EEA colorectal anastomosis is performed (**FIG 12A**). The resected "donuts" should be examined. The integrity of the anastomosis is tested by insufflating it under water. The presence of an air leak would indicate an anastomotic disruption and would require repair or revision of the anastomosis, with or without proximal diversion (**FIG 12B**).

Closure

- If the omentum can be mobilized to the pelvis, it is placed between the anastomosis and the bladder repair as a vascularized soft tissue flap.
- The extraction incision is closed in layers. The large laparoscopic ports may be closed from the outside or with the use of a laparoscopic suture passer. The small ports are closed at skin level only.

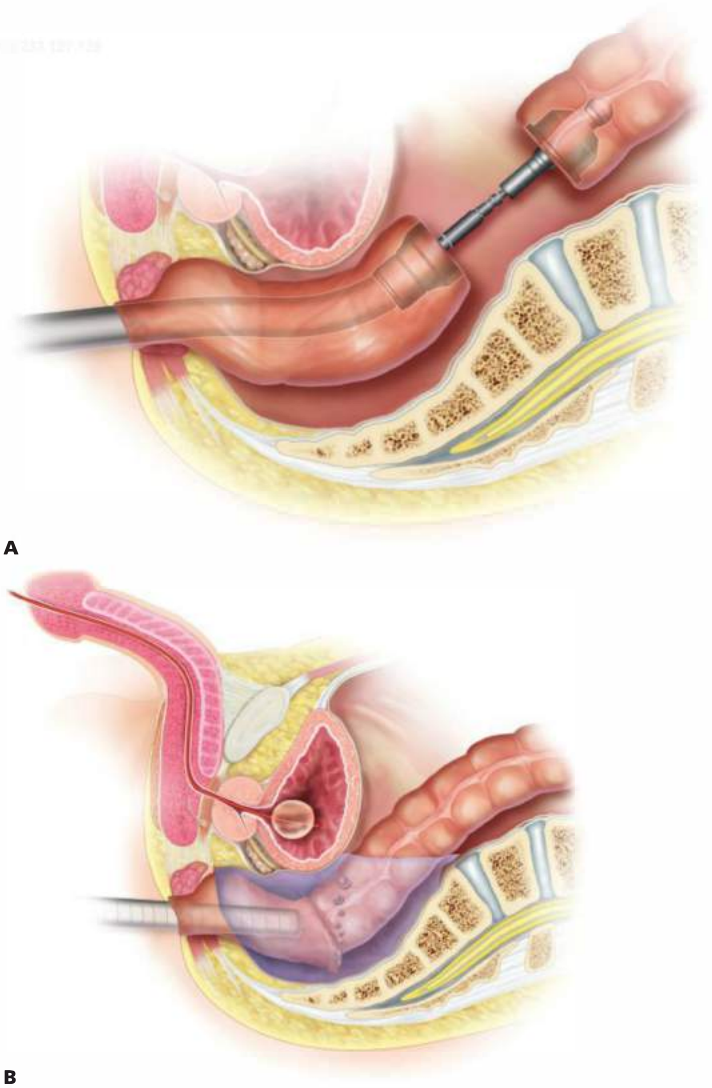

FIG 12 ● The colorectal anastomosis. **A.** A stapled EEA colorectal anastomosis is performed. **B.** The integrity of the anastomosis is tested by insufflating it under water. The presence of an air leak would indicate an anastomotic disruption and would require a revision of the anastomosis.

HARTMANN PROCEDURE

Abdominal Entry, Containing Contamination

- In an emergency setting, a lower midline laparotomy, occasionally with extension above the umbilicus, facilitates rapid and ample exposure.
- In case of purulent or feculent peritonitis, contamination should first be evacuated and irrigated clean. Often, there will be a contained collection or phlegmon overlying a necrotic perforation. Blunt finger fracture will provide exposure of the perforation, then contamination should again be contained rapidly.

Colon Mobilization and Resection

- Mobilization should be kept to the minimum necessary. Unlike in elective sigmoidectomy for diverticulitis, it is not essential to resect the rectosigmoid junction or to mobilize the splenic flexure. Rather, the goal should be to resect the grossly perforated colon segment, divide the colon proximal and distal to the acutely inflamed segment, and maintain as much vascular supply as possible for the future colostomy takedown.

- The descending colon should be mobilized only as much as is required for the divided colon to reach the abdominal wall without tension at the intended colostomy aperture. Excessive mobilization only exposes additional tissue planes into which contamination may extend and establish a future abscess.
- The rectosigmoid may be left in place, and the divided colon/rectal stump marked with a permanent suture. The status of the superior hemorrhoidal artery should be documented in the operative report and dissection in the pelvis should be minimized in order to preserve tissue planes for the potential future colostomy closure.

Abdominal Closure and Stoma Creation

- The colostomy aperture is typically created in the left abdomen, ideally at a site marked preoperatively.
- The abdomen is closed in layers. Depending on the extent of contamination, the skin incision may be closed primarily, closed in a delayed primary fashion, closed over gauze wicks, or left open to heal by secondary intention.
- The colostomy is matured in a standard fashion.

LAPAROSCOPIC LAVAGE AND DRAINAGE

Abdominal Access and Port Placement

- The abdomen may be accessed via a percutaneous Veress needle or an open Hasson cannula technique. Port placement is then chosen, depending on the location of perforation and presence of adhesions to the anterior abdominal wall. A typical port distribution is depicted in **FIG 13**.

Identification and Control of the Perforation

- After laparoscopic assessment, sharp adhesiolysis is performed with scissors and cautery to free adhesions to the anterior abdominal wall.
- Purulent fluid is aspirated and a sample obtained for aerobic and anaerobic bacterial culture.
- Blunt dissection is used to separate omentum and small bowel from the perforated sigmoid colon, exposing loculated fluid collections.
- Copious irrigation (4 L or more) with sterile saline, with or without dilute iodine and/or antibiotics, is used to clear any residual contamination.
- If a small perforation is identified, it may be sutured closed with absorbable Lembert sutures. It is desirable to buttress this closure with a patch of omentum or epiploic appendage, if easily mobilized, to cover the perforation (**FIG 14**).

Drain Placement and Closure

- Two large closed suction drains are placed through the laparoscopic port incisions and left to reside in the pelvis near the site of perforation.
- The laparoscopic incisions are closed with subcuticular suture, and the drains are sutured to the skin and connected to bulb suction.

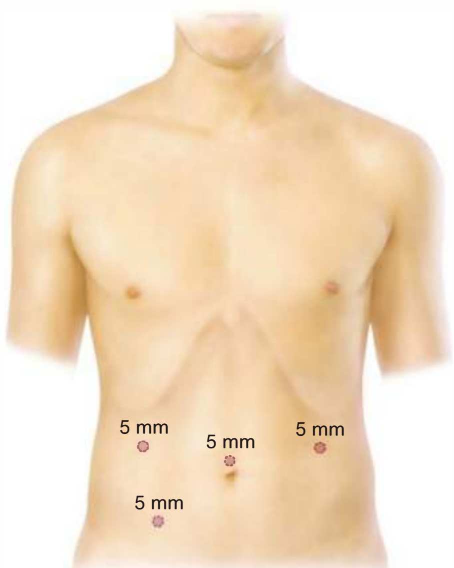

FIG 13 ● Laparoscopic port placement for laparoscopic lavage and drainage. Four 5-mm ports are inserted as shown.

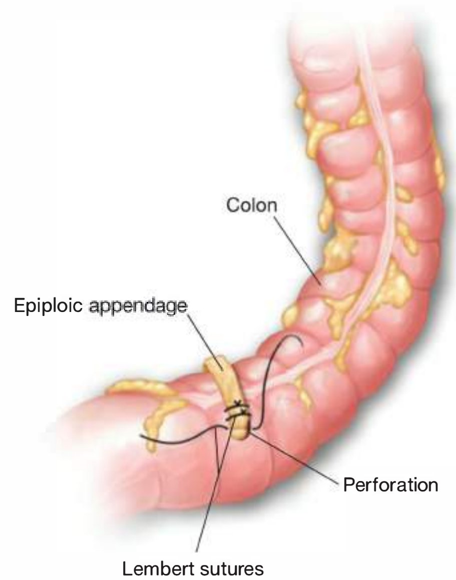

FIG 14 ● Laparoscopic lavage and drainage. If a small perforation is identified, it may be sutured closed with absorbable Lembert sutures. It is desirable to buttress this closure with a patch of omentum or epiploic appendage, if easily mobilized, to cover the perforation.

PEARLS AND PITFALLS

Indications	■ Traditional recommendations for elective resection after two uncomplicated episodes of diverticulitis have generally been abandoned. ■ Resection is indicated after nonoperative management of complicated diverticulitis, including free perforation, abscess, and fistula. ■ Free perforation with clinical sepsis is an indication for urgent operation.
Preoperative planning	■ Stoma sites should be marked preoperatively, if there is a possibility of colostomy or ileostomy. ■ Ureteral stent(s) should be considered in cases in which severe retroperitoneal inflammation is suspected based on preoperative imaging. ■ In elective cases, colonoscopy should be performed preoperatively to exclude a perforated neoplasm. ■ Mechanical bowel preparation in elective cases remains a controversial topic, left to the discretion of the surgeon, except in cases in which colorectal anastomosis and proximal diverting ileostomy is planned; in which case, bowel preparation should be administered to empty the diverted colon. ■ Appropriate antibiotics and venous thromboembolism prophylaxis should be administered perioperatively.
Choice of operation	■ Proximal diversion without resection ■ Resection with end colostomy and rectal stump closure (Hartmann procedure) ■ Resection with primary anastomosis, with or without diverting loop ileostomy ■ Laparoscopic lavage and drainage
Postoperative management	■ Postoperative antibiotics are not required in elective cases and are left to surgeon discretion in emergency cases with purulent or feculent peritonitis. ■ Cystogram may be used to verify repair of bladder fistula prior to removal of urinary catheter.

POSTOPERATIVE CARE

- Postoperative care should include combined analgesia with acetaminophen, nonsteroidal antiinflammatory medications, narcotics, and/or regional or epidural anesthesia. Mechanical and/or pharmacologic prophylaxis against venous thromboembolism should be provided. Early mobilization and early enteral feeding are both associated with shorter duration of postoperative ileus and should be encouraged. Routine postoperative nasogastric intubation is not recommended.
- Duration of urinary catheterization should be minimized to reduce the risk of urinary tract infection. After repair of colovesical fistula, however, an indwelling urinary catheter is typically left in place for 5 to 10 days, depending on the complexity of the bladder repair. A cystogram may be performed to confirm an intact repair before Foley catheter removal.
- Antibiotics are not given postoperatively after elective resection for colovesical fistula but may be continued for a varying duration after urgent operations for frank perforation with purulent or feculent peritonitis.

OUTCOMES

- The likelihood of recurrent diverticulitis after elective resection is determined largely by the level of anastomosis—less than 5% with a colorectal anastomosis but more than 12% with a colosigmoid anastomosis.
- Complication rates after Hartmann procedure are high. The most common complications are wound infection, sepsis, stoma necrosis, and intraabdominal abscess.
- Less than half of patients who undergo emergency Hartmann procedure go on to have their colostomy reversed.
- After laparoscopic lavage, about 6% of patients will require early reoperation for clinical deterioration. About half of the remaining patients will eventually require elective resection, and the remainder recover without further operative intervention.

COMPLICATIONS

- Anastomotic leak
- Abscess
- Ureteral injury
- Bowel obstruction
- Hemorrhage
- Stoma complications (necrosis, dehiscence, obstruction)
- Bladder leak

SUGGESTED READINGS

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Chapter 24

Total Abdominal Colectomy: Open Technique

Tarik Sammour   Andrew G. Hill

DEFINITION

- Total abdominal colectomy is defined as the removal of the entire colon, following which the distal ileum is anastomosed to the rectum or an end ileostomy is created.

DIFFERENTIAL DIAGNOSIS

- Inflammatory bowel disease (IBD)
- Severe acute colitis (various etiologies)
- Polyposis syndromes, including familial adenomatous polyposis (FAP) and hereditary nonpolyposis colorectal cancer (HNPCC)
- Slow-transit constipation
- Malignancy

PATIENT HISTORY AND PHYSICAL FINDINGS

- Specific history and examination findings will depend on the indication for total abdominal colectomy.
- History of previous abdominal surgery is important, particularly in the setting of IBD. If the patient has had multiple small bowel resections and is at risk of short-gut syndrome, then total abdominal colectomy is contraindicated.

IMAGING AND OTHER DIAGNOSTIC STUDIES

- Endoscopy: Colonoscopy is required to diagnose the disease for which total colectomy is required, and an up-to-date flexible sigmoidoscopy is needed to assess the state of the rectum and ensure it is disease/polyp-free.
- Patients with IBD also require small bowel imaging (preferably computed tomography [CT] or magnetic resonance imaging [MRI] enteroclysis) to ensure that the small bowel is free of diseased segments.
- Patients with severe constipation require a colonic transit study to confirm functional colonic disease.
- Patients with malignancy require a staging CT scan of the chest/abdomen/pelvis.

SURGICAL MANAGEMENT

Preoperative Planning

- The surgeon obtains informed consent from the patient, explaining the procedure, expected recovery, and risks and benefits of the operation. Consent should also be obtained for a stoma should this be required.
- The patient's nutritional status should be optimized prior to surgery.
- A suitably qualified nurse should carry out preoperative stoma marking.
- Blood crossmatching is performed (at least two units available).
- A preoperative sodium phosphate enema is administered.
- Enhanced recovery after surgery (ERAS) perioperative care protocols are applied.[1,2]
- A midthoracic epidural should be inserted preoperatively.[3]
- An indwelling Foley catheter is inserted preoperatively.
- Appropriate intravenous antibiotic prophylaxis is given on induction.[4]
- Consideration should be given to intravenous steroid supplementation if the patient is steroid-dependent.
- Subcutaneous low-molecular-weight heparin is given on induction.
- Calf compression stockings are applied.
- Note: Mechanical bowel preparation is not recommended.[5]

Positioning

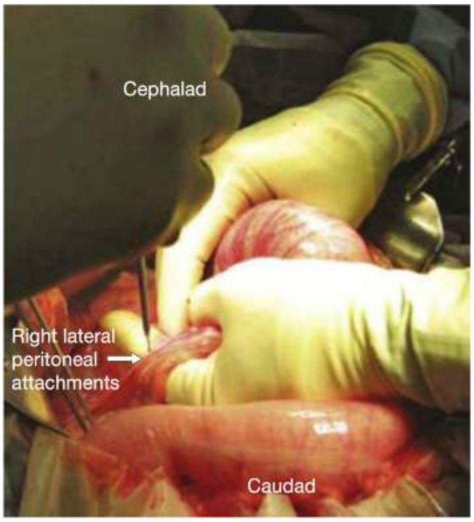
- The patient should be placed on a supine position with the arms out. Ensure that the arms are not hyperabducted to avoid brachial plexopathy.
- The patient should be as far down the bed as possible (to provide access to the anus). Ensure that the buttocks remain well supported on the bed.
- The legs should be placed in lithotomy braces with adequate padding. Ensure that there is no pressure on the common peroneal nerves bilaterally.
- A strap should be placed across the pelvis to hold the patient on the bed.
- Once the patient is positioned, a digital rectal examination and proctoscopy should be performed to ensure that there is no rectal abnormality.
- The patient's skin is prepped and draped from the xiphisternum to the pubis, ensuring access to the anus.
- The surgeon stands on the patient's left side, and the first assistant stands on the opposite side.

INCISION AND ACCESS

- A generous midline laparotomy is performed.
- A suitable laparotomy retractor is inserted.
- After general inspection, the small bowel is packed with moist, large swab packs into the upper abdominal cavity.

ASCENDING COLON MOBILIZATION

- The ascending colon is mobilized by medial traction and dissection along the right paracolic gutter using diathermy (FIG 1).
- Care is taken to identify, and avoid damage to, the right gonadal vessels, the right ureter, and the duodenum.



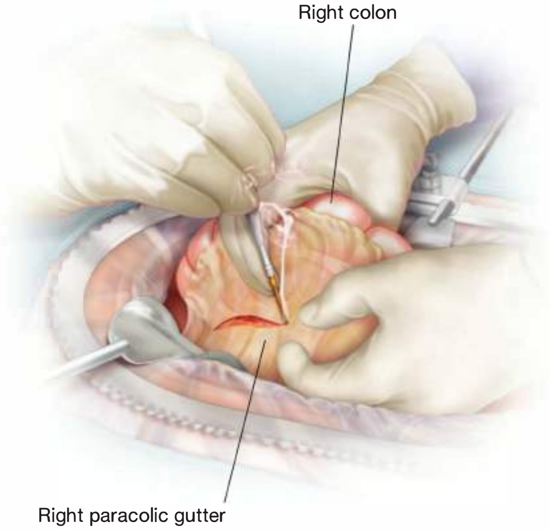
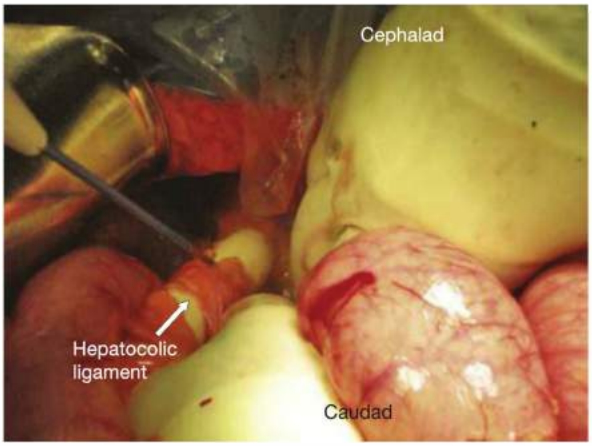


FIG 1 ● Ascending colon mobilization. The surgeon retracts the ascending colon medially. Dissection proceeds along the right paracolic gutter.

TRANSVERSE COLON MOBILIZATION

- The hepatic flexure is mobilized by dividing adhesions between the gallbladder and liver. Gentle traction on the hepatocolic ligament exposes the hepatocolic ligament, which is then transected with electrocautery (FIG 2).
- The gastrocolic ligament is exposed as the assistant retracts the greater omentum superiorly while the surgeon retracts the transverse colon anteroinferiorly.
- Diathermy is used to separate the greater omentum from the anterior leaf of the transverse mesocolon.
- The splenocolic ligament is divided as close to the colon as feasible, avoiding undue traction on the spleen. The splenocolic ligament needs to be approached from both sides to facilitate ease of mobilization of the splenic flexure. Once the gastrocolic ligament has been completely transected, transection of the lateral peritoneal



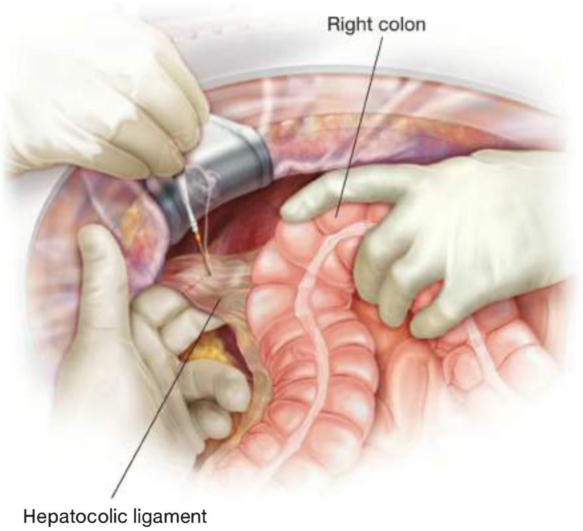
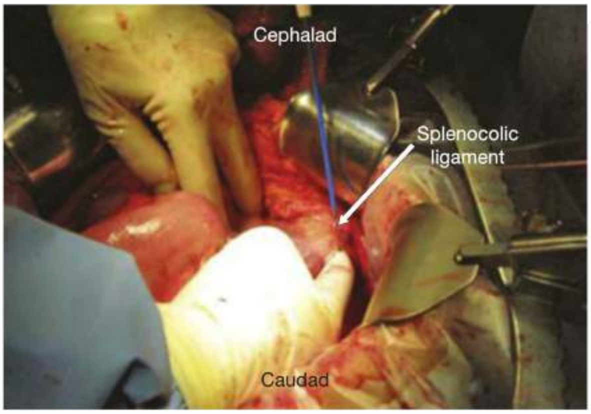


FIG 2 ● Hepatic flexure mobilization. Gentle traction on the hepatic flexure of the colon exposes the hepatocolic ligament, which is then transected with electrocautery.



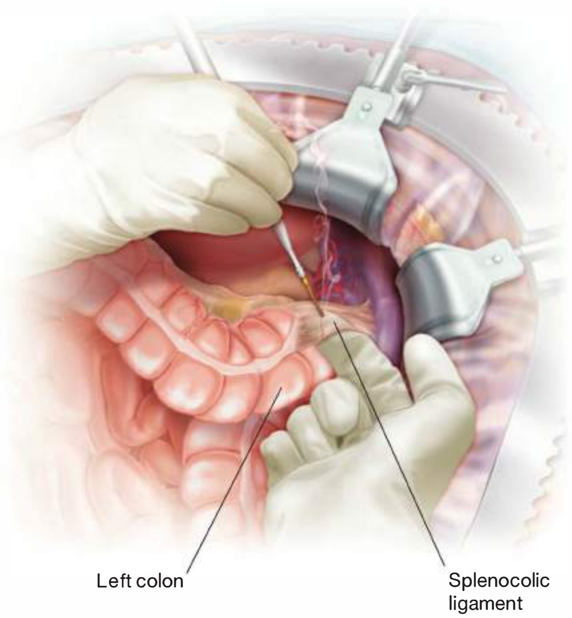
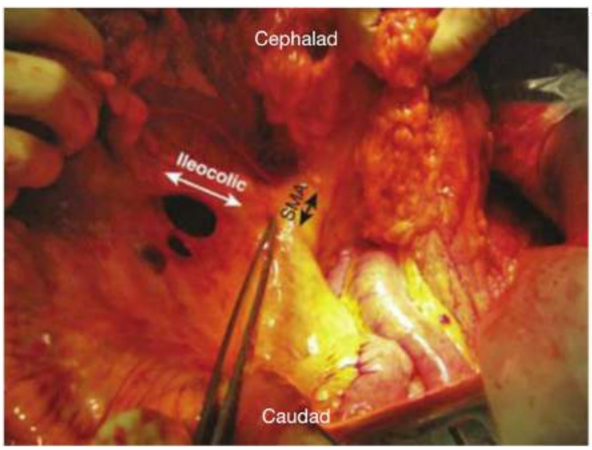


FIG 3 ● Splenic flexure mobilization. After medial and lateral mobilization of the splenic flexure attachments, the surgeon hooks his or her right index finger under the splenocolic ligament, providing good exposure and allowing for a safe transection of this ligament.

attachments allows for mobilization of the splenic flexure. At this point and from the right side of the table, the surgeon hooks the splenocolic ligament anteriorly with his or her right index finger, exposing the ligament adequately for the assistant to transect it using electrocautery (**FIG 3**).

PROXIMAL DIVISION

- The terminal ileum is mobilized by division of surrounding adhesions proceeding with the dissection toward the root of the mesentery.
- The ileocolic pedicle (and right colic pedicle, if present) is identified and clamped with heavy artery forceps by creating windows on either side with diathermy (**FIG 4**).
- The pedicle is divided between the artery forceps and ligated proximally and distally with absorbable braided, size 0 ties.



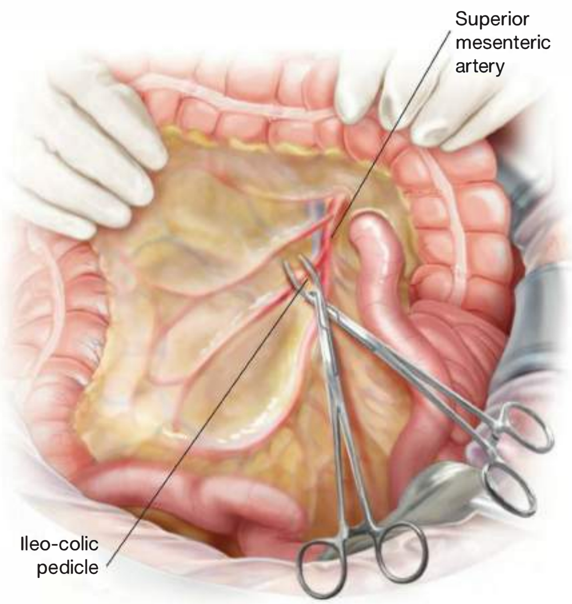
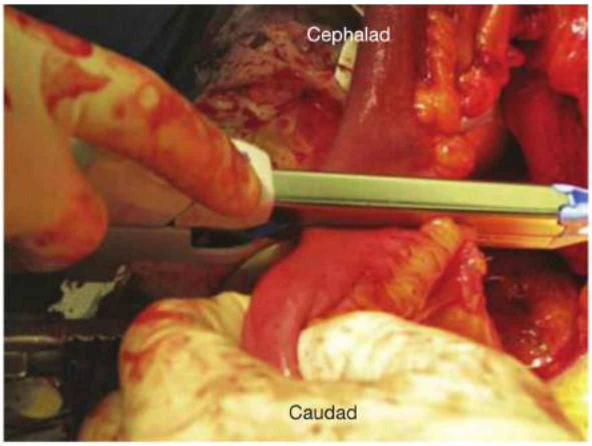


FIG 4 ● Ileocolic pedicle division. The ileocolic vessels are transected between clamps and will be subsequently ligated with heavy silk sutures. SMA, superior mesenteric artery.

- Alternatively, if the surgeon is certain of the absence of malignancy, then the mesenteric blood supply to the proximal segment can be taken close to the bowel wall.
- The terminal ileum is transected with a single firing of a linear stapler, such as gastrointestinal anastomosis (GIA) 60-3.5 stapler or GIA 60-4.8 if the ileum is thickened or inflamed (**FIG 5**).
- The ascending colon mesentery is divided, proceeding from proximal to distal until the middle colic pedicle is encountered.
- The middle colic pedicle is clamped with heavy artery forceps by creating windows on either side with diathermy.
- The pedicle is divided between the artery forceps and ligated proximally and distally with absorbable braided, size 0 ties.



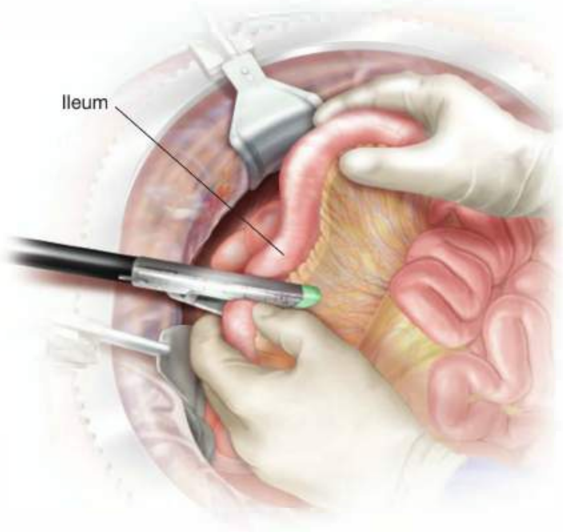
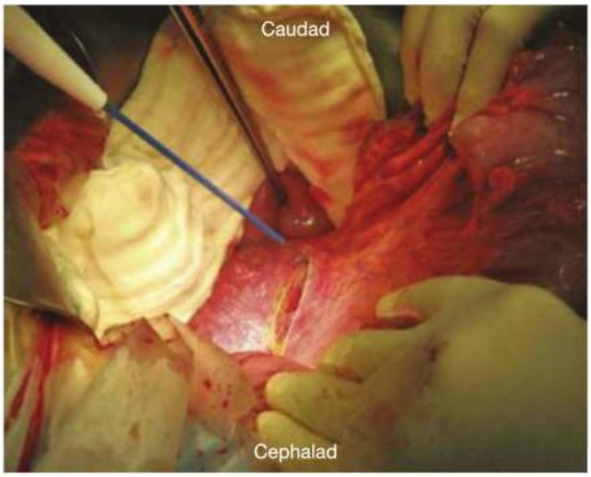


FIG 5 ● Proximal division. The terminal ileum is transected with a linear stapler.

DESCENDING COLON MOBILIZATION

- The descending colon is mobilized by medial traction and dissection along the left paracolic gutter using diathermy (**FIG 6**).
- Care is taken to identify, and avoid damage to, the left gonadal vessels and left ureter (**FIG 7**).
- Dissection is stopped at the rectosigmoid junction.



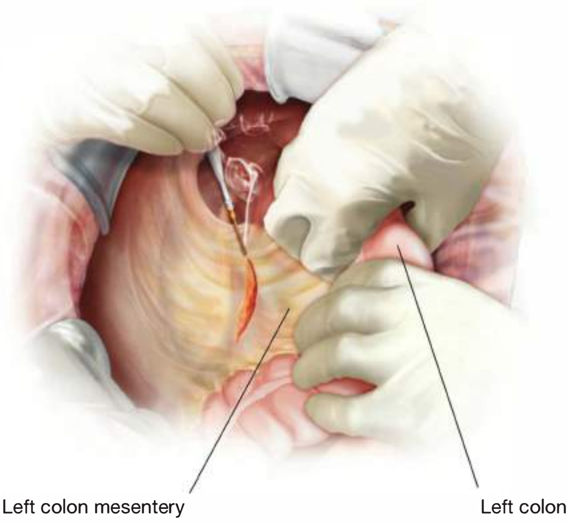


FIG 6 ● Descending colon mobilization. With the descending colon retracted medially, the lateral peritoneal attachments are transected with electrocautery along the left paracolic gutter.

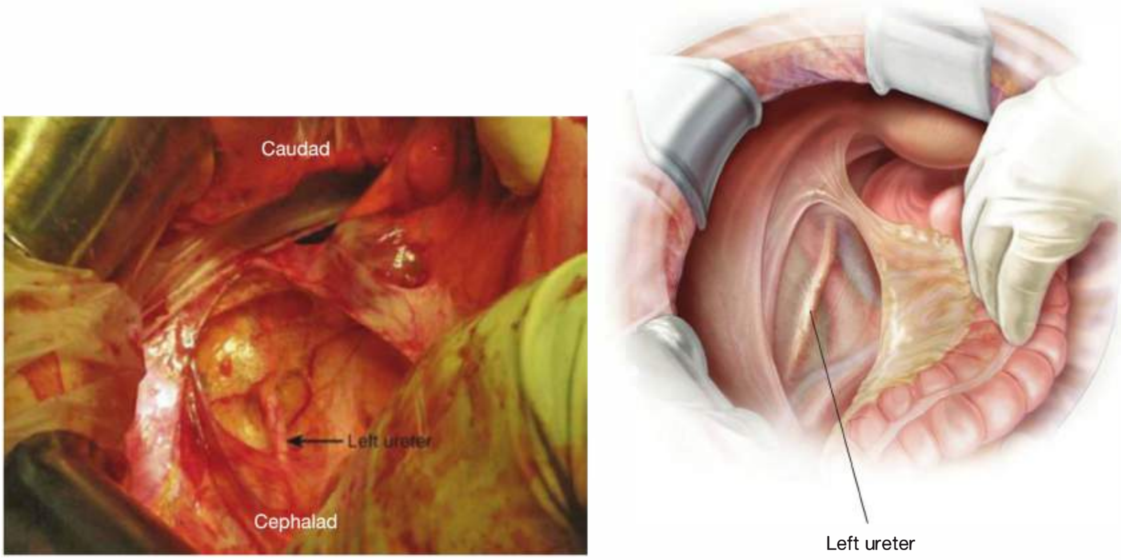


FIG 7 ● Identification of left ureter. After full mobilization of the descending colon, the left ureter is exposed in the retroperitoneum. The surgeon is retracting the descending colon medially.

DISTAL DIVISION

- The inferior mesenteric pedicle is identified and clamped with heavy artery forceps by creating windows on either side with diathermy.
- The pedicle is divided between the artery forceps and ligated proximally and distally with absorbable braided, size 0 ties (**FIG 8**).
- Alternatively, if the surgeon is certain of the absence of malignancy, then the mesenteric blood supply to the distal segment can be taken close to the bowel wall.
- The rectosigmoid junction is then divided with a linear stapler (such as a thoracoabdominal [TA] 60-4.8 stapler; **FIG 9**).
- The specimen is removed and sent to the laboratory in formalin.

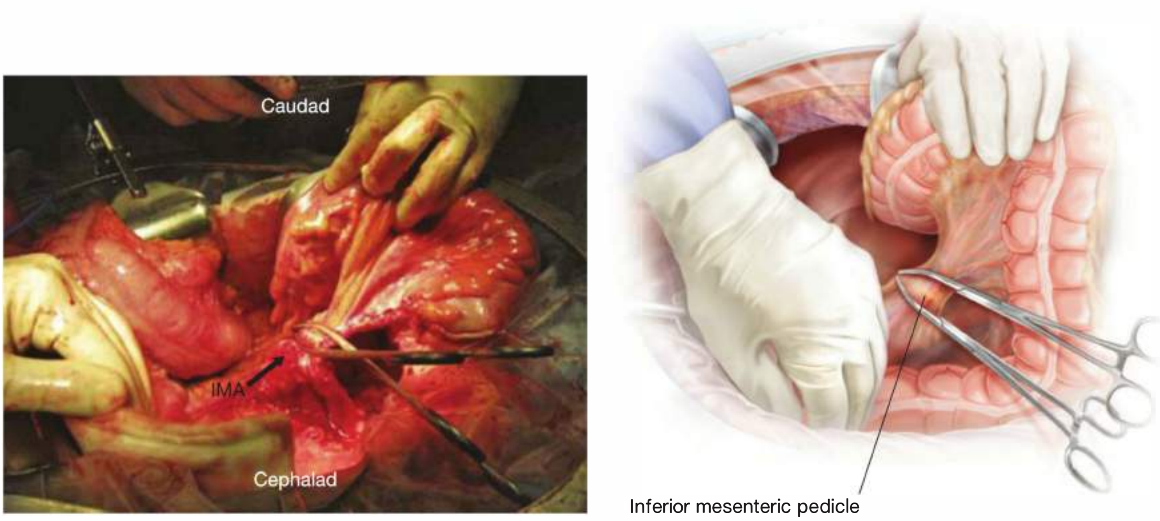
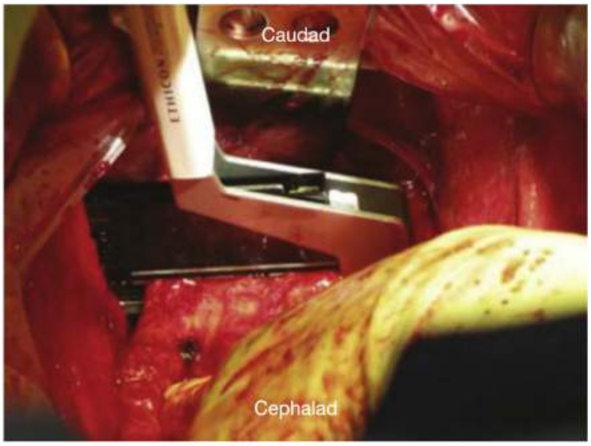


FIG 8 ● Inferior mesenteric artery (IMA) division. The IMA is transected between clamps and will subsequently be ligated with heavy silk sutures.



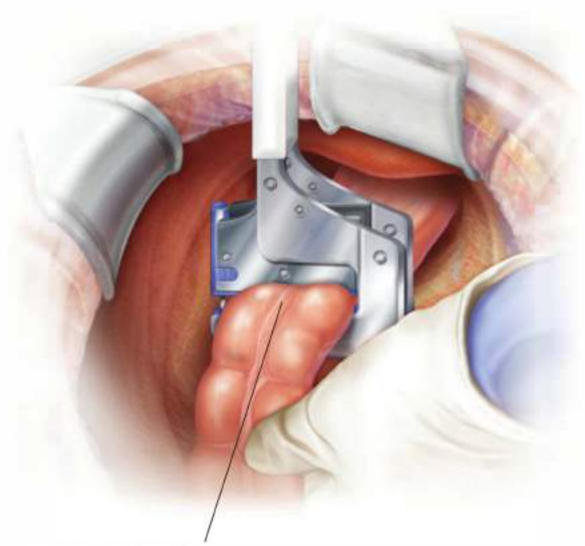
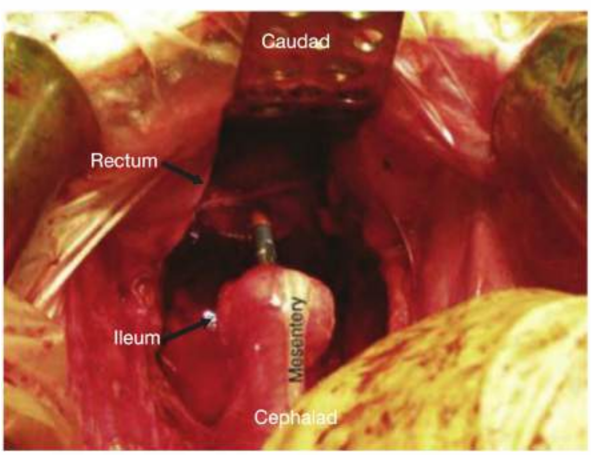


FIG 9 ● Distal division. Distal transection, at the level of the rectosigmoid junction, is performed with a linear TA stapler device.

ILEORECTAL ANASTOMOSIS

- The distal ileum is inspected to ensure adequate blood supply and length for a tension-free ileorectal anastomosis.
- An enterotomy is made with diathermy on the antemesenteric border of the distal ileum, 2 cm proximal to the division staple line.
- The anvil of a circular stapler (e.g., end-to-end anastomosis [EEA] 4.8 stapler), the size of which can be established with anal sizers, is inserted into the enterotomy and secured with a purse-string suture (nonabsorbable, monofilament size 0).
- The circular stapler is inserted through the anus, and the trocar is pushed out through the rectum anterior to the staple line.
- The trocar and anvil are joined, ensuring that the small bowel mesentery is not twisted and the anastomosis is tension-free (**FIG 10**). The stapler is then fired, creating a side-to-end ileorectal anastomosis.
- An underwater air leak test is performed by pouring warm water into the pelvis and insufflating air from the below with a proctoscope.
- Consideration is given to a protecting, diverting loop ileostomy if the air leak test is positive, if the patient is malnourished or acutely unwell, or if there are any technical issues with the anastomosis. In more extreme cases, where an anastomosis is undesirable or not possible, an end ileostomy can be fashioned, leaving a closed rectal stump in the pelvis.



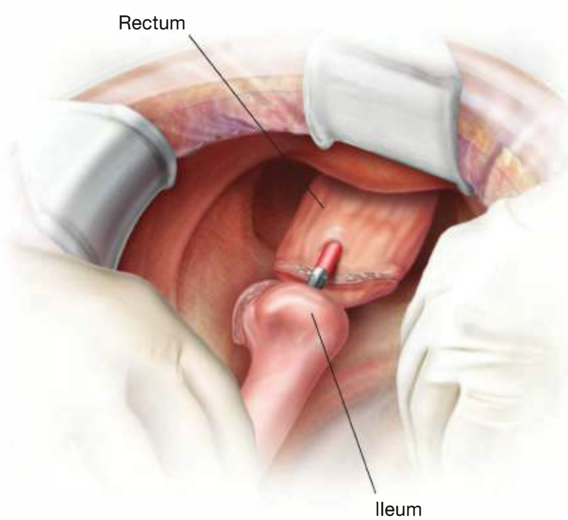


FIG 10 ● Ileorectal anastomosis.

TECHNIQUES

CLOSURE

- Mass fascial closure is performed with size 1 absorbable, monofilament suture.
- The skin incision is closed with staples.
- No intraabdominal or rectal drains are used.

PEARLS AND PITFALLS

Bleeding from the spleen	■ Minimizing traction on the splenic flexure is critical to reducing the incidence of splenic tears. If the spleen is torn, hemostatic agents (such as cellulose sheets or fibrin powders) can be used in the first instance with a swab applying pressure for 5 min in an attempt to achieve hemostasis. Ultimately, however, if bleeding cannot be stopped, then a splenectomy may be required.
Difficult splenic flexure mobilization	■ It may be easier to mobilize the splenic flexure by standing between the patient's legs rather than on the patient's right side. Approaching the splenic flexure proximally and distally repeatedly until it is freed further helps the dissection.
Identification of the ureters	■ On both sides, the ureters are identified by direct visualization to avoid injury. In their normal anatomic position, they are located in front of the psoas muscle just lateral to the transverse spinous processes, and then they pass over the bifurcation of the common iliac arteries to lie anterior to the sacroiliac joints, turning underneath the vas deferens (uterine arteries in females) to enter the bladder. The right colic, ileocolic, and gonadal vessels cross the right ureter. The left colic, gonadal, and sigmoid vessels cross the left ureter. With local invasion or severe inflammation, the ureters can be in a nonanatomic location and be more difficult to identify, in which case, preemptive ureteric stents (with or without lighting) can help avoid injury.
Management of the rectal stump	■ In the event that an anastomosis cannot be performed and an end ileostomy and closed rectal stump are fashioned, it may be desirable to suture the rectal stump to the inferior aspect of the midline wound fascia. This is because if the rectal stump leaks, a mucous fistula (rather than frank intraperitoneal contamination) will be the result.

POSTOPERATIVE CARE

- ERAS perioperative care protocols is applied.[1,2]

COMPLICATIONS

- Anastomotic leak (4.4%)[6]
- Pelvic abscess
- Intraabdominal bleeding
- Adhesive small bowel obstruction (30 %)[7]
- Postoperative ileus
- Wound infection
- Cardiopulmonary complications
- Urinary tract infection
- Failure of treatment in IBD (17% to 26%)[6]
- Overall reduced quality of life compared to general population[8]

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Chapter 25

Total Abdominal Colectomy: Laparoscopic Technique

Matthew G. Mutch

DEFINITION

- Total abdominal colectomy (TAC) is the removal of the abdominal colon, which extends from the cecum to the top of the rectum. The upper rectum is an intraperitoneal structure and the top of the rectum can be identified as the point where the teniae coli splay out. After resection, an end ileostomy or ileorectal anastomosis can be created. The determination to perform an ileostomy versus an anastomosis is based on the diagnosis and indication for the resection.

PATIENT HISTORY AND PHYSICAL FINDINGS

- There are several indications for a laparoscopic TAC:
  - Ulcerative colitis or Crohn's colitis
    - Refractory to medical management
    - Complications
      - Acute colitis
      - Stricture
      - Perforation
      - Dysplasia
      - Neoplasm
  - Colon cancer
    - Synchronous cancers
    - Colon cancer in a patient younger than age 40 years
  - Familial adenomatous polyposis (FAP) with rectal sparing
  - Colonic inertia
- A thorough history and physical examination are necessary prior to surgery. Prior abdominal surgery is not an absolute contraindication for the laparoscopic approach.
- In colitis patients, the extent of medical management is dependent on previous regimens with immunomodulators and response to intravenous steroids. Typically, failure to respond after 7 days of intravenous steroids is considered failure of medical management.
- Patients with acute colitis can be safely approached laparoscopically. However, if they have peritonitis or are showing signs of hemodynamic instability, the laparoscopic approach should not be attempted.

IMAGING AND OTHER DIAGNOSTIC STUDIES

- Each indication for surgery has unique or specific evaluations that are necessary to determine the optimal treatment.
  - Acute colitis
    - Endoscopic examination of the colon is necessary to confirm the diagnosis.
    - For patients that are hospitalized for acute colitis, stool cultures to rule out *Clostridium difficile* and cytomegalovirus (CMV) infections are very helpful.
  - Colon cancer
    - Pathologic confirmation of adenocarcinoma is necessary.
    - Review of the colonoscopy report to confirm the number and locations of the lesions. Ideally, the lesion(s) are tattooed with a vital dye to mark the location. It is best to inject the ink distal to the most distal lesion and in at least three different locations around the circumference of the lumen.
    - Preoperative staging is completed with a computed tomography scan of the chest, abdomen, and pelvis and a serum carcinoembryonic antigen (CEA) level.
    - Patients younger than age 50 years and/or with a strong family history of colorectal cancer should be considered for genetic counseling.
  - FAP
    - Endoscopy and pathology: confirming the presence of more than 100 adenomatous polyps
    - Genetic testing confirming the diagnosis of FAP is desirable, but not all patients with endoscopic findings consistent with FAP will have an identifiable mutation.
    - If the patient is going to be considered for a rectal sparing procedure, the rectum needs to be examined and cleared of all polyps. If there are 10 or fewer polyps in the rectum that can be removed or destroyed, rectal sparing can be considered.
  - Colonic inertia
    - Normal bowel function ranges from three bowel movements a day to one bowel movement every 3 days. These patients give a long history of constipation that is no longer responsive to laxatives. When the patient gets to the point where his or her abdominal complaints and bowel function are not responsive to laxatives and their symptoms become intolerable, surgery management should be considered.
    - A total colon exam is necessary to rule out a mechanical cause of the patient's constipation.
    - A colonic transit study is necessary to confirm the diagnosis of colonic inertia. The patient ingests a capsule with 25 radiopaque markers and the patient is not allowed to use laxatives during examination period. Plain abdominal x-rays are obtained 3 and 5 days after ingestion. An abnormal exam is when five or more markers are retained in the colon after 5 days. The distribution of the markers is the diagnostic key: Markers scattered throughout the colon are consistent with colonic inertia, whereas accumulation of the markers in the rectum or distal sigmoid colon are suggestive of obstructed defecation.
    - Patients should also be evaluated with either a video defecography or dynamic magnetic resonance imaging (MRI) to evaluate for obstructive defecation. If a patient demonstrates evidence of obstructive defecation, they should undergo biofeedback prior to discussing surgery as a definitive treatment option.

SURGICAL MANAGEMENT

Preoperative Planning

- Depending on the operative plan, patients should be marked for a diverting or end ileostomy. The patient needs to be assessed in the supine, sitting, and standing positions. The stoma should rest on the apex of skin fold and be of adequate distance from bony prominences, skin creases, and the waistline of their pants. The stoma should be brought through the rectus muscle to minimize the risk of developing a parastomal hernia.
- The use of ureteral stents is left to the discretion of the surgeon.

Positioning

- A mechanical bed that is able to place the patient in the extremes of position is necessary.
- The patient is secured to the bed with either a beanbag, a nonslip pad, shoulder braces, or foam pads.
- The patient should be placed in the modified lithotomy position with Allen or Yellofin stirrups (**FIG 1**). This allows access between the legs to assist with mobilization of the left colon and to the perineum for the anastomosis.
- Both arms are tucked to the patient's side with the thumbs facing up. This allows the surgeon, assistant, and camera driver plenty of room to maneuver during the case.

FIG 1 ● Patient positioning. The patient is placed on a lithotomy position with the hips slightly flexed and the legs in Yellofin stirrups. The thighs are placed parallel to the ground to avoid interference with the surgeon's arms and instruments.

- A monitor should be placed off the patient's right shoulder during the mobilization of the right and transverse colon.
- A monitor should be placed off the patients left shoulder for the mobilization of the left colon and splenic flexure.

PORT PLACEMENT AND TEAM SETUP

- There are several options for port placement and they depend on whether a total laparoscopic surgery or hand-assisted laparoscopic surgery (HALS) is going to be used.
  - Straight laparoscopic approach
    - Camera port—The port is placed in the peri-umbilical area in equal distance between the xiphoid process and the pubic symphysis (**FIG 2A**). The camera should be placed at the apex of the pneumoperitoneum so the widest field of view can be obtained.
    - Working ports—There are two working ports on the right side and two ports on the left side. They should be centered on the camera port,

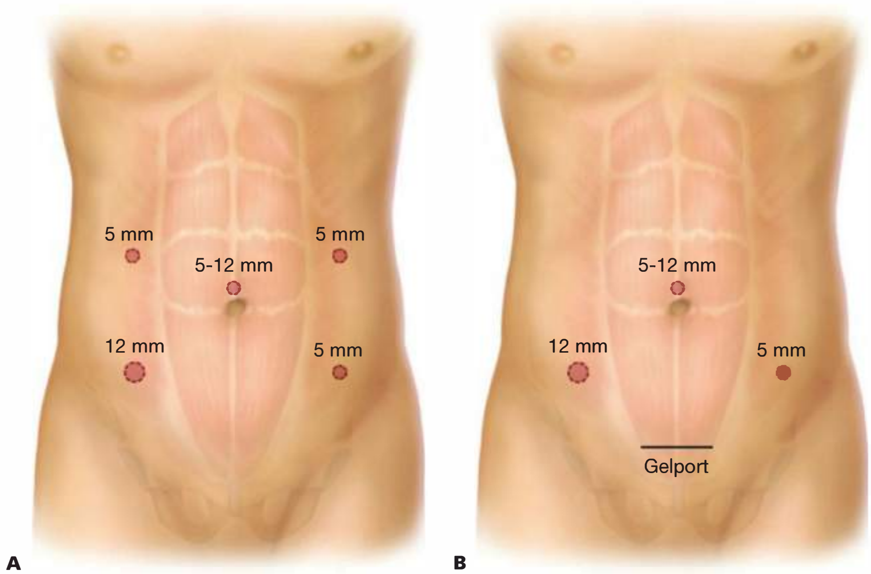

FIG 2 ● Port placement. **A.** Port placement for a conventional laparoscopic total colectomy. **B.** Port placement for a hand-assisted laparoscopic total colectomy.

lateral to the rectum muscle, and greater than a hand's width apart.

- HALS approach
  - Hand port—The hand port is placed in the suprapubic position via either a midline or Pfannenstiel incision (FIG 2B).
  - Camera port—The camera is placed in the supraumbilical position so that the port does not interfere with skirt of the hand port.
  - Working ports—There is one working port placed on the right and left sides. They are placed in equal distance between the hand port and the camera and lateral to the rectum muscle.
- Team setup
  - For the HALS approach to the right and transverse colon, the surgeon stands on the patient's left side with his or her left hand placed in the hand port and with his or her right hand on the energy source.
  - During the mobilization of the left colon, the surgeon stands on the patient's right side, right hand in the abdomen and left hand on the energy source (FIG 3). The camera operator stands to the head side of the surgeon.
  - The operative steps described in the chapter are the same whether the procedure is being performed straight laparoscopically or as HALS. For the purpose of this chapter, the HALS approach to the total colectomy operation will be described.

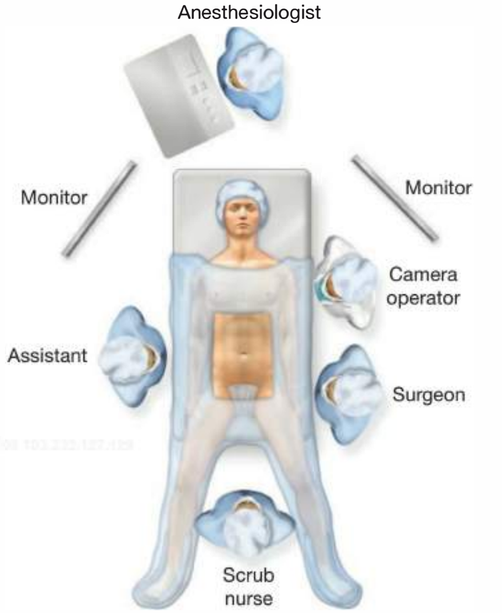

FIG 3 ● Operating team setup. For the HALS approach to the right and transverse colon, the surgeon stands on the patient's left side with his or her left hand placed in the hand port and with his or her right hand on the energy source. During the mobilization of the left colon, the surgeon will stand on the patient's right side, right hand in the abdomen and left hand on the energy source. The camera operator stands to the head side of the surgeon.

MOBILIZATION OF THE RIGHT COLON

- Once the abdomen has been accessed and inspected, the patient is placed in steep Trendelenburg position to pack the small bowel in the right upper quadrant (RUQ). The posterior approach will be described for the mobilization of the right colon. The specific steps of operation are the same for medial to lateral, lateral to medial, and superior to inferior, but the order of the steps is different depending on the approach.
- The goals of the operation are to access the retroperitoneal plane, identify and sweep the duodenum out of the way, mobilize the right colon mesentery, divide the lateral attachments and omentum, and ligate the vasculature.
- For the posterior approach, the small bowel is placed in the RUQ and the base of the ascending colon mesentery is exposed from the third portion of the duodenum to the cecum (FIG 4). The ileocolic vessels (ICV) are seen as they cross over the third portion of the duodenum. The patient is not tilted so that the small bowel will stay in the RUQ.
- The middle finger and thumb grasp the ICV off the retroperitoneum. The index finger then sweeps under the mesentery to expose the third portion of the duodenum (FIG 5). The peritoneum is then scored dorsal to the ICV from the duodenum all the way down to the cecum.

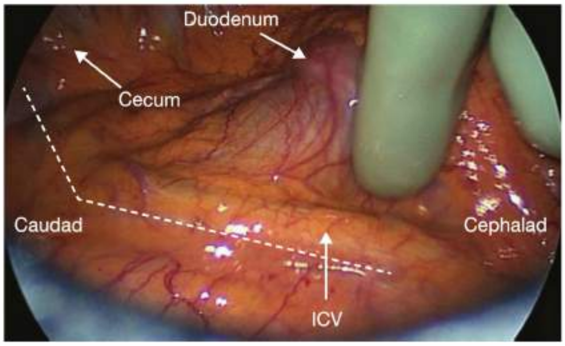

FIG 4 ● Root of the ascending colon mesentery: key anatomy. The base of the ascending colon mesentery is exposed from the third portion of the duodenum to the cecum. The ICV are seen as they cross over the third portion of the duodenum. The dissection plane will be initiated along the dorsal aspect of the ICV *(dotted line)*.

- Once the retroperitoneum is accessed, the duodenum is identified and swept posteriorly. After the retroperitoneum has been accessed, the hand is placed under

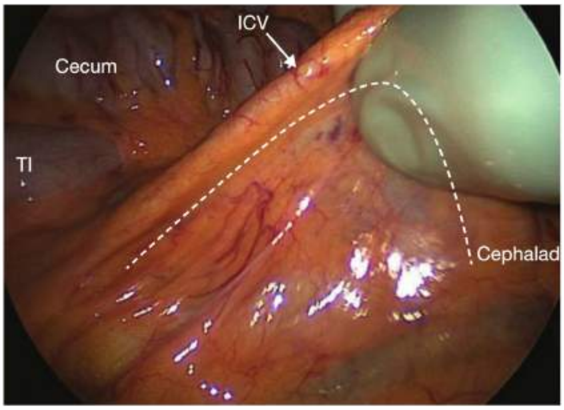

FIG 5 ● Initiation of the medial to lateral mobilization. With the surgeon holding the ICV anteriorly, the peritoneum is scored dorsal to the ICV from the duodenum all the way down to the cecum *(dotted line)*. TI, terminal ileum.

the mesentery, palm down, and the ascending colon mesentery is elevated off the retroperitoneum (**FIG 6**) through a medial to lateral dissection approach. The retroperitoneum is bluntly swept down with an energy device.

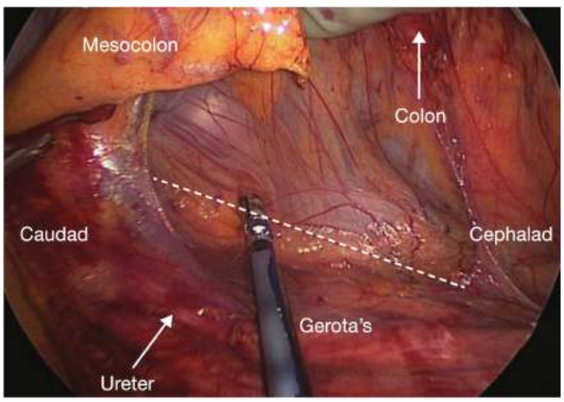

FIG 6 ● Medial to lateral mobilization of the ascending colon. With the surgeon's hand retracting the colon anteriorly, the ascending mesocolon is separated from the retroperitoneum (Gerota's fascia) by sweeping the retroperitoneal tissues dorsally with a 5-mm energy device. This dissection is carried along the transition between the two distinctive fat planes of the mesocolon and Gerota's fascia *(dotted line)*.

- This medial to lateral dissection is carried out beyond the colon from the midtransverse colon, out to the hepatic flexure, and down the ascending colon to the cecum. The more extensively the dissection can be carried laterally, the easier the lateral dissection will be.
- Tension is the key to facilitating an easy dissection as this is an avascular plane than can be effortlessly dissected with adequate tension. The motion should almost be a swimming-type motion in which tension is created, the tissue is swept down, tension is recreated, and the tissue is swept down, over and over.
- Now all that remains is the lateral attachments, which are transected with an energy device up along the right gutter (**FIG 7**). At this point, the patient is in airplane position with the right side up so the small bowel will fall to the left upper quadrant (LUQ). This exposes the lateral attachments of the right colon and the hepatic flexure.
- At this point, the hand may get in the way so it can be removed and instruments can be passed through the hand port. With a grasper in the right hand, the cecum is grasped and retracted medially, and the energy source in the left hand is passed through the hand port.
- Once the cecum is adequately mobilized, the hand is placed back into the abdomen. The left hand is placed under the right colon mesentery and lateral to the colon to expose the lateral attachments, which are divided under tension by the first assistant.
- The right colon and its mesentery are elevated to expose the retroperitoneum and dissect any remaining retroperitoneal attachments. This dissection is carried all the way up to the hepatic flexure.

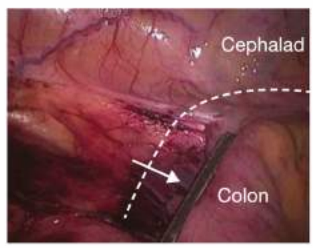

FIG 7 ● Lateral mobilization of the ascending colon. The white line of Toldt is transected along the right paracolic gutter *(dotted line)*. The medial to lateral dissection plane previously dissected is readily entered, greatly facilitating this step of the operation.

MOBILIZATION OF THE TRANSVERSE COLON

- The key to mobilizing the transverse colon is accessing the lesser sac. This is accomplished by either dividing the lesser omentum and taking the omentum with the specimen or preserving the omentum by separating it from the transverse colon and its mesentery.
- To resect the omentum, the lateral dissection of the right colon is continued up to the hepatic flexure. The colon is rolled medially and the lateral cut edge of the lesser omentum or hepatocolic attachments are elevated with a laparoscopic instrument. The hepatocolic ligament is then transected with an energy device (**FIG 8**). This plane between the omentum, mesentery, and duodenum/stomach is developed, ensuring the duodenum and

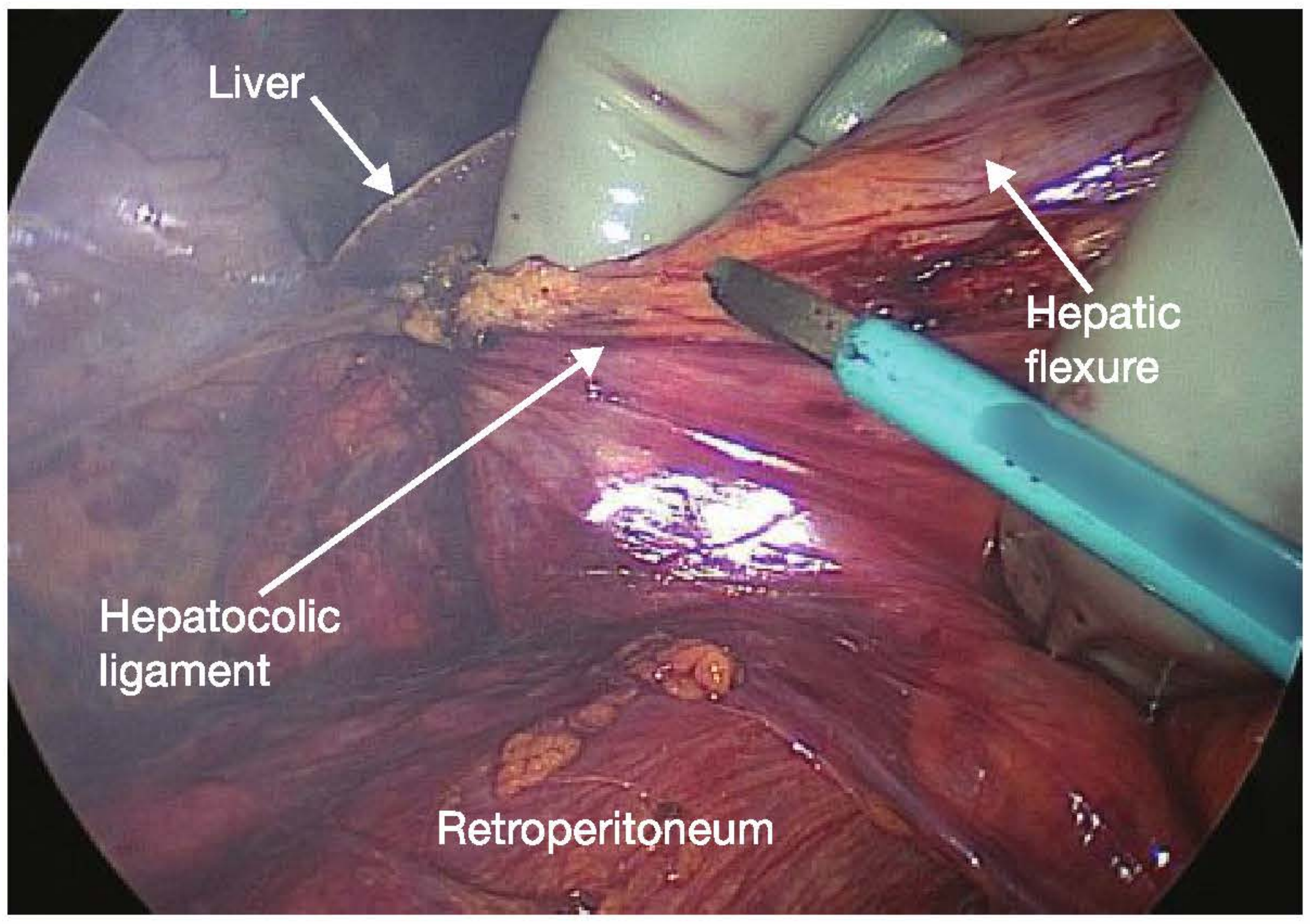

FIG 8 ● Mobilization of the hepatic flexure. The hepatocolic ligament is transected with an energy device.

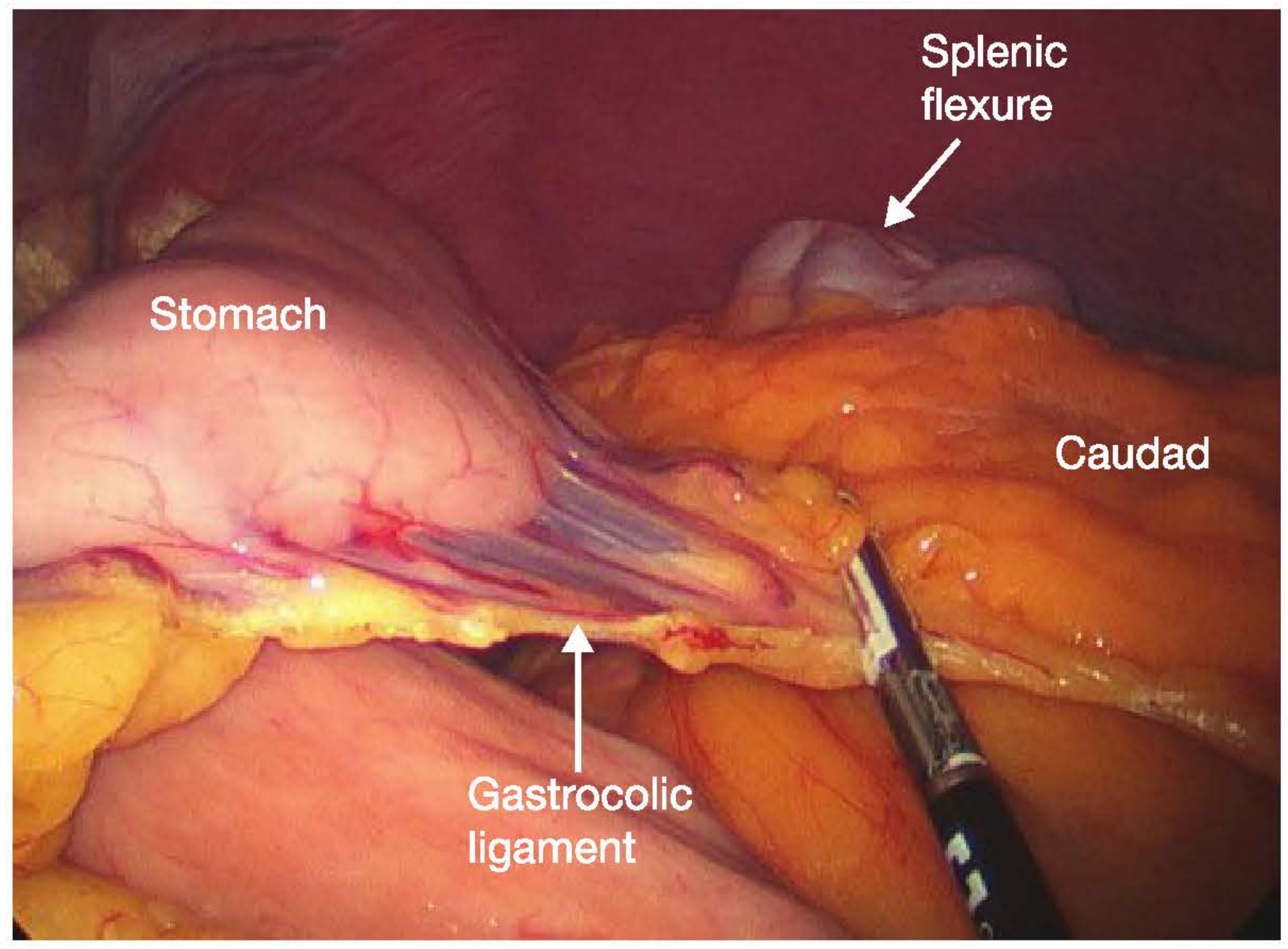

FIG 9 ● Mobilization of the transverse colon. The gastrocolic ligament is transected from right to left, toward the splenic flexure of the colon, with an energy device.

stomach are swept free; this step is greatly facilitated by the previous medial to lateral dissection step, which already separated the hepatic flexure from the duodenum and the head of the pancreas.

- The gastrocolic ligament is then divided from right to left with an energy device (**FIG 9**). This can be a very tedious dissection, as the entire plane tends to be fused, but with good exposure, tension, and patience, the lesser sac is entered. The lesser sac opens up toward the middle of stomach. Care must be taken to not dissect into the transverse colon mesentery. Once in the lesser sac, the dissection should be carried as far toward the splenic flexure as possible.
- There may be residual attachments of the mesentery to the antrum of the stomach that are taken down by elevating the stomach and pushing the mesentery down.
- With the lesser omentum divided and the lesser sac completely open, the ICV and right colic and middle colic vessels will be easily isolated when it comes time for them to be transected.

TRANSECTION OF THE MESENTERIC VASCULATURE

- The ICV pedicle is first isolated. The ileocolic pedicle, easily identified because it has been dissected off the retroperitoneum already, is lifted anteriorly. With the ICV pedicle adequately isolated, it can be transected with an energy device (**FIG 10**). Transection of the ICV as they cross the third portion of the duodenum ensures that the ICV are transected at their origin without compromising the superior mesenteric vessels, which are located medially at the root of the mesentery.

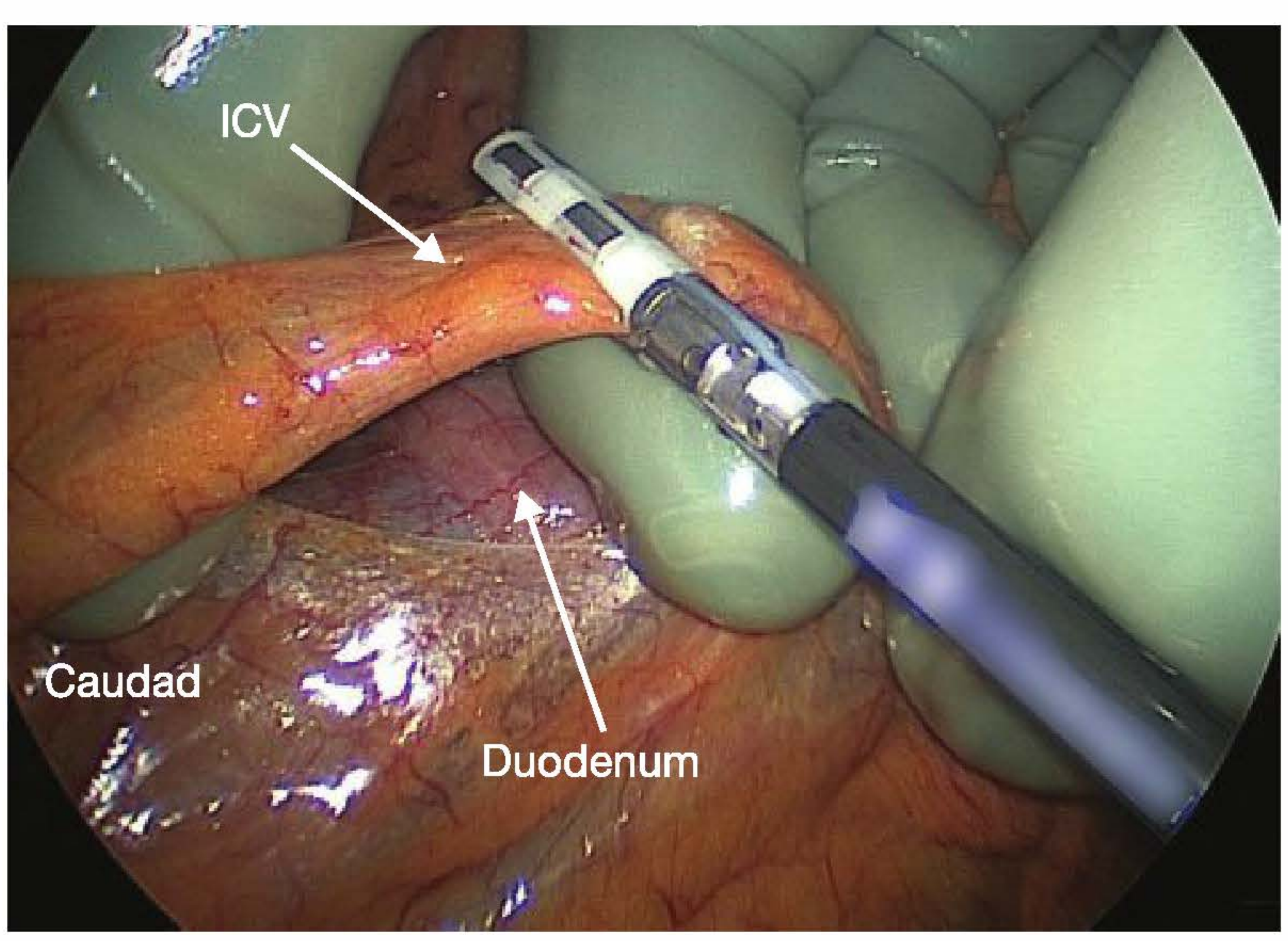

FIG 10 ● Transection of the ICV. The ICV are transected with the energy device at their origin as they cross over the third portion of the duodenum.

- Next, the transverse colon is elevated to expose the medial or inferior aspect of the mesentery (**FIG 11A**). The surgeon elevates the proximal transverse colon and passes his or her left hand through the mesenteric defect of the ileocolic pedicle, into the lesser sac, anterior to the pancreas, and encircles the middle colic vessels. The first assistant stands between the legs and via the right left quadrant (RLQ) port elevates the distal transverse colon and its mesentery. With the middle colic vessels elevated, the base of the mesentery and a bare area should be seen near the ligament of Treitz (**FIG 11B**).
- With the transverse colon mesentery elevated, the peritoneum is incised from the bare area on the left (by the ligament of Treitz) to the previously cut edge of the mesentery on the right (**FIG 11B**). This allows the individual middle colic vessels to be safely isolated and transected with an energy device. Because of the mobilization and separation of the omentum from the transverse colon mesentery, the vessels can be safely transected without fear of injury to the omentum or stomach.

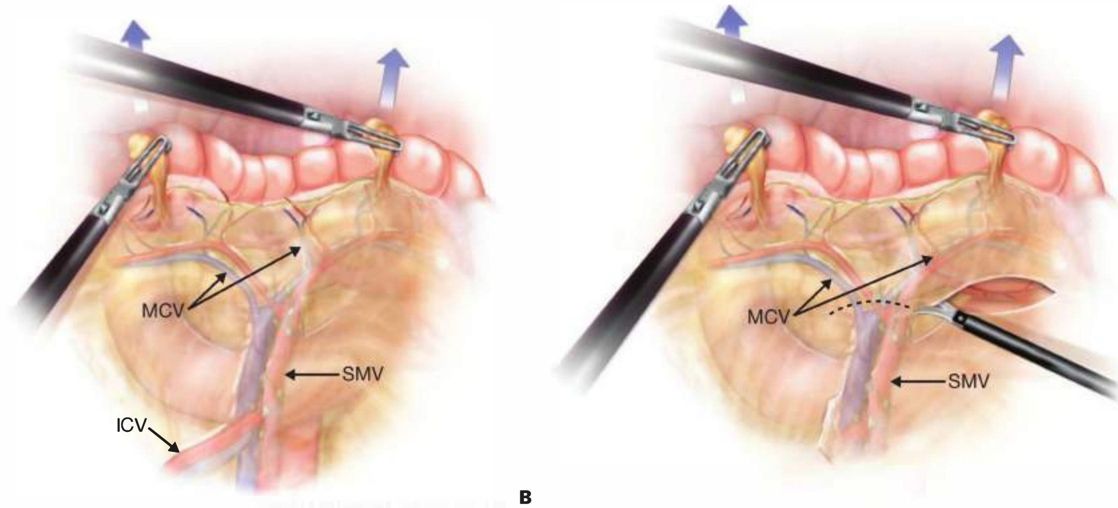

FIG 11 ● Transection of the middle colic vessels. **A.** With the transverse colon tented upward, the vascular anatomy at the root of the mesentery is identified. The middle colic vessels (MCV) are seen as they originate from the superior mesenteric vessels (SMV). **B.** Transection of the MCV. The root of the mesentery is incised from the bare area on the left (by the ligament of Treitz) to the previously cut edge of the mesentery on the right. This allows the individual middle colic vessels to be safely isolated and transected with an energy device. The *dash line* represents the line for incising the peritoneum over the middle colic vessels.

MOBILIZATION OF THE LEFT COLON

- The surgeon now moves to the patient's right side, places his or her right hand in the hand port, and with his or her left hand, he or she wields the energy device.

TRANSECTION OF THE INFERIOR MESENTERIC ARTERY

- The patient is placed in a steep Trendelenburg position and in airplane position with the left side up to use gravity to place the small bowel in the RUQ and the omentum in the upper abdomen to expose the transverse colon and splenic flexure. This helps to expose the inferior mesenteric artery (IMA) at its origin off the aorta and the inferior mesenteric vein (IMV) at the level of the ligament of Treitz.
- The surgeon's right hand is placed through the hand port and an energy source is placed through the RLQ working port.
- The retroperitoneum is accessed at the level of the sacral promontory. The superior hemorrhoidal artery (SHA) is grasped and elevated (**FIG 12A**), exposing the IMA and its terminal branches, the SHA, and left colic artery. A wide incision is made in the peritoneum dorsal to this artery (**FIG 12B**); the wider the incision, the more the artery can be more elevated to obtain better exposure. Because of the curve of the pelvis at this point, the sigmoid mesentery curves up and away from the visual field. Therefore, the retroperitoneal plane is higher than expected, so the more mobile the arterial pedicle is, the easier it is to visualize the correct plane.
- Identification of the left ureter is necessary before the IMA can be ligated (**FIG 13**). The following text is a four-step algorithm to identify the left ureter.
  - Mobilization of the superior rectal artery is as described earlier and the ureter is identified.
  - At the level of the IMV: The IMV is grasped and elevated. The peritoneum is incised dorsal to the IMV and the retroperitoneum is accessed. The retroperitoneum is flat in this area and is often more easily accessed. Once in the correct plane, the dissection is carried in a caudad fashion to meet up with the initial plane under the superior rectal artery.

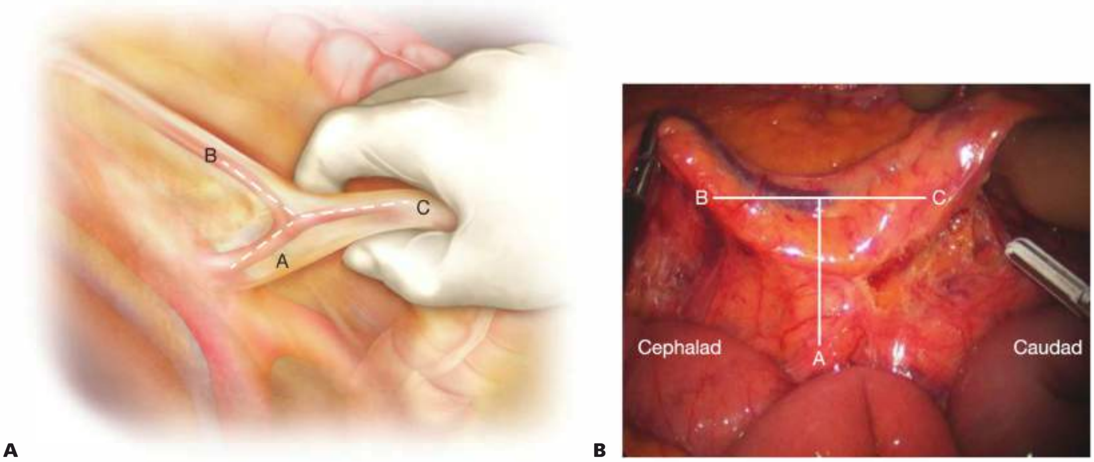

FIG 12 ● Identification of IMA and its branches. **A.** Grasping the SHA anteriorly helps identify the "letter T" formed between the IMA *(A)* and its left colic artery *(B)* and SHA *(C)* terminal branches. The IMA takeoff is just cephalad from the aortic bifurcation. The thumb and index finger are lifting the SHA off the groove located anterior to the right common iliac artery. **B.** Incision along the dorsal aspect of both the left colic vessels *(B)* and the SHA *(C)* allows for safe entry into the retroperitoneal space, helping isolate the IMA *(A)* at its origin.

   - If the ureter is still not identified, the sigmoid and left colon is mobilized in a lateral to medial fashion.
   - Finally, the top of the hand port can be removed and the left ureter can be located via an open fashion.
- After the left ureter is identified and swept into the retroperitoneum, the IMA can be isolated at its origin. The index finger elevates the superior rectal artery and the middle finger is used to sweep down the retroperitoneum along the course of the IMA. This motion continues until the bare area is exposed cephalad to the IMA and medial to the IMV.
- It is important to sweep down the retroperitoneal tissue in this area to help preserve the sympathetic plexus around the IMA. Once the IMA is safely isolated and the left ureter is clearly out of harm's way, the IMA can be transected at its origin from the aorta with a linear vascular stapler (**FIG 14**) or with an energy device.

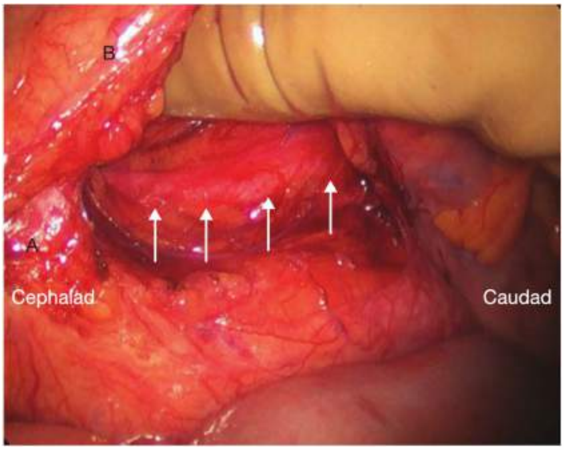

FIG 13 ● Identification of the left ureter. After the IMA *(A)* and SHA *(B)* have been lifted off the retroperitoneum, the left ureter *(arrows)* can be identified and preserved intact. Identification of the left ureter at this stage is critical in order to avoid injuring the ureter during the IMA transection.

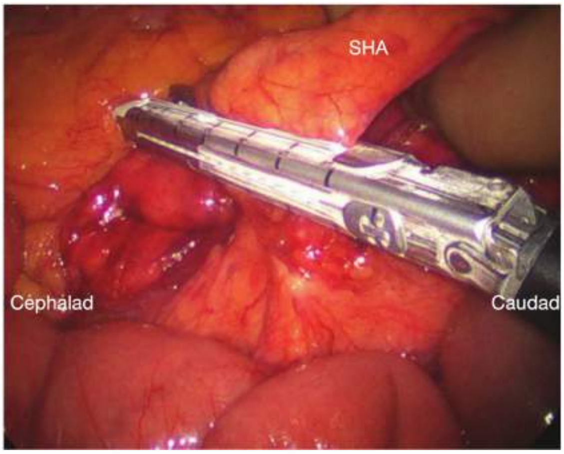

FIG 14 ● Transection of the IMA. With the left ureter safely dissected away into the retroperitoneum, the IMA is transected with a linear vascular stapler at its origin of the aorta. The surgeon's hand is holding the SHA anteriorly.

TRANSECTION OF THE INFERIOR MESENTERIC VEIN

- The IMV courses parallel to the left colic artery. The previous IMA dissection plane is carried cephalad with Endo Shears and 5-mm energy device (sweeping the retroperitoneal tissues dorsally) until the left colic artery separates from the IMV as it courses toward the splenic flexure at the level of the ligament of Treitz.
- Now that the IMV is elevated off the retroperitoneum, it is isolated at the inferior border of the pancreas and near the ligament of Treitz (**FIG 15**). It can be isolated with the same technique used for the IMA: The index finger and thumb elevate and create tension on the IMV, and the middle finger and/or dissecting instrument sweeps the retroperitoneum dorsally along the course of the vein.
- A bare area is then created near the inferior border of the pancreas that allows the IMV to be safely isolated.
- Once isolated, it can be safely transected with an energy device (**FIG 16**).

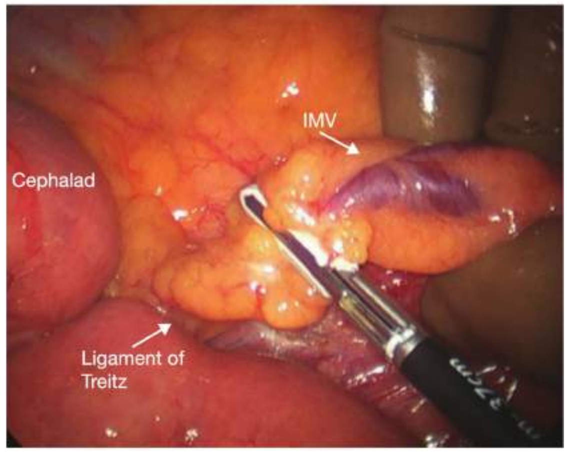

FIG 16 ● IMV transection. The IMV is transected at the level of the ligament of Treitz with an energy device.

Mobilization of the Left Colon

- The left colon mesentery is now dissected off the retroperitoneum using a medial to lateral dissection approach (**FIG 17**) all the way out to the lateral abdominal wall.
- The hand is placed palm down under the mesentery to elevate it as a fan-type retractor. The plane is dissected bluntly with an energy device from the sigmoid colon up to the splenic flexure. The further laterally and superiorly the dissection is carried, the easier the lateral dissection and splenic flexure mobilization will be later during the case. Care must be taken during mobilization near the inferior border of the pancreas, as it is very easy to carry the dissection deep to the pancreas.
- All that remains at this point are the lateral attachments. The hand is used to depress the sigmoid colon and lateral peritoneum is incised (**FIG 18**). It is not uncommon for the hand to get in that way at this point, so it may be necessary to pass the energy source through the surgeon's fingers or the hand may be taken out and an instrument can be passed through the hand port to begin the dissection.
- Once the medial plane of dissection is accessed, the hand can be passed in the opening and the lateral attachments are elevated and exposed. At this point, the surgeon uses a grasper for exposure and the first assistant uses the energy source through the left lower quadrant (LLQ) port to transect the rest of the lateral colon attachments, moving toward the splenic flexure.

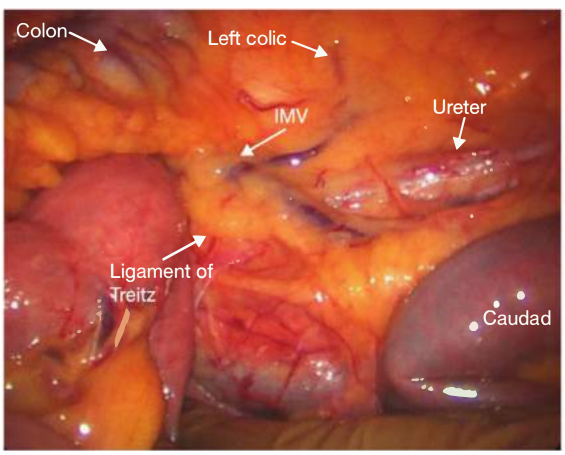

FIG 15 ● Identification of the IMV. The IMV can be identified at the root of the mesotransverse colon at the level of the ligament of Treitz. At this level, the IMV has separated from the left colic artery (which courses away from the IMV and toward the splenic flexure of the colon) and from the left ureter.

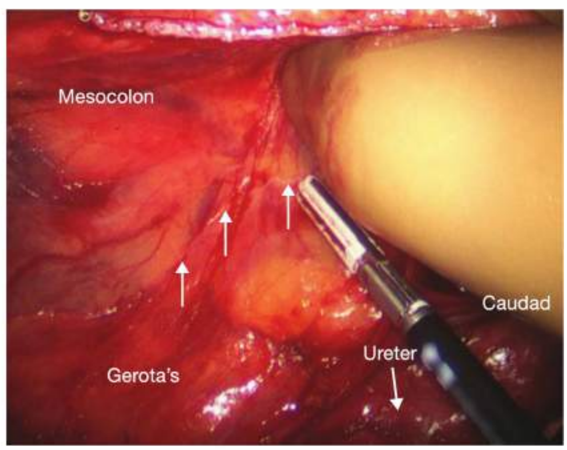

FIG 17 ● Medial to lateral dissection. With the surgeon holding the mesocolon anteriorly (notice the stapled transected IMA stump in between the surgeon's fingers), the retroperitoneal tissues are swept downward (dorsally) with an energy device. The dissection progresses along the transition of the two fat planes: mesocolon and Gerota's *(arrows)*.

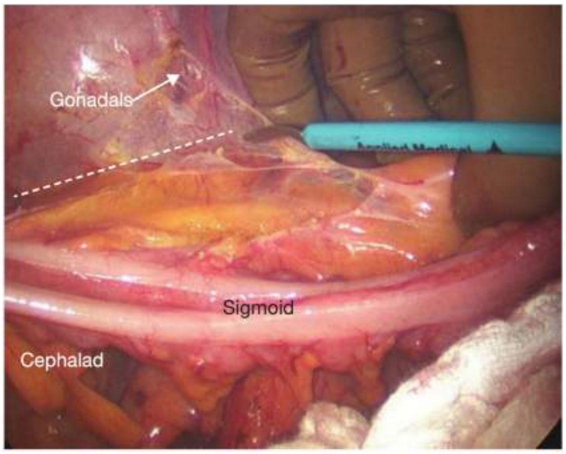

FIG 18 ● Lateral mobilization of the sigmoid and descending colon. The white line of Toldt *(dotted line)* is transected with an energy device. The medial to lateral dissection plane is readily entered, greatly facilitating the lateral mobilization of the descending colon.

MOBILIZATION OF THE SPLENIC FLEXURE

- The mobilization of the splenic flexure is greatly facilitated by the previous transection of the gastrocolic ligament and the previous medial to lateral mobilization of the descending colon.
- The splenic flexure is grasped laterally with the hand and medially with a grasper. The colon is put on stretched and pulled down and medial to identify the next level of attachment between the splenic flexure of the colon and the diaphragm and spleen. The splenodiaphragmatic and splenocolic ligaments are then transected with an energy device (**FIG 19**).
- All that remains are the posterior attachments to the inferior border of the pancreas. Division of these attachments to the midline allows for a full mobilization of the splenic flexure. This ensures adequate reach of the proximal colon for a tension-free anastomosis.

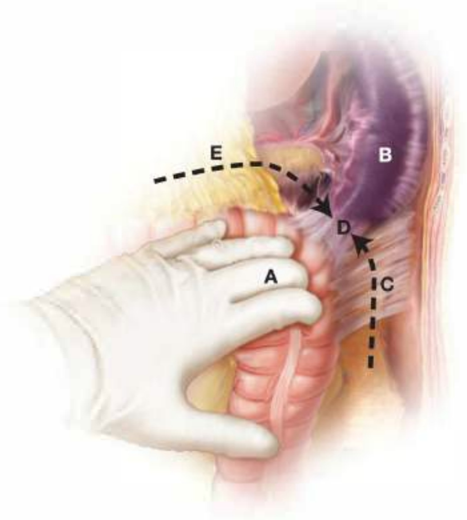

FIG 19 ● Mobilization of the splenic flexure. The surgeon retracts the splenic flexure of the colon *(A)* downward and medially, exposing the attachments of the splenic flexure to the spleen *(B)*. The phrenocolic *(C)* and splenocolic *(D)* ligaments are transected in an inferior to superior and lateral to medial direction, meeting the previously transected gastrocolic ligament *(E)* dissection plane around the splenic flexure.

RECTAL TRANSECTION

- Depending on the approach, the rectum can now be prepared for division.
  - HALS
    - Once the colon is completely mobilized and free, it can be extracted through the hand port and the rectum can be divided in an open fashion.
    - The colon is extracted by passing the small bowel underneath the colon and its mesentery. The surgeon stays on the patient's right side and the left colon is elevated while the proximal small bowel is fed under the colon and its mesentery. The patient is then placed in airplane position left side down to facilitate migration of the small bowel into the LUQ. Once the entire small bowel is passed under the colon, the cecum is grasped and brought out through the hand port. This allows the small bowel to be positioned in the left side of the abdomen, with the cut edge of the small bowel straight and facing to the patient's right side. It is in the correct orientation for an ileostomy or ileorectal anastomosis.

- Straight laparoscopic approach
  - The top of the rectum is identified by the splaying out of the teniae coli.
  - The mesorectum is scored at a right angle at the point of distal transection. A window is created between the posterior wall of the rectum and the mesorectum. The rectum is divided with an endoscopic stapler.
  - The mesorectum is then ligated with the energy source of choice.
  - The colon is then extracted via an LLQ or suprapubic extraction port.

ILEORECTAL ANASTOMOSIS/END ILEOSTOMY

- The site of the specimen extraction will depend on whether an anastomosis or an end ileostomy is going to be created.
- Ileorectal anastomosis
  - HALS
    - The colon can be extracted via the hand port and the rectum and terminal ileum can be divided in an open fashion.
    - Once the anvil has been placed in the terminal ileum, a side-to-end, or an end-to-end anastomosis (EEA), ileorectal anastomosis is created in an open fashion by direct visualization through the hand port or laparoscopically (**FIG 20**).
    - The entire cut edge of the small bowel mesentery must be visualized to face the patient's right side to ensure there is no twisting.

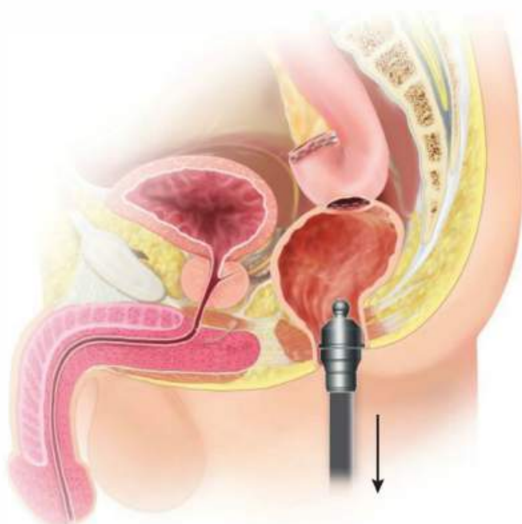

FIG 20 ● Stapled ileorectal anastomosis. A side-to-end EEA stapled ileorectal anastomosis is constructed.

    - The anastomosis is tested under water (air leak test) in standard fashion via the open hand port site.
  - Straight laparoscopic approach
    - A Pfannenstiel or an LLQ incision can be used as the extraction site. If the rectum has been divided, the extraction incision is made and the colon is extracted, starting with the distal transected end.
    - The terminal ileal mesentery is divided.
    - The terminal ileum is divided and a purse string is placed so an EEA can be created.
    - The ileum is dropped back into the abdomen and the extraction site is closed.
    - Laparoscopically, the stapling cartridge is passed transanally up to the top of the rectal stump.
    - The anvil is reassembled ensuring the small bowel mesentery is not twisted.
    - The anastomosis can be tested with either an air leak test or endoscopic visualization.
- End ileostomy
  - HALS approach
    - The colon is resected and the stoma is created via the open incision of the hand port as described elsewhere in this textbook.
  - Straight laparoscopic approach
    - The colon can be extracted through the ileostomy site, but care must be taken when this approach is used.
      - If the colon is dilated, full of stool, or significantly inflamed, avoid using the stoma site as an extraction site.
      - If the stoma is going to be permanent, realize that in order to get the specimen out, the stoma site may need to be made bigger than usual. This may increase the risk of the patient developing a parastomal hernia.
    - The colon can be extracted via an LLQ or a periumbilical position. Once the colon is extracted and the terminal ileum is divided, it can be dropped back into the abdomen and brought out of the stoma site.
- The ileostomy is then matured in a Brooke ileostomy fashion with absorbable sutures as described elsewhere in this textbook.

CLOSURE OF THE ABDOMEN

- All 10-mm ports should be closed. The 5-mm ports do not need to be closed.
- The hand port or extraction site can be closed with either interrupted or running stitch of no. 1 suture.

PEARLS AND PITFALLS

Options for right colon/mesocolon mobilization	■ Posterior approach: under the small bowel mesentery ■ Medial to lateral: through the right colon mesentery, caudad to the ileocolic pedicle ■ Lateral to medial: incise laterally at the cecum and roll it medially ■ Superior to inferior: enter the retroperitoneum by first dividing the lesser omentum along hepatocolic ligament
Right colon mobilization: posterior approach	■ If it is difficult to elevate the right colon mesentery and expose the fourth portion of the duodenum, start the dissection at the level of the cecum and work in an inferior to superior direction to mobilize the right colon mesentery.
Right colon mobilization: medial to lateral approach	■ The further the mobilization of the right colon can be carried out laterally, the easier the lateral and hepatic flexure mobilization will be.
Right colon mobilization: superior to inferior approach	■ When trying to enter the lesser sac, roll the right colon medially and elevate the lateral cut edge of the lesser omentum with the grasper. This will allow for direct visualization of this avascular plane, which can be easily dissected in a blunt fashion.
Transection of the middle colic vessels	■ With the lesser sac completely opened and the stomach free of the transverse colon mesentery, the middle colic vessels are free to be safely ligated. ■ When encircling the middle colic vessels, confirm that your hand is on top of the pancreas and ensure that the line of division of the middle colic vessels starts above the ileocolic pedicle, as this ensures that the superior mesenteric artery will not be injured.
Options for mobilization of the left colon/mesocolon	■ Medial approach: This can be done at the level of the sacral promontory or at the level of the IMV. ■ Lateral approach
Four ways of identifying the left ureter	■ A four-step technique was described earlier. Do not spend a lot of time with one approach if you are having difficulty, as the other steps described are necessary to complete the case. Therefore, alternating your approach to identifying the ureter also helps to complete the other steps of the procedure.
Mobilization of the splenic flexure	■ Completing the medial to lateral dissection makes it easier to mobilize the splenic flexure. ■ Be patient when entering the lesser sac. Incise the peritoneum fusing the omentum to the transverse colon and dissect the omentum off the backside of the mesentery one layer at a time.

POSTOPERATIVE CARE

- The patient can begin a liquid diet on the day of surgery. The diet can be advanced as tolerated. Solid food can be safely provided before the resumption of bowel function.
- A urinary catheter should be removed within 24 hours of surgery unless it is needed to assess patient volume status.
- Patients can begin ambulation as early as the day of surgery and by postoperative day 1; they are to be encouraged to spend more time out of bed than in bed.
- Venous thromboembolism (VTE) prophylaxis is important because of the magnitude of the operation. Low-molecular-weight heparin (LMWH), subcutaneous heparin, or pneumatic compression boots are all acceptable methods. There is data supporting the use of LMWH for 21 days postoperatively to decrease the risk of VTE.
- For patients with ileostomies, it is important to provide extensive stoma teaching. Points that need to be covered are diet, expected output, measuring of output, and pouching issues.

OUTCOMES

- Laparoscopic TAC for acute colitis is safe, with improved short-term outcomes and no increase in morbidity.
- For patients with hereditary nonpolyposis colorectal cancer (HNPCC), the risk of a developing a metachronous cancer is 25%. This high risk is also found in patients younger than age 40 years without a documented mutation in a mismatch repair gene. Therefore, treatment options include segmental resection with annual colonoscopy versus TAC with annual proctoscopy.
- Patients with a strong family history of colorectal cancer or documented HNPCC have a significantly lower risk of developing a metachronous colorectal cancer after a more extensive resection compared to those patients who underwent a segmental resection.
- HALS and straight laparoscopy have equivalent short-term outcomes for patients undergoing TAC. There was no difference in pain scores, length of stay, return of bowel function, and narcotic usage, but the operative time for the HALS approach was 57 minutes shorter.
- TAC with ileorectal anastomosis provides an excellent functional outcome and improved quality of life for patients with medically refractory constipation due to colonic inertia.

COMPLICATIONS

- Bleeding
- Anastomotic leak
- Rectal stump leak
- Parastomal hernia
- Pelvic abscess

- Wound infection
- Postoperative ileus
- VTE

SUGGESTED READINGS

1. Chung TP, Fleshman JW, Birnbaum EH, et al. Laparoscopic vs. open total abdominal colectomy for severe colitis: impact on recovery and subsequent completion restorative proctectomy. *Dis Colon Rectum*. 2009;52(1):4–10.
2. Marcello PW, Fleshman JW, Milsom JW, et al. Hand-assisted laparoscopic vs. laparoscopic colorectal surgery: a multicenter, prospective, randomized trial. *Dis Colon Rectum*. 2008;51(6):818–826.
3. Sample C, Gupta R, Bamehriz F, et al. Laparoscopic subtotal colectomy for colonic inertia. *J Gastrointest Surg*. 2005;9(6):803–808.
4. Fitz-Harris GP, Garcia-Aguilar J, Parker SC, et al. Quality of life after subtotal colectomy for slow-transit constipation: both quality and quantity count. *Dis Colon Rectum*. 2003;46(4):433–440.

Chapter **26**

Total Abdominal Colectomy: Hand-Assisted Technique

Daniel Albo

DEFINITION

- Total abdominal colectomy (TAC) is the removal of the abdominal colon, which extends from the cecum to the top of the rectum, following which the distal ileum is anastomosed to the rectum or an end ileostomy is created.
- Hand-assisted laparoscopic surgery (HALS) is a minimally invasive surgical approach that uses conventional laparoscopic-assisted (LA) surgery techniques with the addition of a hand-assist device (placed in the projected specimen extraction site), which allows for the introduction of a hand into the surgical field. HALS in colorectal surgery retains all of the same advantages of conventional LA surgery over open surgery, including less pain, faster recovery, lower incidence of wound complications, and reduction of cardiopulmonary complications, especially in the obese and in the elderly.
- Advantages of HALS over conventional LA colorectal surgery include the following:
  - Reintroduces tactile feedback into the field
  - Shorter learning curves; easier to teach
  - Shorter operative times and lower conversion to open rates
  - Higher usage rates of minimally invasive surgery

DIFFERENTIAL DIAGNOSIS

- Indications for HALS TAC are as follows:
  - Inflammatory bowel disease (IBD)
  - Severe acute colitis (various etiologies)
  - Polyposis syndromes, including familial adenomatous polyposis (FAP) and hereditary nonpolyposis colorectal cancer (HNPCC)
  - Slow-transit constipation
  - Malignancy

PATIENT HISTORY AND PHYSICAL FINDINGS

- Most patients with colon tumors generally present after an incidental finding during screening colonoscopy or with occult bleeding and iron deficiency anemia.
- A thorough history and physical examination should include the following:
  - Previous surgeries (does not preclude a laparoscopic approach)
  - Presence of obstructive symptoms
  - A detailed personal and family history of colorectal cancer, polyps, and/or other malignancies
  - In IBD, the extent of previous medical management, including use of immunomodulators and steroids and response to therapy, is important.
  - Routine abdominal examination, noting any scars

IMAGING AND OTHER DIAGNOSTIC STUDIES

- A colonoscopy with documentation of all polyps should be performed. Suspicious lesions should be tattooed to facilitate localization during surgery.
- A computed tomography (CT) of the chest, abdomen, and pelvis evaluates for potential metastases in cancer patients. In IBD, a CT of the abdomen/pelvis allows evaluation for possible strictures, abscesses, fistulae, and/or active inflammation.
- In IBD, CT or magnetic resonance (MR) enterography and push enteroscopy may help evaluate the extent of small bowel disease.
- Patients with severe constipation require a colonic transit study to confirm functional colonic disease.
- A preoperative carcinoembryonic antigen level should be obtained in cancer patients.

SURGICAL MANAGEMENT

Preoperative Preparation

- Patients in which an ileostomy is possible should undergo stoma marking by an enterostomal therapist.
- Clinical trials have shown no need for mechanical bowel preparation.
- Intravenous cefoxitin is administered within 1 hour of skin incision.
- Use hair clippers if needed and chlorhexidine gluconate skin preparation is used.
- A preoperative time-out and briefing is performed.
- Ultrasound-guided bilateral transversus abdominis plane (TAP) block reduces the need for postoperative narcotics.

Equipment and Instrumentation

- 5-mm camera with high-resolution monitors
- 5-mm and 12-mm clear ports with balloon tips—they hold ports in the abdomen and minimize their intraabdominal profile during surgery.
- Laparoscopic endoscopic scissors and a blunt-tip 5-mm energy device
- 60-mm linear reticulating laparoscopic staplers with vascular and tan cartridges
- We use the GelPort hand-assist device due to its versatility and ease of use. This device allows for the introduction/removal of the hand without losing pneumoperitoneum and allows for insertion of multiple ports through the hand-assist device if necessary. It also allows for the introduction of laparotomy pads into the field and is very useful in retracting bowel/omentum in obese patients.

Patient Positioning and Surgical Team Setup

- Place the patient on a modified lithotomy position (**FIG 1**), with the arms tucked and padded (to avoid nerve/tendon injuries). The patient is taped over a towel across the chest, without compromising chest expansion.

- Place the legs on Allen stirrup with the heels firmly planted on the stirrups to avoid pressure on the calves and the lateral peroneal nerves.
- Keep the thighs parallel to the ground to avoid conflict between the thighs and the surgeon's arms/instruments.
- The coccyx should be readily palpable off the edge of the table.
- The surgeon starts at the patient's right lower side, with the assistant to his or her left side and with the scrub nurse to his or her right or in between the patient's legs (**FIG 2**).
- Align the surgeon, ports, targets, and monitors in straight lines. Place monitors in front of the surgeon and at eye level to prevent lower neck stress injuries.
- Avoid unnecessary restrictions to potential team movement around the table. All energy device cables exit by the patient's upper left side. All laparoscopic (gas, light cord, and camera) elements exit by the patient's upper right side.
- The energy instruments are placed in a plastic pouch in front of the surgeon to avoid unnecessary instrument transfer during the operation (**FIG 2**).

FIG 1 • Patient positioning. The patient is on a modified lithotomy position, with the thighs parallel to the ground to avoid conflict with the surgeon's elbows/instruments. The arms are tucked. The patient is secured to the table by taping across the chest over a towel. All pressure points are padded to avoid neurovascular injuries.

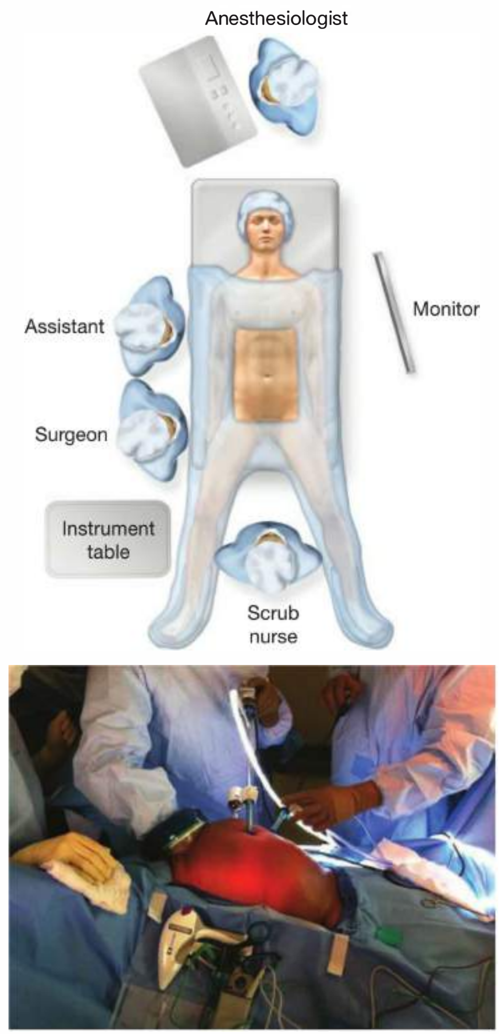

FIG 2 • Team setup. The surgeon stands to the patient's right side, with the assistant to his or her left, and the scrub nurse to his or her right or in between the patient's legs. The team, ports, targets, and monitors are aligned. Notice the energy devices placed in a pouch in front of the surgeon to minimize instrument transfer.

PORT PLACEMENT AND OPERATIVE FIELD SETUP

- Insert the GelPort through a 5- to 6-cm Pfannenstiel incision (**FIG 3**). This incision will be also used for specimen extraction. It provides a better cosmetic result and lowers the incidence of wound infections and incisional hernias. It also allows for more working space between the hand and the instruments. Alternatively, the GelPort can also be inserted in the epigastrium, if access to the middle colic vessels is of concern.
- Ports: Insert a 5-mm working port in the right upper quadrant (RUQ), a 12-mm working port in the right lower quadrant, and a 5-mm camera port above the umbilicus. These three ports are triangulated, with the camera port at the apex of the triangle. This setup avoids conflict between the instruments and the camera and prevents disorientation (avoids "working on a mirror"). A third 5-mm working port is inserted in the left anterior flank of the abdomen for the mobilization of the right colon; it can also be valuable for the mobilization of the splenic flexure in patients with deep left upper quadrants.

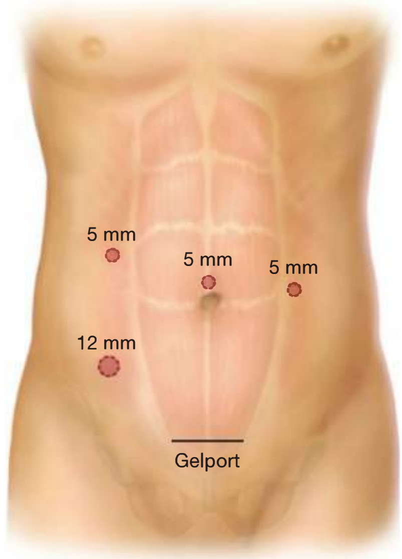

FIG 3 ● Port placement. The GelPort is placed through a 5- to 6-cm Pfannenstiel incision. Alternatively, the GelPort can be placed on an epigastric location. A 5-mm periumbilical camera port site is inserted. Working ports are inserted in the RUQ, right lower quadrant (RLQ), and left anterior flank of the abdomen. All ports are triangulated.

OPERATIVE STEPS

- Our HALS TAC operation is highly standardized and consists of 13 steps. After the initial point of entry, every step will expose the necessary planes of dissection for the following steps, ensuring that no truly virgin tissue planes are encountered anymore, thus greatly reducing the complexity of this operation. These steps, in order, are as follows:
  - Transection of the inferior mesenteric vein (IMV)
  - Transection of the inferior mesenteric artery (IMA)
  - Medial to lateral dissection of the descending mesocolon
  - Lateral mobilization of the sigmoid and descending colon
  - Mobilization of the splenic flexure and transverse colon
  - Mobilization of the hepatic flexure
  - Supramesocolic transection of the middle colic vessels
  - Transection of the ileocolic pedicle
  - Medial to lateral mobilization of the ascending colon
  - Lateral mobilization of the ascending colon
  - Intracorporeal distal transection
  - Extracorporeal mobilization and proximal transection
  - Intracorporeal ileorectal anastomosis

Step 1. Transection of the Inferior Mesenteric Vein

- This is the critical "point of entry" in this operation. We favor it over starting dissection at the IMA level due to the IMV's constancy in location, the ease of its visualization by the ligament of Treitz, and the absence of structures that can be injured around it (no iliac vessels or left ureter nearby). This will be the only time during the operation when a virgin tissue plane is entered. Every step will set up the following ones, opening the tissue planes sequentially.
- The patient is placed on a steep Trendelenburg position with the left side up. Using the right hand, move the small bowel into the RUQ and the transverse colon and omentum into the upper abdomen. If necessary, place a laparotomy pad to hold the bowel out of the field of view, especially in obese patients. This pad can also be used to dry up the field and to clean the scope tip intracorporeally. Make sure that the circulating nurse notes the laparotomy pad in the abdomen on the white board.
- Identify the critical anatomy: IMV, ligament of Treitz, and left colic artery (**FIG 4**).
- If there are attachments between the duodenum/root of mesentery and mesocolon, transect them with laparoscopic scissors. This will allow for adequate exposure of midline structures
- Pick up the IMV with the right hand. Dissect under (dorsal) the IMV and in front of Gerota's fascia with endoscopic scissors, starting at the level of the ligament of Treitz and proceeding with the dissection caudally toward the IMA. The assistant provides upward countertraction with a grasper.
- Transect the IMV (**FIG 5**) cephalad of left colic artery, which moves away from the IMV and toward the splenic flexure of the colon, with the 5-mm energy device.

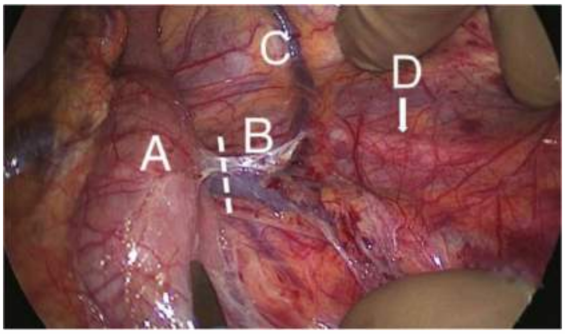

FIG 4 ● Step 1: transection of the IMV. Key anatomy. Ligament of Treitz *(A)*. IMV *(B)*. Left colic artery *(C)* as it separates from the IMV and goes toward the splenic flexure of the colon. The left ureter *(D)* is located far from the IMV projected transection *(dotted lines)*.

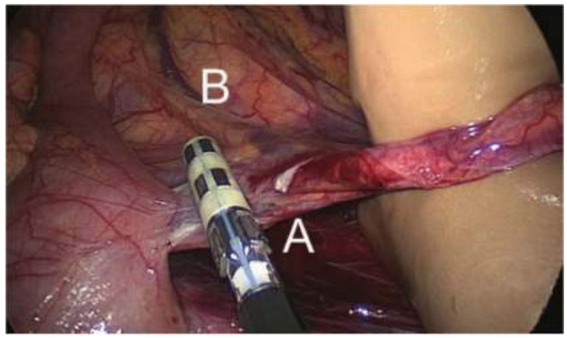

FIG 5 ● Step 1: transection of the IMV. The surgeon holds the IMV *(A)* anteriorly with his or her right hand and transects it cephalad of the left colic artery *(B)* with a 5-mm energy device.

Step 2. Transection of the Inferior Mesenteric Artery

- Identify the critical anatomy: the "letter T" formed between the IMA and its left colic and superior hemorrhoidal artery (SHA) terminal branches (**FIG 6**).
- Using the right hand, the aorta is identified and tracked down to the level of its bifurcation. The IMA will originate 1 to 2 cm proximal to this level.
- Holding the SHA up with the right hand, dissect the plane along the palpable groove between the SHA and the left iliac artery using laparoscopic scissors. A wide incision is made in the peritoneum dorsal to the SHA; the wider the incision, the easier the SHA can be elevated to obtain better exposure. After scoring the peritoneum under the SHA, use a 5-mm energy device to dissect by gently pushing the retroperitoneal tissues downward (dorsally) along the avascular plane located between the mesodescending colon, anteriorly, and the retroperitoneum, posteriorly. This avascular plane can be identified by the transition between the two distinctive fat planes of the mesocolon and Gerota's fascia.
- Preserve the sympathetic nerve trunk intact in the retroperitoneum. This avoids autonomic dysfunction postoperatively.
- Identify the left ureter (**FIG 7**), located in front of the left iliac artery and psoas muscle and medial to the gonadal vessels, before transecting anything. If you are directly on the psoas muscle, chances are that you left the left ureter attached to the dorsal surface of the mesocolon; bring it down into the retroperitoneum gently using blunt dissection with the energy device.
- If you cannot identify the ureter, try dissecting superior to inferior, starting from the IMV plane of dissection and moving caudally behind the IMA. If you still cannot find it, perform a lateral to medial mobilization of the sigmoid colon toward the midline. In this latter scenario, you will encounter the left gonadal vessels first, lateral to the left ureter.

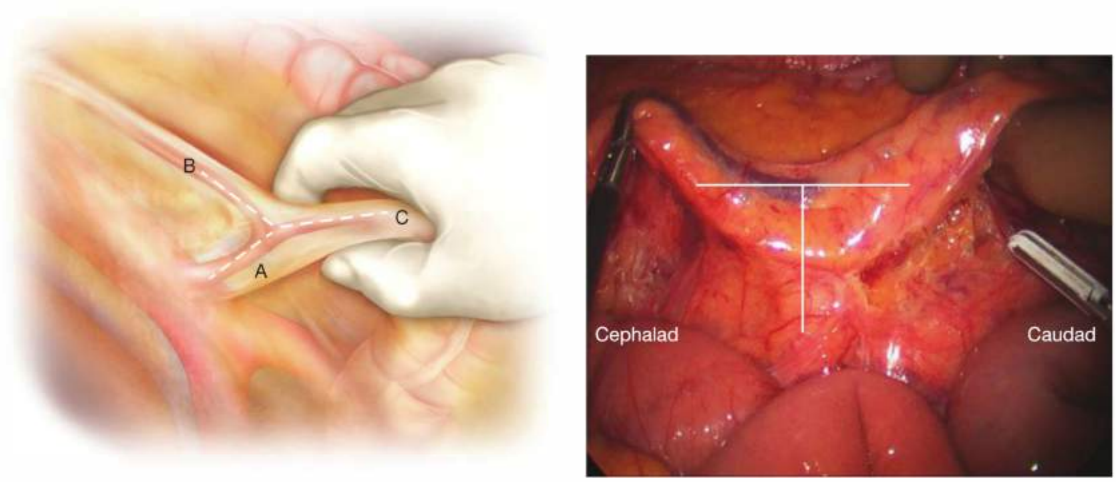

FIG 6 ● Step 2: critical anatomy. Identify the "letter T" formed between the IMA *(A)* and its left colic artery *(B)* and SHA *(C)* terminal branches. The IMA takeoff is just cephalad from the aortic bifurcation. The thumb and index finger are lifting the SHA off the groove located anterior to the right common iliac artery.

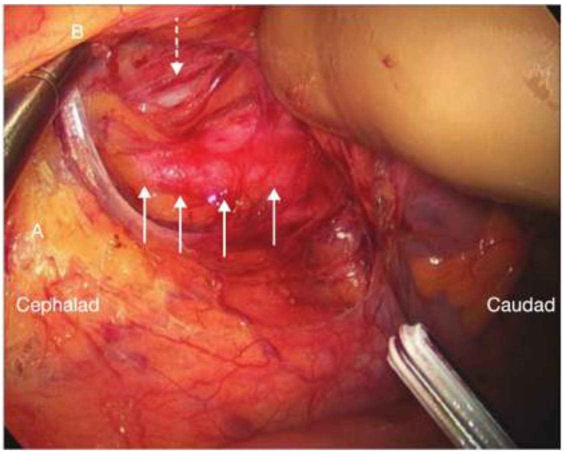

FIG 7 ● Step 2: identification of the left ureter and gonadal vessels. After the IMA *(A)* and SHA *(B)* have been lifted off the retroperitoneum, the left ureter *(solid arrows)* can be identified and preserved intact. Identification of the left ureter at this stage is critical in order to avoid injuring it during the IMA transection. Distal to the takeoff of the IMA, the left gonadal vessels can be identified lateral to the left ureter *(dotted arrow)*.

- Dissect with your thumb and index finger around and behind the IMA and again visualize the letter "T" formed between the IMA, the left colic artery, and the SHA (**FIG 8**).
- With the left ureter safely preserved in the retroperitoneum, transect the IMA at its origin with a vascular load stapler (**FIG 9**) or energy device. This ensures excellent lymph node harvest and allows great exposure for the following step.

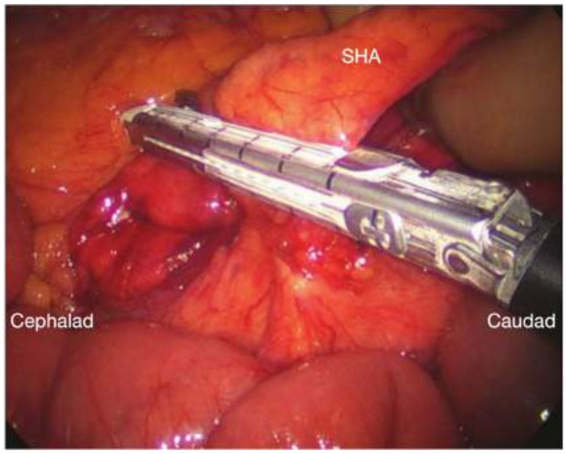

FIG 9 ● Step 2: transection of the IMA. With the left ureter safely dissected away into the retroperitoneum, the IMA is transected with a linear vascular stapler at its origin of the aorta. The surgeon's hand is holding the SHA anteriorly.

Step 3. Medial to Lateral Dissection of the Descending Mesocolon

- The surgeon's right hand and the assistant's grasper hold the descending mesocolon up, creating a working space between the mesocolon and the retroperitoneum (**FIG 10**). The plane between the mesocolon and Gerota's fascia, readily identified by the transition between the two fat planes, is dissected bluntly in a downward direction toward the retroperitoneum with the 5-mm energy device.
- Dissect laterally until you reach the lateral abdominal wall, caudally toward the pelvic inlet, and cephalad until

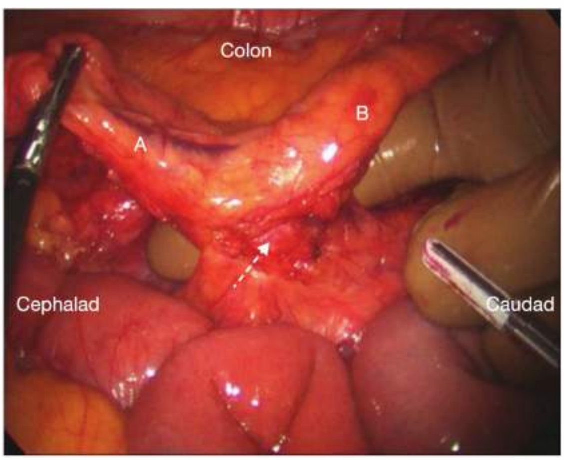

FIG 8 ● Step 2: circumferential dissection of the IMA. After the left ureter has been identified, the IMA *(arrow)* is circumferentially dissected at its origin of the aorta. Again, the "letter T" formed between the IMA and its terminal branches, the left colic artery *(A)*, and the SHA *(B)* can be clearly identified.

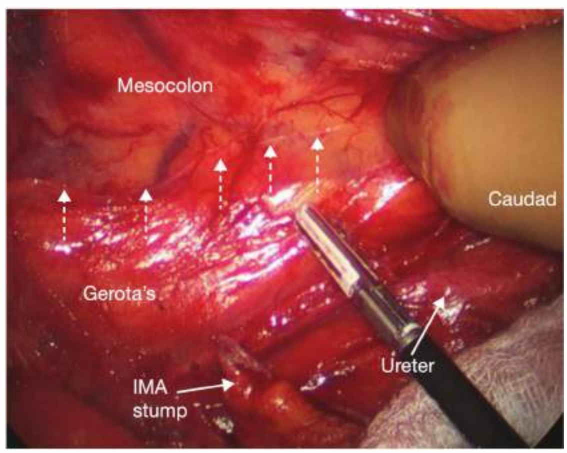

FIG 10 ● Step 3: medial to lateral mobilization of the mesocolon. With the surgeon holding the mesocolon anteriorly, the retroperitoneal tissues are swept downward (dorsally) with an energy device. The dissection progresses along the transition of the two fat planes *(dotted arrows)*: mesocolon (anteriorly) and Gerota's fascia (posteriorly). Notice the stapled IMA stump and left ureter in the retroperitoneum.

you separate the splenic flexure from the tail of the pancreas. Completing this step will greatly facilitate performance of steps 4 and 5.

Step 4. Lateral Mobilization of the Sigmoid and Descending Colon

- The surgeon pulls the sigmoid colon medially, exposing the lateral sigmoid colon attachments (**FIG 11A**). Transect the attachments between the sigmoid and the pelvic inlet with laparoscopic scissors in your left hand, staying medially, close to the sigmoid and mesosigmoid, to avoid injuring the ureter/gonadal vessels.
- Dissect caudally until reaching the entrance to the left pelvic inlet.
- Retract the descending colon medially with your hand to expose the white line of Toldt. The assistant holds the omentum/bowel out of way.
- Transect the white line of Toldt up to the splenic flexure using endoscopic scissors or energy device (**FIG 11B**). You should readily enter the medial to lateral dissection plane dissected during step 2, greatly facilitating this lateral mobilization of the descending colon.
- Dissect in a cephalad direction until reaching the splenic flexure of the colon.

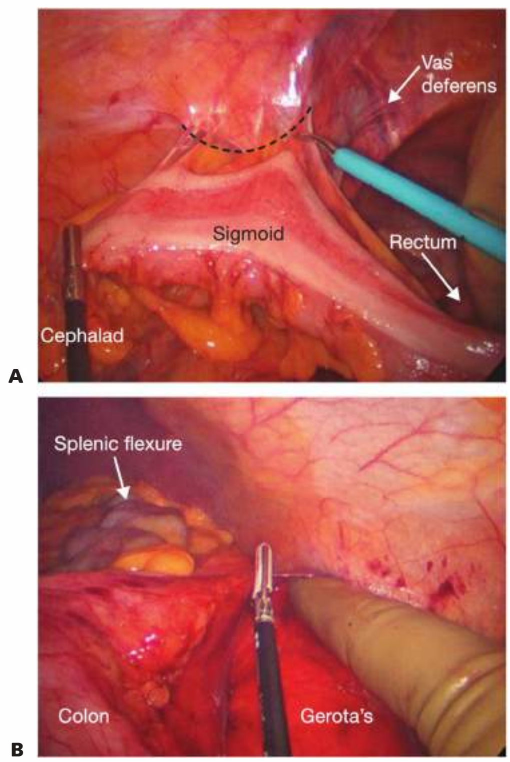

FIG 11 ● Step 4: lateral mobilization of the sigmoid and descending colon. **A.** The white line of Toldt *(dotted line)* is transected with an energy device. **B.** The medial to lateral dissection plane is readily entered, greatly facilitating the lateral mobilization of the descending colon.

- The left ureter and gonadal vessels, dissected in step 3, should be readily visible in the retroperitoneum.

Step 5. Mobilization of the Splenic Flexure and Transverse Colon

- The patient is now placed on a reverse Trendelenburg position with the left side up to allow the splenic flexure of the colon to come down into the surgical field.
- The mobilization of the splenic flexure is best accomplished by a combination medial to lateral and lateral to medial dissection approaches. The key to an easy splenic flexure mobilization is to have completed the separation of the splenic flexure off the retroperitoneum during the medial to lateral mobilization (step 3).
- The medial to lateral phase of the splenic flexure mobilization is started by entering the lesser sac at the midline. The transverse colon is retracted downward and the stomach is retracted superiorly, exposing the gastrocolic ligament. The gastrocolic ligament is then transected medially with an energy device until the lesser sac is entered.
- Transection of the gastrocolic ligament then proceeds along the transverse colon in a medial to lateral direction until the splenic flexure is reached (**FIG 12A**). Care must be taken to avoid inadvertent injury to the colon.
- At this point, a superior to inferior and lateral to medial dissection around the splenic flexure is performed (**FIG 12B**). The surgeon inserts his or her right hand behind the splenic flexure (possible due to the previous medial to lateral mobilization step) and hooks his or her index finger under the splenocolic ligament, gently pulling the splenic flexure down and exposing the splenocolic ligament fully, which is then transected with an energy device (**FIG 12C**).
- Attachments of the splenic flexure to the pancreas are transected and the splenic flexure is now fully mobilized to the midline.

Step 6. Mobilization of the Hepatic Flexure

- The patient is kept in a reverse Trendelenburg position but with the table now rotated with the right side up to allow the hepatic flexure to come down into the field.
- Standing at the left side of the table, the surgeon retracts the transverse colon downward with his or her left hand and completes the transection of the gastrocolic ligament until reaching the hepatic flexure of the colon using a 5-mm energy device.
- At this point, the hepatocolic ligament is readily visible. Slide your left index finger under it, hold it upward, and transect it with a 5-mm energy device (**FIG 13**).
- Proceeding on a superior to inferior dissection, and retracting the hepatic flexure downward with your hand, separate the hepatic flexure form the second portion of the duodenum and the head of the pancreas with the 5-mm energy device by gently teasing the retroperitoneal tissues down. Take care to avoid avulsing the gastrocolic venous trunk of Henle and its tributaries, which can lead to severe bleeding that is difficult to control.

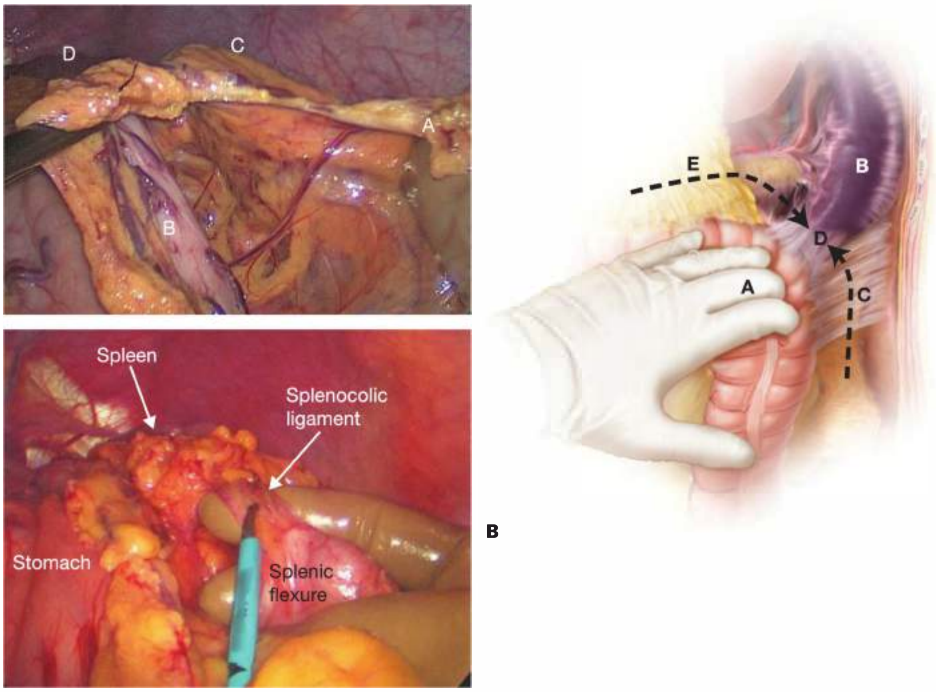

FIG 12 ● Step 5: mobilization of the splenic flexure. **A.** The lesser sac, between the transverse colon *(A)* and the stomach *(B)*, is entered. The gastrocolic ligament is transected with an energy device from right to left, toward the splenic flexure of the colon *(C)* until the spleen *(D)* is reached. **B.** The surgeon retracts the splenic flexure of the colon *(A)* downward and medially, exposing the attachments to the spleen *(B)*. The phrenocolic *(C)* and splenocolic *(D)* ligaments are transected in an inferior to superior and lateral to medial direction, meeting the previously transected gastrocolic ligament *(E)* dissection plane around the splenic flexure. **C.** With the surgeon "hugging" the splenic flexure with his or her right hand, the index finger is hooked under the splenocolic ligament, which is then transected with an energy device.

Step 7. Transection of the Middle Colic Vessels (Supramesocolic Approach)

- Dissection and transection of the middle colic vessels can be one of the most daunting maneuvers in colorectal surgery. Traditionally, these vessels are approached inframesocolically by dissecting the root of the mesotransverse colon at the intersection with the root of the mesentery, where the venous anatomy is extremely variable and complex. The superior mesenteric vein and its branches and the gastrocolic venous trunk of Henle and its branches surround the middle colic vessels. Venous tears tend to travel distally to the next major tributary. In terms of the SMV and the gastrocolic trunk of Henle, this next "tributary" is the portal vein confluence, which lies in a retroperitoneal plane for which you do not have control at this time.

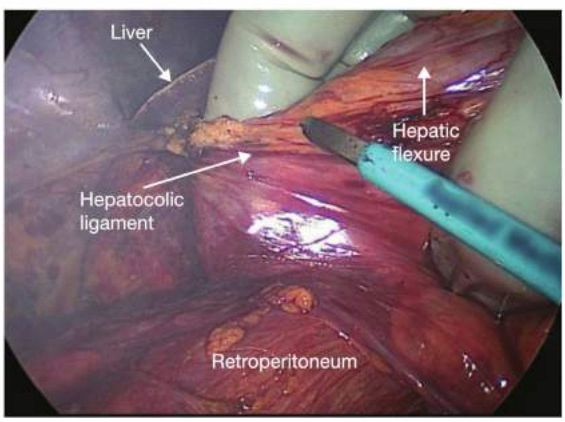

FIG 13 ● Step 6: mobilization of the hepatic flexure. Slide your left index finger under the hepatocolic ligament, hold it upward, and transect it with an energy device.

- In order to prevent potentially devastating bleeding complications during the dissection and transection of the middle colic vessels, we have developed a supramesocolic approach to these vessels. The hand-assisted technique greatly facilitates the performance of this technique and makes it very safe.
- The superior aspect of the transverse mesocolon is now readily visible, with the middle colic vessels easily palpable as they cross the third portion of the duodenum in the midtransverse colon (**FIG 14**). With the assistant pulling down on the transverse colon downward with a grasper, the surgeon "picks up" the middle colic vessels supramesocolically with his or her left thumb and index finger. Using his or her right hand, the surgeon now dissects under the middle colic vessels with the 5-mm

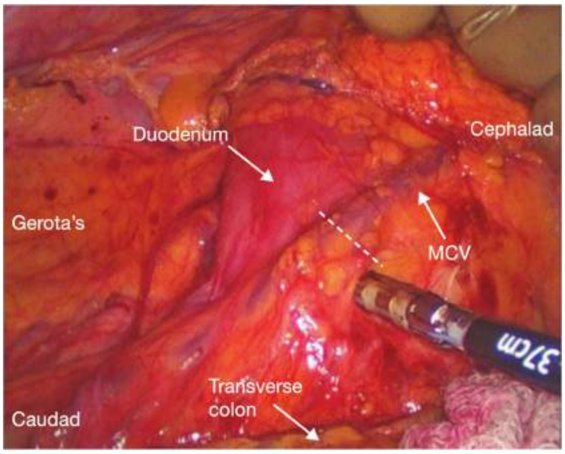

FIG 14 ● Step 7: supramesocolic transection of the middle colic vessels (MCV). With the transverse colon retracted caudally, the MCV are readily visualized at this point through a supramesocolic approach as they cross over the third portion of the duodenum. This allows for a safe dissection and high transection *(dotted line)* with a 5-mm energy device without risking injury to the SMV and gastrocolic venous trunk of Henle.

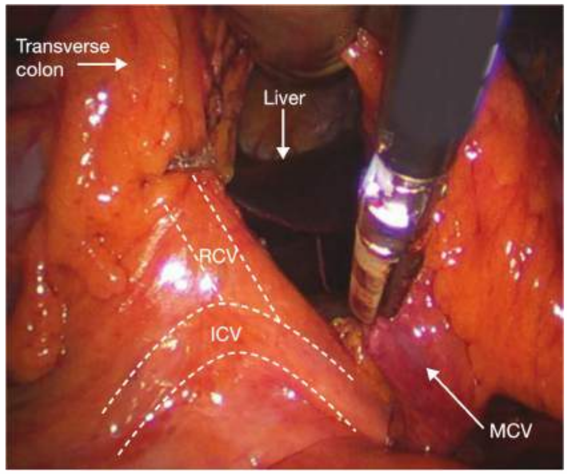

FIG 15 ● Vascular anatomy after transection of the middle colic vessels (MCV). While pulling upward on the transverse colon, the transected stump of the MCV is observed. The ICV, with its right colic vessels (RCV) branch, can be readily identified as they cross over the third portion of the duodenum.

energy device, completely encircling the middle colic vessels with the thumb and index finger. With great exposure and control, now the surgeon transects the middle colic vessels with the 5-mm energy device (FIG 14).

- During this approach, the transverse mesocolon separates the middle colic vessels from the SMV and the gastrocolic venous trunk of Henle from shielding them and thus greatly reducing the potential risk of serious venous injuries. It also allows for a very high transection of the middle colic vessels and therefore a great lymphatic nodal capture.
- After transection of the middle colic vessels, the ileocolic vessels (ICV) can now be readily identified as they cross over the third portion of the duodenum (FIG 15).

Step 8: Transection of the Ileocolic Pedicle

- Place the patient on a Trendelenburg position with the right side up to facilitate exposure to the ICV. Place the hepatic flexure back in the RUQ. Move the transverse colon and the omentum into the upper abdomen. Move the small bowel into the left lower quadrant (LLQ) to expose the duodenum and the root of the mesoascending colon. In obese patients, a laparotomy pad may greatly assist in retracting the bowel.
- Grab the ICV as they cross over the third portion of the duodenum with your thumb and index finger and pull them up anteriorly (FIG 16A).
- With the ICV on stretch, a parallel incision is made with hot scissors on the peritoneal layer underneath (dorsal) the pedicle (FIG 16B) extending to the root of the mesentery and the superior mesenteric vein, using hot scissors.
- A window is created under the ileocolic pedicle in the avascular plane that separates the pedicle from the retroperitoneum.
- The ileocolic pedicle is isolated and divided close to its origin off the superior mesenteric vessels using an energy device (FIG 16C).

Step 9: Medial to Lateral Mobilization of the Ascending Colon

- The retroperitoneum is now exposed by the surgeon pulling upward (anteriorly) on the distal transected ICV stump while the assistant retracts the mesoascending colon upward (anteriorly) with a grasper.
- Using blunt dissection with a 5-mm energy device, the ascending mesocolon is mobilized off the retroperitoneum by gently sweeping the duodenum and Gerota's fascia down (dorsally), using a medial to lateral dissection approach.
- As the dissection proceeds from medial to lateral, and to facilitate exposure, the surgeon's left hand should be pronated and placed underneath the mesocolon, giving upward traction for the retroperitoneal dissection (FIG 17).
- Mobilization of the right mesocolon is carried out laterally to the abdominal wall, superiorly to the hepatorenal recess and medially exposing the third portion of the duodenum and the head of the pancreas.
- At this point, critical structures including the right ureter, the right gonadal vein, and the duodenum are identified and preserved intact in the retroperitoneum.

A B C

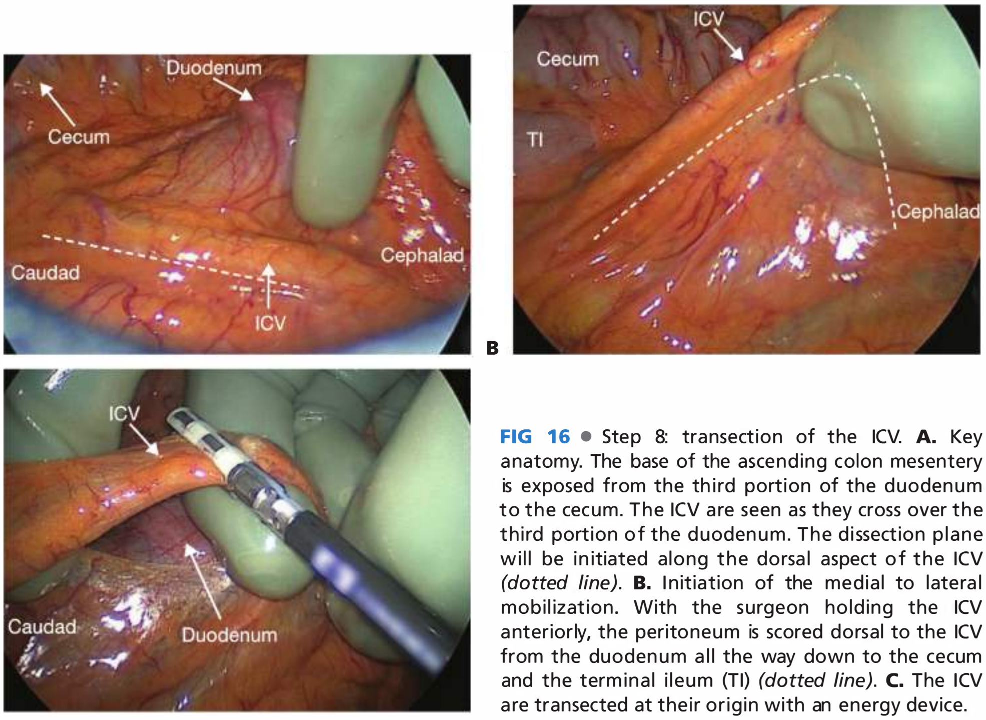

FIG 16 ● Step 8: transection of the ICV. **A.** Key anatomy. The base of the ascending colon mesentery is exposed from the third portion of the duodenum to the cecum. The ICV are seen as they cross over the third portion of the duodenum. The dissection plane will be initiated along the dorsal aspect of the ICV *(dotted line)*. **B.** Initiation of the medial to lateral mobilization. With the surgeon holding the ICV anteriorly, the peritoneum is scored dorsal to the ICV from the duodenum all the way down to the cecum and the terminal ileum (TI) *(dotted line)*. **C.** The ICV are transected at their origin with an energy device.

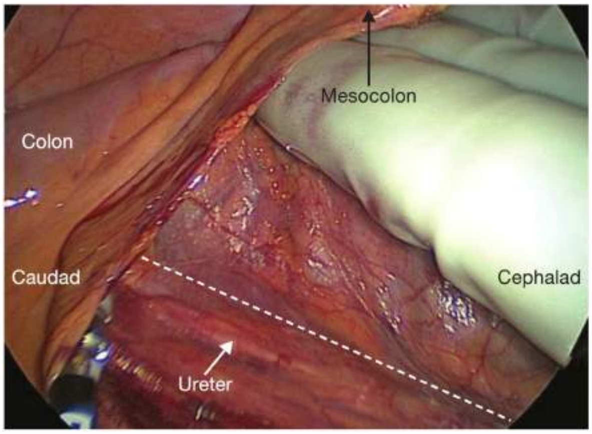

FIG 17 ● Step 9: medial to lateral mobilization of the ascending mesocolon. The surgeon, while retracting the ascending mesocolon upward (anterior) with the hand fully pronated and facing upward, separates the ascending mesocolon from the retroperitoneum by dissecting along the transition of the two distinct fat planes *(dotted line)*. The right ureter can be readily identified in the retroperitoneum and is preserved intact.

STEP 10: LATERAL MOBILIZATION OF THE ASCENDING COLON

- The base of cecum is grasped and retracted anteriorly toward the abdominal wall.
- With the ileum on stretch by the assistant, a peritoneal incision is created from the cecum medially along the root of the terminal ileum mesentery (**FIG 18A**). You should readily enter the retrocolic space previously created by the medial to lateral mobilization of the ascending mesocolon.
- The right ureter and the right gonadal vein are most easily identified at this phase of the operation coursing over the right iliac vessels and into the pelvis (**FIG 18B**). Lateral and anterior to the psoas muscle, the lateral femoral cutaneous nerve is also frequently identified.

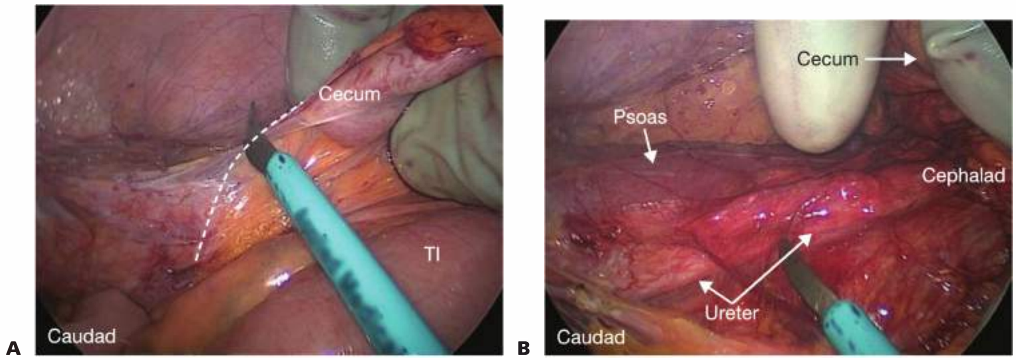

FIG 18 ● Step 10: lateral mobilization of the ascending colon. **A.** With the surgeon pulling on the cecum medially and superiorly, a peritoneal incision is created from the cecum medially along the root of the terminal ileal mesentery. **B.** After mobilization of the cecum, the right ureter is readily identified in the retroperitoneum. *TI*, terminal ileum

- The white line of Toldt is incised, dividing the only remaining attachments of the ascending colon if the medial to lateral dissection was carried out adequately during the previous step.
- The entire colon is now fully mobilized and ready for transection.

Step 11: Intracorporeal Distal Transection

- Dissect the rectosigmoid junction circumferentially. The rectosigmoid junction can be identified by the splaying of the teniae coli. Transect the upper mesorectum with the 5-mm energy device at the level of the projected distal bowel transection.
- While pulling on the sigmoid upward with the left hand, transect the bowel intracorporeally just distal to the rectosigmoid junction with a linear Endo GIA stapler device (**FIG 19**).

Step 12: Extracorporeal Mobilization and Proximal Transection

- The entire colon and the terminal ileum are delivered extracorporeally through the Pfannenstiel incision site with the Alexis wound protector in place to prevent infectious and/or oncologic soilage of the wound (**FIG 20**). There should be absolutely no tension during the extraction of the specimen.
- The terminal ileum is transected at a suitable site between Kocher clamps. The specimen is sent to the pathologist.

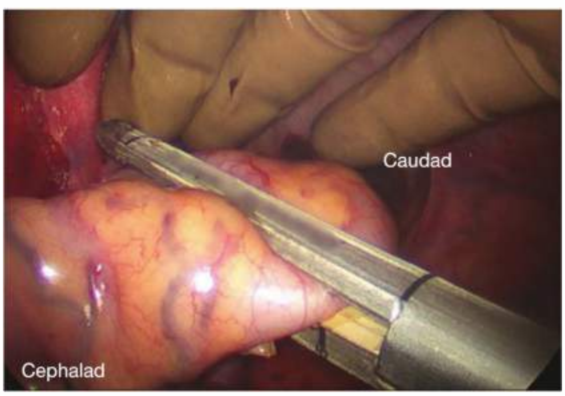

FIG 19 ● Step 11: intracorporeal distal transection. The specimen is transected with a linear stapler just distal to rectosigmoid junction, which can be identified by the splaying of the teniae coli.

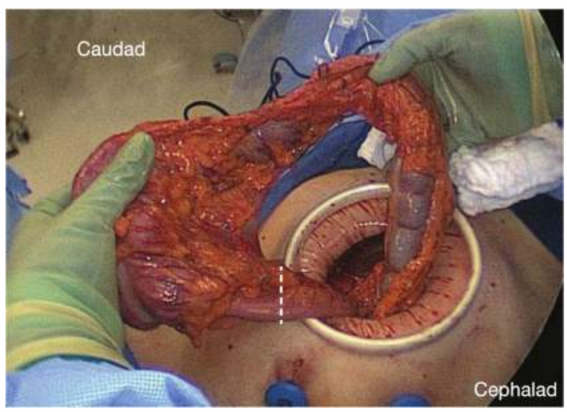

FIG 20 ● Step 12: extracorporeal mobilization and transection. The entire colon is extracted without any tension. The distal ileum will be transected along the *dotted line* between Kocher clamps.

STEP 13: INTRACORPOREAL ILEORECTAL ANASTOMOSIS

- At this point, the anvil of a 28-Fr end-to-end anastomosis (EEA) stapler device is placed through the open end of the terminal ileum and is exteriorized with a spear through the antimesenteric border approximately 5 cm from the open end of the ileum. The open end of the terminal ileum is then closed with an endoscopic linear stapler with a 60-mm vascular stapler.
- The terminal ileum, with the anvil in place, is reintroduced into the abdominal cavity, the Gelcap is reapplied, and the pneumoperitoneum is reinsufflated.
- The surgeon stands to the patient's right side, with the left hand through the GelPort and with the camera in his or her right hand through one of the right lateral port sites. The patient is placed on a slight Trendelenburg position.
- An experienced assistant introduces the 28-Fr EEA stapler into the rectum and delivers the spear anterior to the rectal stump staple line. The EEA stapler and the anvil are mated (by the surgeon's left hand); the EEA stapler is closed and then fired, creating a side-to-end ileorectal anastomosis (**FIG 21**).
- Two intact doughnuts should be obtained. The distal doughnut is sent for evaluation as the distal margin. The anastomosis is inspected to ensure that it is tension-free and that it has excellent blood supply.
- Finally, the anastomosis is insufflated under water to ensure that it is airtight. The presence of air bubbles would indicate an anastomotic disruption and should prompt a revision of the anastomosis.
- Alternatively, the distal transection and ileorectal anastomosis can be constructed extracorporeally through the open Pfannenstiel incision site. We find it easier to perform the anastomosis intracorporeally, due to the superior visualization and exposure that laparoscopy provides.

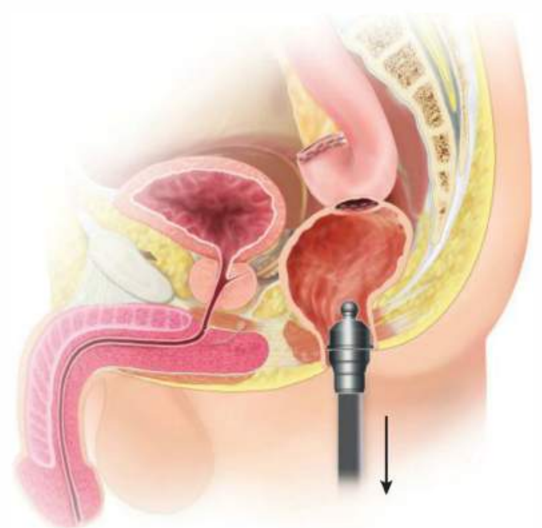

FIG 21 ● Step 13: intracorporeal anastomosis. A side-to-end ileorectal anastomosis is constructed with a 28-Fr EEA stapler device.

PEARLS AND PITFALLS

Setup	■ Proper patient, team, port, and instrumentation setup is critical.
Operative technique	■ Point of entry: IMV at the ligament of Treitz. Ideal due to its ease of localization and the absence of critical nearby structures that can be injured. ■ The medial to lateral dissection steps set up all other steps. ■ Visualize the "letter T" and high IMA ligation in malignancy; identify the left ureter prior to IMA transection. ■ The supramesocolic approach allows for a much easier and safer transection of the middle colic vessels. ■ The ICV can be readily identified by the third portion of the duodenum. ■ Distal transection and anastomosis: Although possible to perform extracorporeally, it is easier to do it intracorporeally (better visualization).
Pitfall: dissecting anterior to the SHA	■ Solution: Identify "groove" between left common iliac artery and SHA and dissect in between the two vessels.
Pitfall: floppy sigmoid difficult to handle	■ Use the back of the hand as a "shelf" to hold the sigmoid up while picking up the SHA with thumb and index finger.
Pitfall: cannot identify the left ureter during SHA/IMA dissection	■ Extend the IMV dissection plane on a superior to inferior direction behind the IMA. ■ If still unable to locate left ureter, mobilize the sigmoid lateral to medial. Distally, the left ureter is located medial to the gonadal vessels.

POSTOPERATIVE CARE

- Postoperative care is driven by a clinical pathway that includes the following:
  - Pain control: intravenous acetaminophen for 24 hours (start in the operating room) followed by intravenous ketorolac for 72 hours (if creatinine is normal). The TAP nerve block greatly reduces the need for narcotics.
  - Deep vein thrombosis (DVT) prophylaxis with enoxaparin, starting within 24 hours of surgery
  - No additional antibiotics; judicious use of intravenous fluids
  - No nasogastric tube. Remove Foley catheter on postoperative day 1.
  - Early ambulation, diet ad lib, aggressive pulmonary toilet
  - Targeted discharge: postoperative days 3 to 4

OUTCOMES

- HALS leads to improvements in short-term outcomes, including less pain, faster recovery, shorter hospital stay, and lower incidence of cardiac/pulmonary complications when compared to open surgery.
- When compared to conventional laparoscopy, HALS results in higher usage rates of minimally invasive surgery, shorter learning curves, lower conversion rates, shorter operative times, and shorter hospital stays.
- For cancer resection, minimally invasive surgery oncologic outcomes are at least comparable to those of open surgery.

COMPLICATIONS

- Wound infections and incisional hernias are markedly reduced with the use of a Pfannenstiel extraction site.
- Urinary/sexual dysfunction: important to preserve hypogastric nerves intact
- Ureteral injury: critical to identify the ureters prior to vascular transection
- DVT: low risk with use of DVT prophylaxis
- Cardiac and pulmonary complications: significantly reduced compared to the open surgery approach

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Chapter 27

Low Anterior Resection and Total Mesorectal Excision/ Coloanal Anastomosis: Open Technique

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DEFINITION

- Low anterior rectal resection (LAR) with total mesorectal excision (TME) is defined as the removal of the rectum en bloc with an intact perirectal fascial envelope distal to the cancer-bearing rectal wall. The visceral endopelvic fascia, also known as fascia propria or investing fascia of the mesorectum, is identified by a thin, loose areolar tissue that circumferentially separates the rectum and mesorectum from surrounding pelvic structures. Removal of the rectum with an intact mesorectum ensures complete removal of all lymph nodes and lymphatics that drain the diseased rectum without oncologic contamination of the pelvis at the time of surgery.
- Coloanal anastomosis is the attachment of a mobilized proximal colon segment to the anal canal while preserving the anal sphincter musculature with a negative distal margin.
- This operation is performed primarily for distal rectal cancer, when tumor location mandates rectal transection at the level of the pelvic floor (levator ani and puborectalis).

PATIENT HISTORY AND PHYSICAL FINDINGS

- A detailed history should identify locally advanced rectal lesions that are causing bowel obstruction, bleeding, pseudodiarrhea, fecal incontinence, or excessive pelvic or anal pain. Nearly obstructed patients may require a temporary laparoscopic loop sigmoid colostomy prior to neoadjuvant chemoradiation. Patients with pain due to fixed tumors in the anal canal and sphincter are not candidates for coloanal anastomosis.
- Prior colon and anorectal surgery, vascular surgery, or sphincter trauma during childbirth may have compromised the vascular supply to the planned colonic conduit or reduce the anal sphincter function.
- Patients with poor functional status or poor fecal control prior to surgery are likely to have reduced quality of life and fecal soiling after surgery. These patients may be best served with a permanent colostomy rather than a sphincter-sparing coloanal anastomosis.
- Digital rectal exam and rigid proctoscopy should be performed by the lead surgeon prior to the administration of neoadjuvant therapy. Anal sphincter, pelvic floor function, topography of rectal wall involvement, and distance of the distal aspect of the tumor from the dentate line determine the likelihood of sphincter salvage and method of reanastomosis. Submucosal tattooing distal to the rectal tumor identifies the location of clinically regressed tumors after neoadjuvant chemoradiation and is helpful for determining tumor clearance during pelvic dissection.
- A detailed family history is necessary to identify risk of an inherited colon and rectal cancer syndrome as well as risk for metachronous colorectal cancer. We currently screen all young patients (<60 years of age) for Lynch syndrome and refer patients to genetic counseling when they have a positive screen or if they have multiple affected relatives.
- Past medical history should identify patients with cardiopulmonary, liver, or kidney disease not medically suitable for a physiologically demanding operation.

IMAGING AND OTHER DIAGNOSTIC STUDIES

- A complete colonoscopy is obtained.
- Preoperative staging with endorectal ultrasound (ERUS) or magnetic resonance imaging (MRI) determines the need for neoadjuvant chemoradiation. ERUS has a higher sensitivity and specificity for tumor depth rather than lymph node involvement as compared to MRI. MRI allows for assessment of the circumferential margin at the mesorectal envelope.[1]
- Tumors located at the distal two-thirds of the rectum with greater than or equal to T3 wall invasion or greater than or equal to N1 nodal status will be referred for neoadjuvant treatment to decrease the risk of locoregional recurrence.[2] Additionally, neoadjuvant therapy may lead to tumor shrinkage, increasing the likelihood of sphincter preservation while avoiding exposure of the small bowel, colonic conduit, and anastomosis to postoperative radiation. Postoperative radiation is associated with increased risk of anastomotic stricture and radiation enteritis.[3]
- We routinely order a contrast-enhanced computed tomography (CT) scan of the chest, abdomen, and pelvis to evaluate for distant metastatic disease. Selected patients with liver metastases will be treated with a combination of staged resections and chemotherapy, whereas patients with synchronous peritoneal carcinomatosis will be evaluated for cytoreductive surgery with hyperthermic intraperitoneal chemotherapy. Positron emission tomography (PET) for the initial staging of rectal cancer rarely alters disease management.[4]
- Carcinoembryonic antigen (CEA) levels are checked prior to the initiation of neoadjuvant chemoradiation, prior to resection and prior to initiation of adjuvant chemotherapy.

SURGICAL MANAGEMENT

Preoperative Planning

- Patients undergo preoperative counseling and stoma marking by an enterostomal therapist. Counseling allows the patient to understand ostomy care, optimizes stoma placement, and reduces stoma-related complications.[5]

- Placement of ureteral stents can facilitate ureteral identification in the setting of large rectal tumors, inflammation, previous surgery and pelvic radiation, and also contributes to intraoperative identification of ureteral injuries.
- Bowel preparation or enema removes the mechanical obstacle of bowel contents in a narrow pelvis and reduces the tension on an infraperitoneal anastomosis.
- Parenteral antibiotic prophylaxis covering bowel flora is given prior to surgical incision.
- Deep venous thrombosis prophylaxis via sequential compression devices (SCDs) and subcutaneous (SC) heparin or low-molecular-weight heparin (LMWH) prior to surgical incision is administered.
- The surgical tray should include a lighted St. Mark's retractor with the longest available blades, a big bite surgical energy device, and laparoscopic cautery and suction.

Positioning

- LAR with coloanal anastomosis requires access to both the pelvis and the perineum. Therefore, patients are placed in a lithotomy position with the hips slightly flexed and the knees completely flexed in Yellofin stirrups. Extra padding is applied on the fibular head and heels to prevent nerve injury and pressure ulcers. The buttocks are at the edge of the table with the tip of the coccyx accessible. The legs remain adducted during the pelvic dissection but will need to be abducted to allow perineal access during creation of the coloanal anastomosis (**FIG 1**).

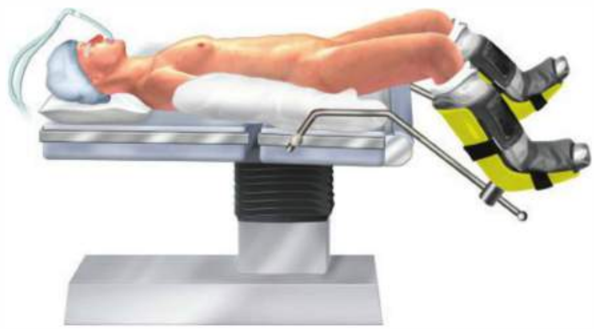


FIG 1 ● The patient is on a lithotomy position with the patient's hips slightly flexed and the legs completely flexed in Yellofin stirrups.

TECHNIQUES

LOW ANTERIOR RECTAL RESECTION WITH TOTAL MESORECTAL EXCISION

Incision, Abdominal Exploration, and Retraction of the Small Bowel

- A laparotomy incision is made from the supraumbilical midline to the pubic bone. The fascia is opened between the rectus muscles. As the incision is opened to the level of the pubic bone, the bladder is mobilized to the left of the incision.
- A careful exploration of the abdominal and pelvic cavity is undertaken to assess for distant metastatic disease and/or unresectable local disease. Attention should be given to the liver, retroperitoneum, aortic and external iliac lymph nodes, as well as peritoneal surfaces. Locally advanced disease may require a diverting colostomy followed by chemotherapy and radiation prior to resection.
- A fixed abdominal retractor, such as a Bookwalter or Thompson retractor, is used for exposure. A laparotomy pad wrapped around the small intestine from the ligament of Treitz to the terminal ileum will prevent loops of small intestine from migrating into the operative field. A midline incision that barely extends above the umbilicus allows for tacking the small bowel under the right abdominal wall.

Mobilization of the Left and Sigmoid Colon, Colonic Mesentery, and Splenic Flexure

- The left colon lateral attachments are incised with a cephalad direction. The areolar plane between the left colonic mesentery and the retroperitoneum is identified and opened. This plane is a few millimeters medial from the peritoneal reflection or white line of Toldt. Developing a plane at the exact edge of the white line of Toldt has the potential of lifting the retroperitoneal structures with subsequent ureteral and nerve injury.
- The splenocolic, phrenocolic, and renocolic attachments are divided at the splenic flexure. In patients with difficult visualization, the transverse colon is retracted downward and the lesser sac is entered over the midtransverse colon by incising the gastrocolic ligament. Development of this plane in a medial to left lateral direction detaches the omentum from the distal transverse colon so that the medial and lateral planes of dissection can be joined to complete the splenic flexure mobilization (**FIG 2**).
- The splenic flexure and proximal left colon mesentery are separated from the Gerota's fascia. Incomplete mobilization of the splenic flexure results in a short colonic conduit and tension on the colorectal anastomosis, which could then lead to a postoperative anastomotic leak.

Vessel Ligation and Left Ureter Identification

- The separation of the left and sigmoid colon from the retroperitoneum is continued by reversing direction toward the pelvis. The left ureter is identified as it crosses over the left iliac artery and into the pelvis in a way that preserves the retroperitoneal location of the ureter but also identifies the areolar plane that medially extends to the superior hemorrhoidal vessels (SHV) arch (**FIG 3**). Lifting the mesosigmoid and placing the index finger behind the SHV arch allows the surgeon to incise with electrocautery the right surface of the peritoneum just under the dorsal surface of the SHV. This plane of dissection along the dorsal aspect of the SHV, as it is carried over the promontory, leads into the presacral tissue plane that will be later developed during the TME. At this

FIG 2 ● Mobilization of the splenic flexure. The splenic flexure of the colon *(A)* is retracted medially to identify and release the lateral peritoneal attachments. Care is taken to avoid injury to the spleen *(B)*. The phrenocolic ligament *(C)*, the splenocolic ligament *(D)*, and the gastrocolic ligament *(E)* are identified and subsequently divided. This dissection can be carried from medial to lateral as well as lateral to medial, until both planes of dissection meet around the spleen.

point, the mesentery is divided in between the sigmoid and descending colon, starting from the antimesenteric border. The SHV are ligated at the level of their origin from the inferior mesenteric artery (IMA) in order to preserve the left colic pedicle intact. The colon itself is not divided. This prevents the colon from dropping into the dissection field during the operation and also allowing for any blood supply deficiencies in the proximal colon to manifest by the end of the dissection and prior to the anastomosis.

- In cases of coloanal anastomosis, a high IMA transection at its takeoff from the aorta is usually performed, in an effort to prevent anastomotic tension (**FIG 4**). The collateral marginal artery that connects the middle colic artery and the IMA and runs close to the colon provides blood supply to the distal descending colon in these cases.
- Reidentification of the ureter prior to IMA or SHV pedicle ligation ensures the left ureter is safe from injury.
- Additional length of the colonic conduit can be achieved by ligating the inferior mesenteric vein just lateral to the ligament of Treitz.

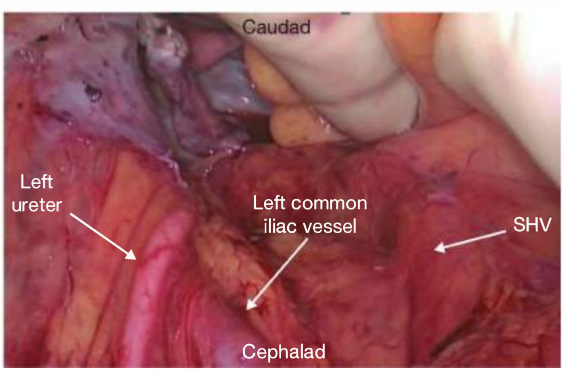


FIG 3 ● The sigmoid colon and its mesentery have been separated from the retroperitoneum to reveal the left ureter as it crosses the left common iliac vessels. The peritoneal reflection over the left side of the rectum and mesorectum has been incised dorsal to the SHV to allow encircling these vessels prior to ligation.

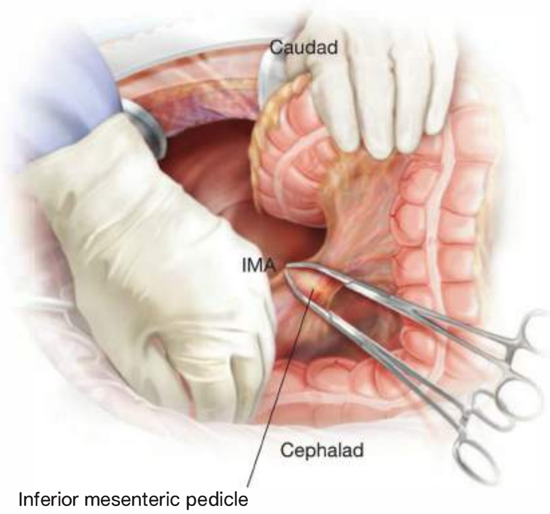


FIG 4 ● High IMA transection. In coloanal anastomosis cases, the IMA is transected at its origin between clamps in order to obtain maximal mobilization of the colonic conduit.

Posterior Mobilization of the Rectum and Hypogastric Nerve Identification

- A lighted St. Mark's retractor is placed posteriorly to the ligated SHV. By retracting the rectum anteriorly, the presacral areolar space is exposed and divided with electrocautery. The hypogastric nerves are identifiable at this location prior to dissecting the presacral space (**FIG 5**). These nerves should be swept posteriorly and preserved as they course in a medial to lateral direction along the presacral fascia.
- The presacral dissection plane is bloodless. Proper retraction with the St. Mark's retractor assists the surgeon in following the areolar plane between the fascia propria anteriorly and the presacral fascia posteriorly, down to the levator muscles and pelvic floor (**FIG 6**).
- Failure to properly expose the presacral space with the lighted St. Mark's retractor risks dissecting to far posteriorly and into the presacral venous plexus. Staying on the anterior surface of the areolar plane close to the mesorectal boundary will allow the surgeon to stay in the presacral space, thus avoiding catastrophic bleeding from injured presacral veins.
- Blunt dissection should be avoided at all cause, because it can lead to violation of the mesorectum with the attendant increased risk of locoregional tumor recurrence. It is imperative to adhere to a sharp dissection technique when dissecting around the mesorectum.

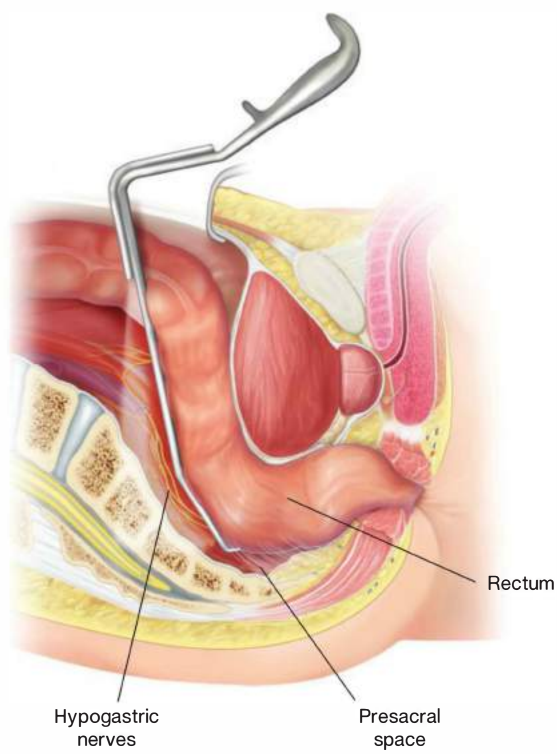


FIG 5 ● Using a lighted St. Mark's retractor, the rectum is retracted anteriorly, exposing the presacral space posteriorly. The hypogastric nerves are exposed and should be swept posteriorly and away from the mesorectum. This begins the superior and posterior portion of the TME.

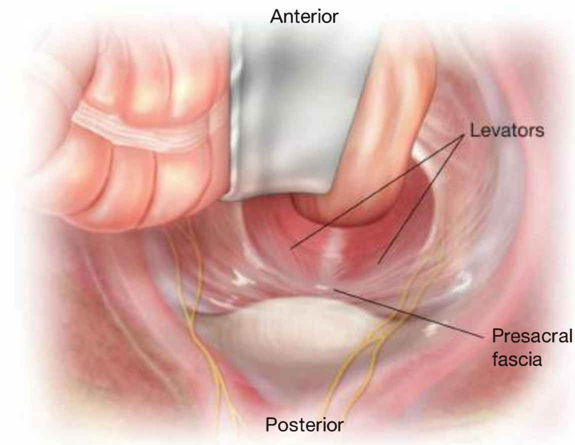


FIG 6 ● Exposed with the aid of a lighted St. Mark's retractor, the presacral plane of dissection should be followed down to the levator muscles and the pelvic floor.

- As the posterior dissection continues laterally, the surgeon must proceed on an anterolateral direction, or in a semicircular fashion, to open the lateral planes. This helps avoiding penetrating through the endopelvic fascia, which holds the hypogastric vein and its branches as well as the parasympathetic plexus attached to the lateral pelvic walls. In this fashion, potentially catastrophic bleeding and severe autonomic dysfunction can be averted.

Division of Lateral Ligaments

- The lateral rectal ligaments can be taken with cautery or with an energy device. It is not usually necessary to ligate vessels within the lateral stalks with the exception of the middle rectal vessel variants. Identification of the lateral rectal ligaments is achieved by placing the rectum on posterolateral traction between the index and middle fingers in the direction opposite of the lateral rectal ligament to be transected (**FIG 7**).

Anterior Mobilization of the Rectum and Proximal Colonic Transection

- Following the areolar tissue circumferentially around the rectum and incising the anterior peritoneal reflection connects the right and left lateral dissections. Once the peritoneal reflection is incised, the dissection continues behind Denonvilliers' fascia, which covers the seminal vesicles and prostate (**FIG 7**). Dissection anterior to Denonvilliers' fascia is associated with annoying bleeding and with an increased risk of parasympathetic nerve damage. This plane is intentionally violated only in anterior tumors that invade into the seminal vesicles or prostate. In these cases, the seminal

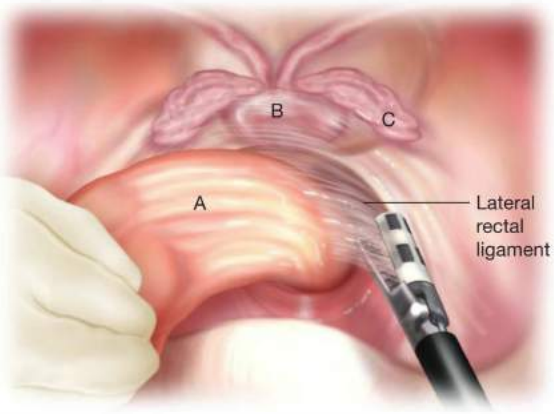


FIG 7 ● Transection of the lateral rectal ligaments and anterior pelvic dissection. Posterolateral retraction of the rectum allows for good exposure of the lateral rectal ligament (the right one is shown here), which can then be transected with cautery or with an energy device. The anterior dissection will then proceed behind Denonvilliers' fascia, in the space between the rectum, posteriorly, and the prostate and seminal vesicles (*B* and *C*, respectively), anteriorly.

vesicles and/or part of the prostate have to be resected en bloc with the rectum in order to achieve a clear radial margin.

- In women, the rectovaginal septum is more easily separated from the rectum anteriorly.
- At this point, the colon is transected proximally between the sigmoid and descending colon lymphovascular distribution in between Kocher clamps. The transected end of the colon should reach the pubis with ease, ensuring adequate mobilization of the colon conduit for a tension-free anastomosis.

COLOANAL ANASTOMOSIS: STAPLED TECHNIQUE

- This method is feasible when there is at least 2 cm of rectal stump above the dentate line.
- The rectum is divided above the levators with a contoured stapler. The specimen, including the entire rectum and mesorectum as well as the sigmoid colon, is now fully disconnected and is sent to the pathologist. The pelvis is now empty with good visualization of the pelvic floor (**FIG 8**).
- The anvil of a 29mm end-to-end anastomosis (EEA) is placed in the open end of the descending colon and a purse string is placed around its shaft.
- A 29-mm EEA stapling device is introduced gently into the rectal stump.
- The trocar is brought out through the rectal stump. The elected site of the rectal drum penetration depends solely on creating an exit angle suitable to accept the anvil without the need for further maneuvering of the stapling device itself. Any repositioning of the stapler post exodus of the trocar runs the risk of lateral tear and incomplete rectal stump donut. A long packing forceps is used to push the rectal stump around the trocar penetration point to avoid lateral tearing of the rectal stump (**FIG 9**), which could lead to an anastomotic leak.

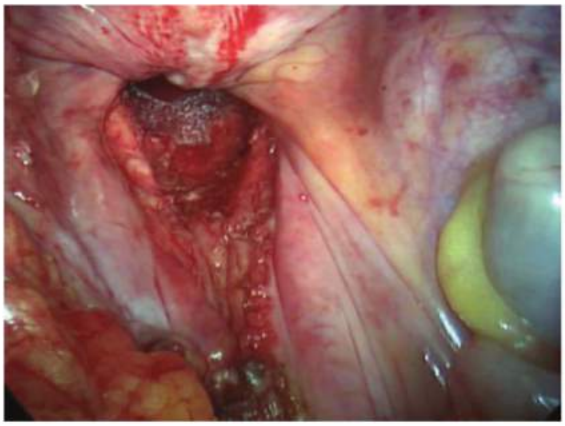


FIG 8 ● After resection of the rectum, the pelvis is empty, with good visualization of the pelvic floor.

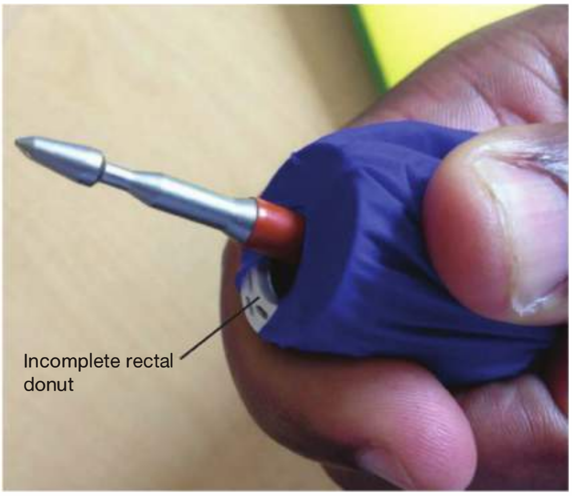
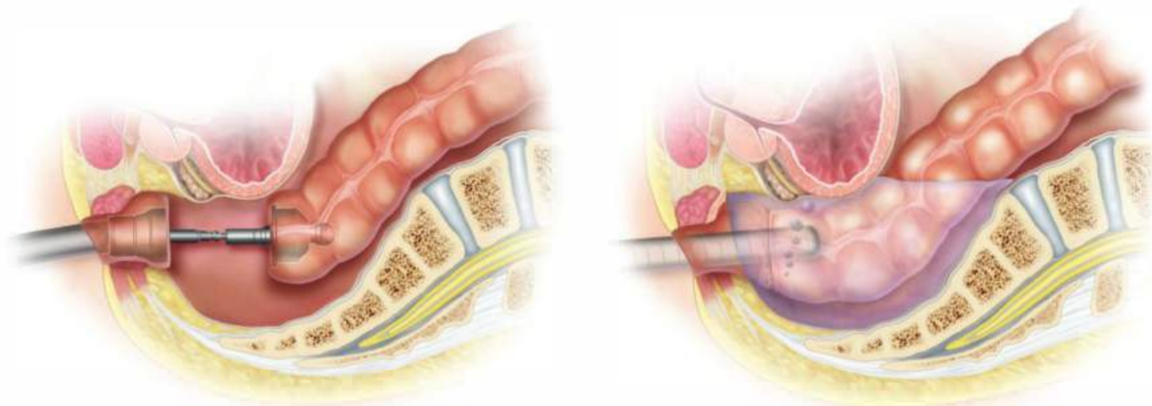


FIG 9 ● Once the trocar is deployed, it is critical to avoid any movement on the EEA stapling device to avoid lateral tearing of the rectal stump, which could lead to an anastomotic leak.

- The anvil and the EEA stapler are then mated and fired, creating a tension-free coloanal anastomosis (FIG 10A). Two complete doughnuts should be obtained; the distal doughnut should be sent to the pathologist for a frozen section evaluation to ensure the distal margin is negative for cancer. A positive margin may necessitate conversion to an abdominoperineal resection (APR). The integrity of the anastomosis is tested by insufflation under water (FIG 10B). Air bubbles would indicate an anastomotic leak, necessitating either a revision of the anastomosis, in addition to a proximal diverting loop ileostomy (depending on the magnitude of the leak).
- The patient is always diverted with a loop ileostomy to protect the anastomosis, and a 19-Fr round drain is placed in the pelvis for no more than 2 to 3 days.



A B

FIG 10 ● Stapled coloanal anastomosis. **A.** An EEA is created with a 29mm EEA stapler. **B.** The completed colorectal anastomosis is tested under water. Air bubbles identified during insufflation of the anastomosis indicate an anastomotic leak.

COLOANAL ANASTOMOSIS: HAND-SEWN TECHNIQUE

Placement of Self-Retaining Anal Retractor

- Eversion of the anal canal with a self-retaining Lone Star anal retractor (FIG 11), or with two Gelpis, can facilitate surgeon visualization.

Injection of Local Anesthetic with Epinephrine

- The dentate line is identified and the submucosal plane is injected circumferentially with a local anesthetic containing epinephrine. This decreases bleeding and loss of visualization. The distal rectum is divided full thickness sharply transendoanally above the dentate line (FIG 11). The distal margin should be sent to the pathologist for a frozen section evaluation to ensure that it is negative for cancer. A positive margin may necessitate conversion to an APR.

Anal Verge Sutures Placed in Four Quadrants

- The 3-0 Vicryl sutures are placed in all four quadrants through the anal mucosa and a small portion of the internal sphincter (outside-in placement). The needles are kept in place and the sutures are tacked down to the Lone Star retractor to keep them secured. These sutures will eventually be placed through the distal colon segment to complete the coloanal anastomosis.

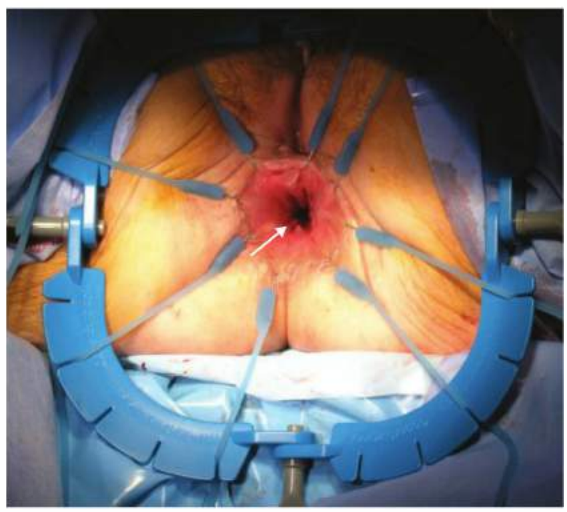


FIG 11 ● A Lone Star retractor is used to evert the anal canal and to expose the dentate line *(arrow)*. The rectum will be transected transendoanally above the dentate line.

Colonic Conduit Delivery

- A purse-string suture is placed in the open end of the descending colon around an insufflated Foley catheter. The descending colon stump is lubricated and is then delivered to the perineum by slowly pulling the Foley catheter

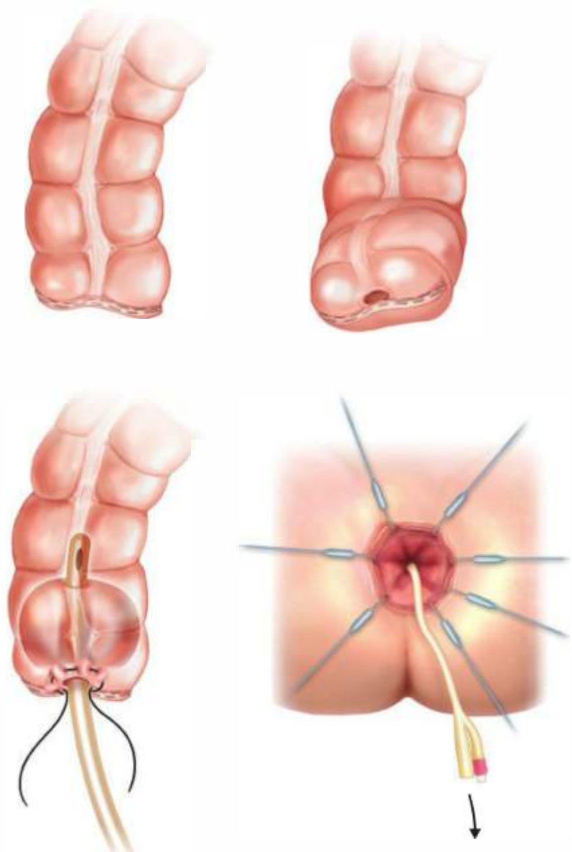


FIG 12 ● A purse-string suture is placed in the open end of the descending colon around an insufflated Foley catheter. The descending colon stump is lubricated and is then delivered to the perineum by slowly pulling the Foley catheter through the open distal rectal stump.

through the open distal rectal stump (FIG 12). The assistant guides the colonic conduit through the pelvis ensuring adequate colon length, lack of tension on the colonic conduit's blood supply, and orientation without twisting.

- The colonic conduit should easily emerge from the anal canal so the surgeon can see the purse string. This ensures there will be a tension-free anastomosis at the level of the dentate line and allows the surgeon to assess the blood supply of the colonic conduit as it passes through the anal canal. Occasionally, it is necessary to clean a portion of mesenteric fat and appendix epiploicae to prevent its inclusion in the coloanal anastomosis and to debulk a large conduit as it passes through the anal canal.

Colon Anchored with Anal Canal Sutures

- The purse string in the distal colon is amputated, the Foley catheter is removed, and the previously placed four-quadrant distal sutures are now placed full thickness through the open distal colon wall (outside-in placement). The colonic conduit is pushed back up into the anal canal when surgical knots are placed to secure the anchoring sutures (FIG 13). The anchored sutures are kept long and secured with a hemostat outside the anal canal to maintain orientation of the colonic conduit and to guide completion of the coloanal anastomosis.

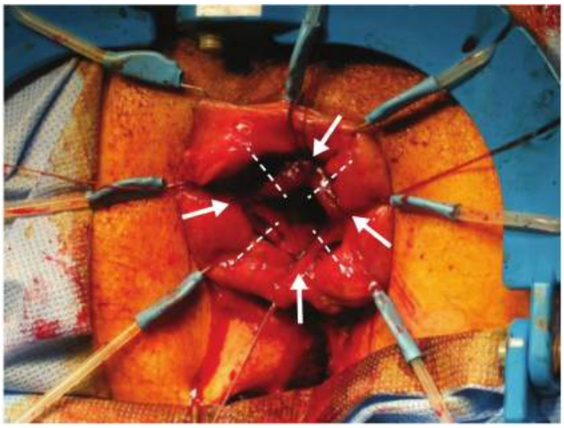


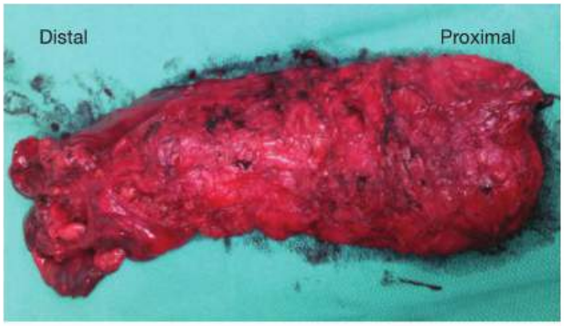
FIG 13 ● The proximal colon is opened and anchored to the anal canal. The previously placed four-quadrant distal sutures have now been placed full thickness through the open distal colon wall *(arrows)*. Placing full-thickness sutures in between these four-quadrant sutures (along the *dotted lines*) will complete the anastomosis.

Completion of Circumferential Anastomosis

- An anal retractor such as a Hill Ferguson or standard Fansler retractor can then be placed through the anal canal and distal colon. Placing interrupted 3-0 Vicryl full-thickness sutures through the colon and anus (inside-out placement) completes the anastomosis (FIG 13).

En Bloc Removal of the Rectal Specimen

- If a more distal resection is required or if the surgeon prefers to perform a perineal anorectal resection en bloc with the rectal dissection, the surgeon can begin the perineal dissection in the intersphincteric plane, located between the internal and external anal sphincters. This dissection can begin at the dentate line or within the intersphincteric groove at the anal verge. The intersphincteric dissection proceeds proximally to the level of the puborectalis sling of the levators. An abdominal assistant can guide the perineal surgeon to then dissect into the pelvis and connect the two dissection planes. The en bloc rectal and internal anal sphincter dissection can then be passed off the field. The coloanal anastomosis is fashioned as previously described at the level where the intersphincteric dissection began. In cases where the internal anal sphincter is excised, the distal anastomosis should include anal mucosa and parts of the external anal sphincter.[6] The resected specimen should show an intact mesorectum with no tapering on the distal end (FIG 14).



Loop Ileostomy Creation and Pelvic Drain Placement

- Creation of a loop ileostomy through a previously marked right lower quadrant location diverts stool from the coloanal anastomosis and protects the anastomosis. A 19-Fr round drain is placed behind the anastomosis.

FIG 14 ● The excised rectum has a smooth posterior surface when the mesorectum is excised intact, with no distal tapering of the mesorectum observed.

PEARLS AND PITFALLS

Mobilizing the left colon	■ Dissect the plane a few millimeters medial to the white line of Toldt.
Left ureter identification	■ Complete mobilization of the sigmoid colon mesentery from the retroperitoneum allows identification of the left ureter during proximal IMA ligation.
Mobilization of colonic conduit	■ High transection of the IMA and transection of the IMV lateral to the ligament of Treitz elongate the colonic conduit for a tension-free anastomosis.
Posterior mesorectal dissection	■ Dissecting the areolar plane behind the mesorectum requires the surgeon to lift the rectum anteriorly with a lighted St. Mark's retractor. Dissection posterior to this plane risks entry into the presacral venous plexus, which can lead to exsanguinating hemorrhage.
Anterior rectal dissection	■ Keep dissection behind Denonvilliers' fascia unless an anteriorly located tumor necessitates excision to obtain a negative radial margin.
Colonic conduit delivery for anastomosis	■ Properly orient the colonic conduit so there is no mesenteric twisting or undue tension as it is delivered though the anal canal. Mesenteric fat can be removed from the distal colon to facilitate placement through the canal, but too much dissection can compromise the blood supply of colon and the proximal portion of the anastomosis.
Stapled anastomosis	■ Avoid maneuvering of the circular stapler after deployment of the trocar. A lateral rectal drum tear extending to the stapler rim will result into an incomplete distal donut and an anastomotic leak.

POSTOPERATIVE CARE

- Prophylactic LMWH is initiated the day of the operation.
- Physical therapy for ambulation is involved on postoperative day (POD) 1.
- Early feeding with clear liquids can increase patient comfort and stimulate return of gastrointestinal motility.
- Bladder dysfunction following deep pelvic dissection is common. We routinely keep a Foley catheter in place for 5 days.
- Although patients wait for return of intestinal function, they can be taught the basics of ileostomy care.
- Patients should be advised that drainage from the rectum could occur despite fecal diversion. A single episode of bloody rectal discharge while the patient is ambulating between PODs 5 and 7 is often an indicator of evacuation of a pelvic fluid collection through the stapler line and does not require further imaging unless the patient shows signs of infection. Persistent rectal drainage that is purulent or bloody should prompt workup for a postoperative complication.

OUTCOMES

- Survival from rectal cancer after multimodality treatment is dependent on disease stage. Overall, 5-year survival is approximately 90% for stage I, 74% to 65% for stage II, and 81% to 33% for stage III of disease. Development of distant metastasis occurs in less than 10% in patients with stage I disease but increases up to 28% and 50% in patients with stages II and III rectal cancer, respectively.[7]
- Local pelvic recurrence of rectal cancer is also dependent on tumor and nodal stage. Local recurrence is less than or equal to 5% for patients with stage I rectal cancer but increases to 15% for stage II disease and 22% for stage III disease.[7] If a pelvic recurrence can be treated with a margin-negative surgical resection, 5-year survival can approach 40%. Often, this requires a pelvic exenteration which demands a multispecialty surgical approach.[8]

COMPLICATIONS

- Complications can occur in up to one-third of patients undergoing TME and coloanal anastomosis with 15% of patients experiencing major complications.[9]
- Rectal cancer patients who have received neoadjuvant chemoradiation and who undergo a coloanal anastomosis with a colonic conduit that depends on collateral blood flow, have multiple risk factors for anastomotic leak. Fecal diversion with loop ileostomy after coloanal anastomosis

reduces the clinical consequences of an anastomotic leak.[10,11]

- Most patients have defecatory dysfunction after removal of the rectum. In the native state, the rectum functions as a distensible organ to store stool until the patient initiates evacuation. Proctectomy patients loose this storage capacity and have more frequent bowel movements. They typically complain of a defecation pattern termed "low anterior syndrome," in which the patient senses a frequent defecation urge. Treatment includes fiber supplementation to bulk up the stool, use of Imodium or Lomotil to slow intestinal transit, and enemas to assist with evacuation. Patients with a severe decrease in quality of life may elect to undergo conversion to a permanent end colostomy.

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Chapter 28

Low Anterior Rectal Resection: Laparoscopic Technique

Joël Leroy   Didier Mutter   Jacques Marescaux

DEFINITION

- Low anterior resection (LAR) is the full mobilization and resection of the rectum at the level of the levators, leaving behind only a short or no rectal stump.
- LAR for rectal cancer requires a total mesorectal excision (TME) to ensure a radical resection with adequate radial and distal margin. The goal is to achieve an en bloc resection of the cancer with complete dissection of the pararectal lymph nodes contained within the mesorectum.
- Laparoscopic LAR is a minimally invasive approach to TME with significant short-term advantages when compared to open LAR, including less pain, faster recovery, lower morbidity, and shorter hospital stays, without compromising the oncologic safety of the operation.

PATIENT HISTORY AND PHYSICAL FINDINGS

- A full history and physical examination will allow the surgeon to determine if a sphincter-sparing operation is possible, whether a temporary ileostomy is likely, and will also aid in discussions regarding postoperative functional status.
- History elements elicited should include baseline functional status, bowel incontinence, sexual and urinary dysfunction, as well as pain with defecation or tenesmus. Previous history of pelvic radiation and pelvic surgery should also be noted.
- History of incontinence should prompt discussions regarding postoperative quality of life with a low anastomosis.
- History of pain or tenesmus suggests involvement of the anal sphincter or a larger tumor. This will alter the course of treatment and a sphincter-sparing operation may not be possible in this subgroup of patients.
- Physical examination should include a digital rectal exam (DRE), vaginal exam, anoscopy, and a thorough abdominal exam.
- DRE should assess tumor size, degree of fixation to rectal and pelvic wall, mobility, location (anterior/posterior/lateral), distance from the anorectal ring, and anterior extension into vagina/prostate. Anal sphincter involvement can also be determined by DRE in the majority of patients.
- Anterior rectal tumors in female patients require a vaginal exam to rule out extension into the vagina.
- Anoscopy for low rectal tumors may allow for better visualization of the tumor during the physical exam.
- The abdominal exam should evaluate for liver metastasis. A bilateral groin exam should be performed to evaluate for potential inguinal lymphadenopathy.

IMAGING AND OTHER DIAGNOSTIC STUDIES

- A colonoscopy with documentation of all polyps should be performed. Suspicious lesions should be tattooed to facilitate localization during surgery.
- Staging with endorectal ultrasound or rectal magnetic resonance imaging (MRI) should be performed to determine the need for neoadjuvant therapy and to plan operative strategy. A computed tomography (CT) of the chest, abdomen, and pelvis evaluates for potential metastases.
- A preoperative carcinoembryonic antigen level should be obtained.

SURGICAL MANAGEMENT

Preoperative Planning

- Informed consent is obtained preoperatively. The patient has been informed of the potential necessity to perform a diverting ileostomy or end colostomy.
- Potential ostomy sites are marked the evening before the intervention.
- We follow the Society of American Gastrointestinal and Endoscopic Surgeons' (SAGES) bowel preparation guidelines.
- Appropriate intravenous antibiotics are administered within 1 hour of skin incision.

Equipment and Instrumentation

- 10-mm, 0-degree camera (30-degree camera is optional) with high-resolution monitors
- Laparoscopic endoscopic scissors and a blunt tip, 5-mm energy device (10-mm can be useful in obese patients)
- Laparoscopic linear staplers

Positioning and Port Placement

Patient setup

- Patient setup is a major operative step.
- The patient should be adequately secured to the table.
- Adequate padding is essential to prevent nerve and venous compressions.
- The patient is placed in a supine position with a cushion placed underneath the left flank in order to obtain a moderate lateral decubitus, which will retract bowel loops toward the right part of the abdomen.
- A rotation to the right and a caudal head tilt (Trendelenburg position) will help to retract bowel loops by means of gravity.
- The patient's legs will then be spread apart in a semiflexion using adjustable leg supports to allow for a double abdominal and perineal access.
- One should control the perfect positioning of the buttocks at the distal edge of the table to allow for an easy access to the anal and perineal area.
- The arms are padded and tucked.
- An orogastric tube is inserted; it will be removed at the completion of the surgery.
- A Foley catheter is inserted; it will be left in place for 24 hours.

FIG 1 ● Team setup. Surgeon *(1)*. First assistant *(2)*. Second assistant *(3)*. Scrub nurse *(4)*. Anesthesiologist *(5)*.

Team positioning

- This procedure is performed with two assistants and a scrub technician.
- During the abdominal part of the procedure (**FIG 1**), the surgeon stands on the right flank of the patient, his or her first assistant lateral to the patient's right shoulder, and the second assistant in between the patient's legs. The scrub technician is then located to the right of the surgeon lateral to lower limbs.
- During the perineal part of the procedure, the entire team shifts toward the extremity of the table once the perineum has been exposed.
- The monitors are placed in front of the operating team and at eye level to improve ergonomics.

Port placement

- One 12-mm supraumbilical port (port A) is introduced first using a mini-open technique. It will be used to accommodate the camera (**FIG 2**).
- Two other ports, a 5-mm port in the right flank (port B) and a 12-mm port in the right iliac fossa (port C), are used as operating ports (**FIG 2**).
- The fourth port in the left flank at the level of the umbilicus is inserted through the rectus muscle (port D, 5 mm in diameter), where the colostomy will be performed (**FIG 2**).
- The last port introduced in the suprapubic area (port E, 12 mm in diameter) is used for pelvic retraction and for exposure of the sigmoid colon's root (**FIG 2**).
- Port fixation in the wall should be perfect in order to prevent any risk of parietal injury and to prevent increased operative times due to a loss in abdominal pressure. One should not hesitate to fix ports to the skin.
- Additional ports may be used in case of difficulty in exposure. In this case, a port will be positioned in the right hypochondrium (port F) to retract the ileocecal area. This is particularly useful in obese patients (**FIG 2**).

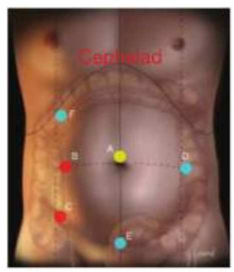


FIG 2 ● Port placement. Optical port *(A)*. Working ports *(B,C)*. Retracting ports *(D,E)*. Additional retracting port *(F)*.

LAPAROSCOPIC LOW ANTERIOR RESECTION

Exploration and Exposure

- The intervention is begun by an exploration of the abdominal cavity to locate the tumor and evaluate for possible metastases. It also allows to expose the pelvis and to evaluate the length and quality of the sigmoid loop, which will allow determining the type of mobilization of the left colon and of the splenic flexure.
- The tumor's identification may be necessary and especially so for tumors located proximally. Combined endoscopy may be required in cases where an effective preoperative marking could not be performed on the day before the intervention.
- Exposure is improved by placing the patient in a Trendelenburg position with the table tilted to the right.
- In women, exposure of the posterior pelvis and of the rectovaginal (Douglas') pouch can be obtained by direct or indirect suspension of the uterus by means of the T'Lift™ (VECTEC, France) tissue retraction device (**FIG 3A,B**) or suprapubic transparietal sutures (**FIG 4A,B**).
- Visceral obesity (in male patients) is more incapacitating than subcutaneous obesity (in female patients). The use of retractors is very helpful.

Primary Vascular Oncologic Approach to the Sigmoid Colon

- As for any oncologic surgical procedure, a primary vascular approach is the rule.

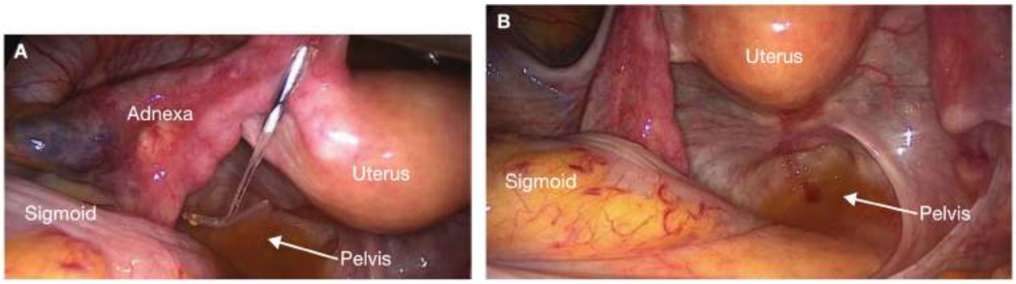


FIG 3 ● T'Lift™ tissue retraction system. **A.** T'Lift™ tissue retraction system passed through the round ligament. **B.** Pelvic exposure in women after bilateral uterine suspension with T'Lift™ tissue retraction system.

- In rectosigmoid cancer, one should approach the inferior mesenteric vessels at their origin in order to perform an "en bloc" removal of all lymph nodes associated with the rectosigmoid junction (D3 resection). It does not preclude the potential preservation of the proximal inferior mesenteric artery (IMA) and of the left colic artery (LCA).
- We always start with a primary approach to the IMA. The inferior mesenteric vein (IMV) is then approached in order to prevent any venous overload related to the late ligation of the IMA.
- Once the root of the sigmoid mesocolon has been exposed, the left retroperitoneal space is opened by incising the posterior peritoneum from the anterior aspect of the promontory up to the left border of the duodenojejunal junction (ligament of Treitz) (**FIG 5A**).
- Once the retroperitoneum has been opened, dissection is initiated opposite the promontory on the posterior aspect of the inferior mesenteric vascular sheath (i.e., the superior rectal artery at this level). This step is facilitated by the anterior traction on the mesocolon, which induces the pneumodissection of the retrovascular space, thanks to intraabdominal carbon dioxide pressure.
- Dissection is carried on in contact with the vascular sheath cranially until the origin of the IMA on the aorta.
- The dissection is continued from caudad to cephalad in contact with the artery, which is skeletonized over approximately 2 cm in order to achieve ligation and division 1 or 2 cm away from the aorta (**FIG 5B**).

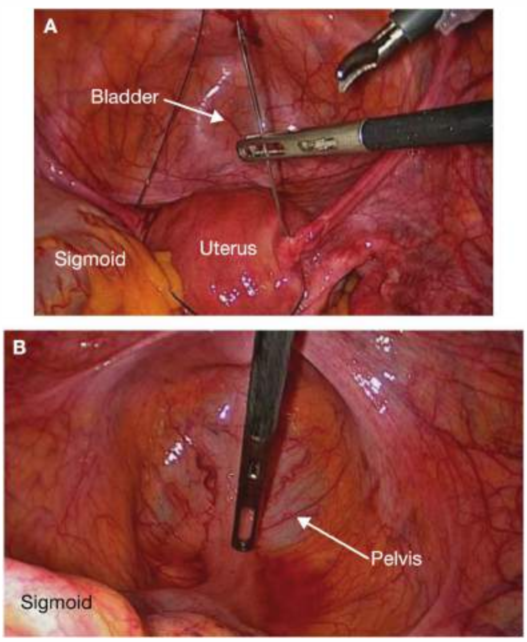


FIG 4 ● **A.** Transparietal suprapubic sutures for uterine suspension. **B.** Exposure of the pelvis in women after transparietal suprapubic suture uterine suspension.

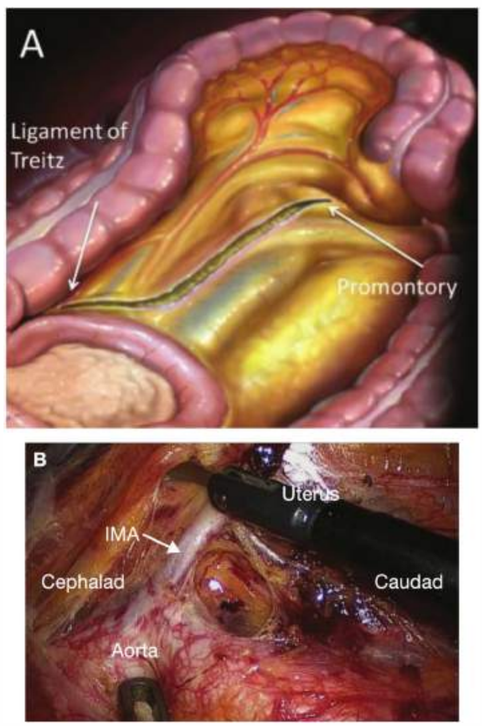


FIG 5 ● Dissection of the IMA. **A.** Opening of the left retroperitoneal space by incising the posterior peritoneum from the anterior aspect of the promontory to the ligament of Treitz. **B.** The IMA has been dissected 1 to 2 cm from the aorta.

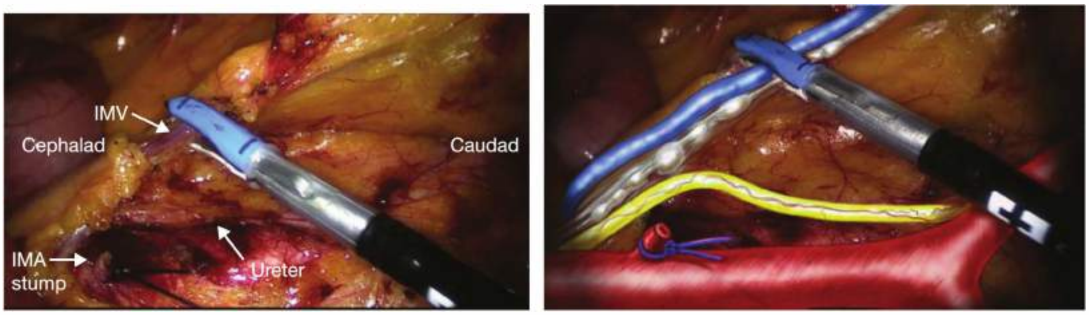


FIG 6 ● IMV transection at the level of the ligament of Treitz. The IMA was previously transected off the aorta. The retroperitoneal structures are exposed.

- This technique allows preserving sympathetic nerve plexuses, which course along the aorta on its right anterior aspect.
- Division of the IMA is performed with the LigaSure™ vessel-sealing device using a ligation with a loop on the IMA stump.
- Once the IMA has been divided, the assistant standing between the patient's legs will grasp the artery using an atraumatic forceps introduced into the suprapubic port (port D) and apply anterior traction to ideally expose dissection planes in contact with the left posterior and lateral aspects of the artery.
- It helps to preserve the nerve plexus in contact with the artery, and notably the left sympathetic trunk of the neurovegetative system that will be progressively freed and parietalized.
- The next operative step will be to identify the IMV lateral to Treitz's flexure underneath the inferior edge of the pancreas.
- The IMV is then transected at the level of the ligament of Treitz with the LigaSure™ vessel-sealing device or in between clips (**FIG 6**).

Mobilization of the Left and Sigmoid Colon

- Many authors prefer to start with the mobilization of the splenic flexure using a medial posterior transverse transmesocolic approach. We prefer to mobilize the splenic flexure at the end of the operation in order to prevent excessive mobilization, which can be a cause of morbidity.
- Our main objective is to perform a medial to lateral mobilization of the mesocolon.
- A medial to lateral mobilization of the sigmoid colon allows for traction on the upper rectum with a perfect exposure of its anterior, posterior, and lateral aspects.
- Mobilization of the mesocolon is performed using a medial to lateral approach (**FIG 7A,B**) by opening the plane between Toldt's fascia anteriorly and Gerota's fascia posteriorly.
- The dissection is carried laterally until the posterior aspect of the descending colon is reached laterally.
- Caudally, the dissection is carried toward the pelvic inlet. One should be cautious when in contact with the aorta as well as with the left iliac vessels where nerve rami of the superior hypogastric sympathetic plexus courses.
- The left ureter is identified during the dissection. It is located between the aorta and the genital vessels, well protected by Gerota's fascia.
- Mobilization of the sigmoid colon is completed with a division of its lateral attachments to the abdominal wall (**FIG 8**).

Dissection of the Rectum According to the Total Mesorectal Excision (Heald's) Technique

- The principle of TME relies on the study of the embryologic development of the pelvis and of organs located within it. A surgical intervention cannot be envisaged without a detailed knowledge of pelvic and fascial

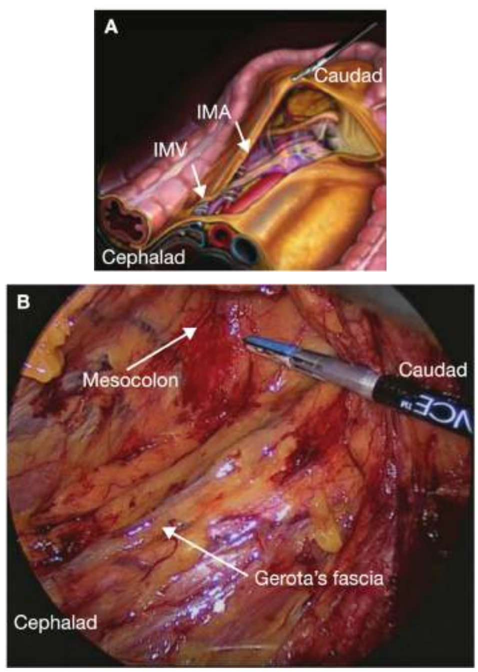


FIG 7 ● **A,B.** Medial to lateral mobilization of the mesocolon. The mesocolon is separated from the retroperitoneum (Gerota's fascia) using a medial to lateral approach. The left ureter and gonadal vessels are visualized in the retroperitoneum. *IMA*, inferior mesenteric artery; *IMV*, inferior mesenteric vein.

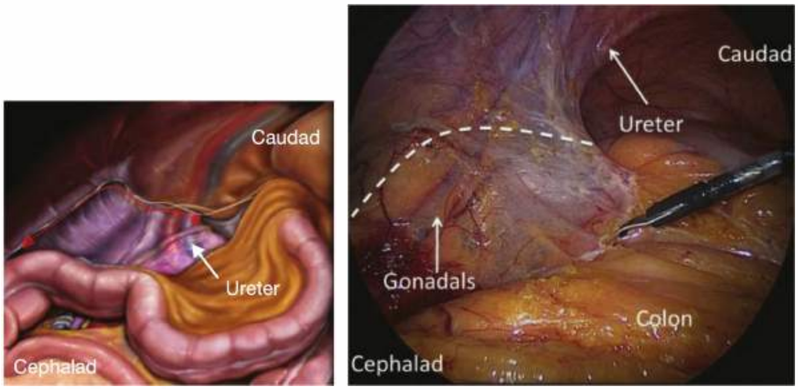


FIG 8 ● Lateral mobilization of the sigmoid loop by dividing the lateral attachments to the abdominal wall *(dotted line)*. The left ureter and gonadal vessels are visualized in the retroperitoneum.

anatomy (**FIG 9A**) that is essential to obtaining appropriate surgical specimens.

- Heald's principles rely on the dissection of the space located between the fascia propria of the rectum and the presacral fascia posteriorly, the lateral pelvic fascia laterally, and Denonvilliers' fascia anteriorly.

Posterior Dissection of the Rectum

- Once the sigmoid colon has been mobilized, a cranial and anterior traction is exerted on the rectum in order to expose the posterior aspect of the upper rectum.
- The presacral space (**FIG 9B,C**) is opened under the effect of traction and of pneumoperitoneum pressure, along with an atraumatic anterior retraction of the posterior rectal wall—a small swab at the tip of an atraumatic grasper is used. The tracts, which cross the space, are divided by means of a 2-mm electrode located at the tip of a LigaSure Advance™ vessel-sealing device.
- Dissection should be continued toward the pelvic floor. When progressing downward, dissection should continue along the presacral fascia until it fuses with the fascia propria (Waldeyer's fascia).
- During this dissection, left and right branches of the inferior hypogastric plexuses can be observed. The lateral pelvic fascia protects them along the pelvic side walls.

Lateral Dissections of the Rectum

- Cranial and medial retraction is maintained on the rectum in order to open the lateral pelvic space. This step is begun on the right side.

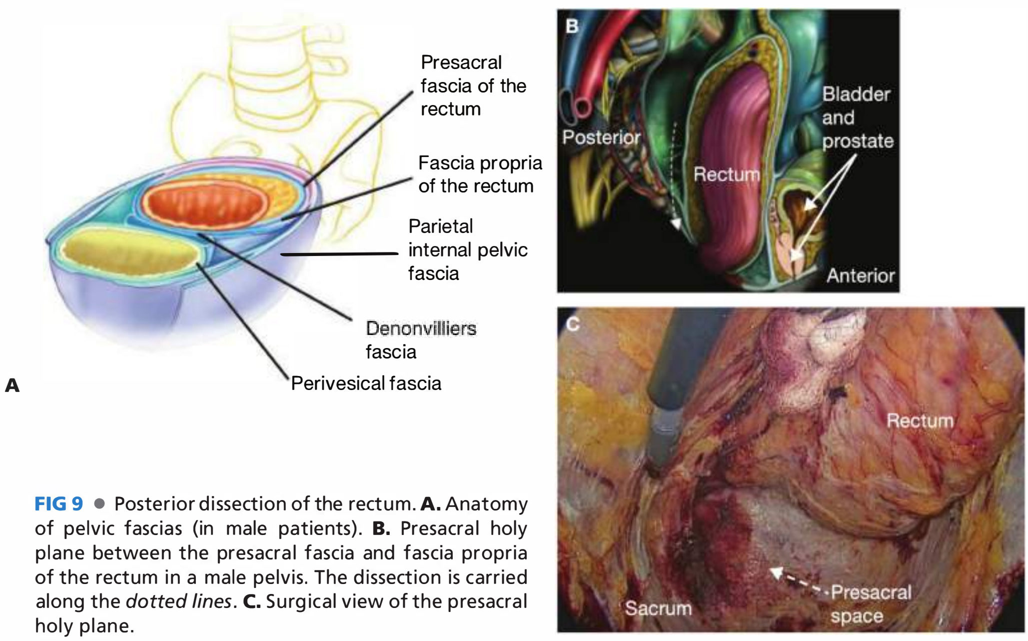


FIG 9 ● Posterior dissection of the rectum. **A.** Anatomy of pelvic fascias (in male patients). **B.** Presacral holy plane between the presacral fascia and fascia propria of the rectum in a male pelvis. The dissection is carried along the *dotted lines*. **C.** Surgical view of the presacral holy plane.

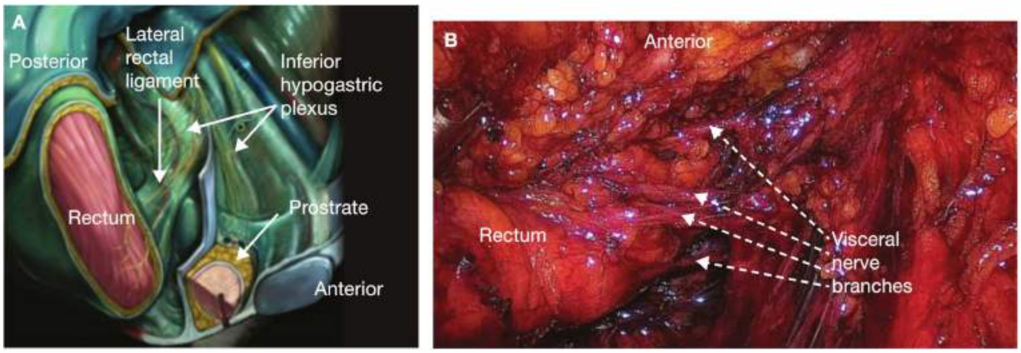


FIG 10 ● Lateral dissection of the rectum. **A.** The rectal branches of the inferior hypogastric plexus traverse along the so-called lateral rectal ligament. **B.** The lateral rectal ligament on the right side of the distal rectum has been skeletonized. The rectal branches of the lateral inferior hypogastric plexus can be seen and will be selectively transected *(dotted lines)* with the LigaSure™ device.

- The peritoneum is incised until seminal vesicles are reached. Under the effect of pneumoperitoneum pressure and of medial retraction, the rectal branches of the inferior hypogastric plexus traverse along the so-called lateral rectal ligament (**FIG 10A**).
- Parietalization of the inferior hypogastric plexus and especially of the sacral branches (3rd and 5th sacral nerves, parasympathetic nerves responsible for male erections) is carried on. Care is taken to avoid violating the parietal endopelvic fascia.
- Between three and five nerve branches can be observed crossing the space between the fascia and the rectum (**FIG 10B**). These branches are divided after skeletonization.
- The least traumatic dissection seems to be the one performed by means of the LigaSure Advance™ device with a 2-mm monopolar electrode, an energy level of 15 Watts being considered sufficient.
- The prostatic branches and the plexus trunk are preserved in order to avoid urinary and ejaculatory autonomic dysfunction.

Anterior Dissection of the Rectum

- In order to open and dissect the space between the anterior aspect of the rectum and Denonvilliers' aponeurosis, minimal cranial and posterior traction should be maintained on the rectum; Denonvilliers' aponeurosis should be retracted anteriorly.
- Retraction is usually easy to perform in female patients. In male patients, especially obese ones, this step is more difficult. We recommend the use of specific retractors developed by KARL STORZ (Endo-Retractors™) (**FIG 11A,B**) in order to reproduce the technique used in open surgery with St. Mark's retractor. It is the use of the three-directional retraction described by Heald's

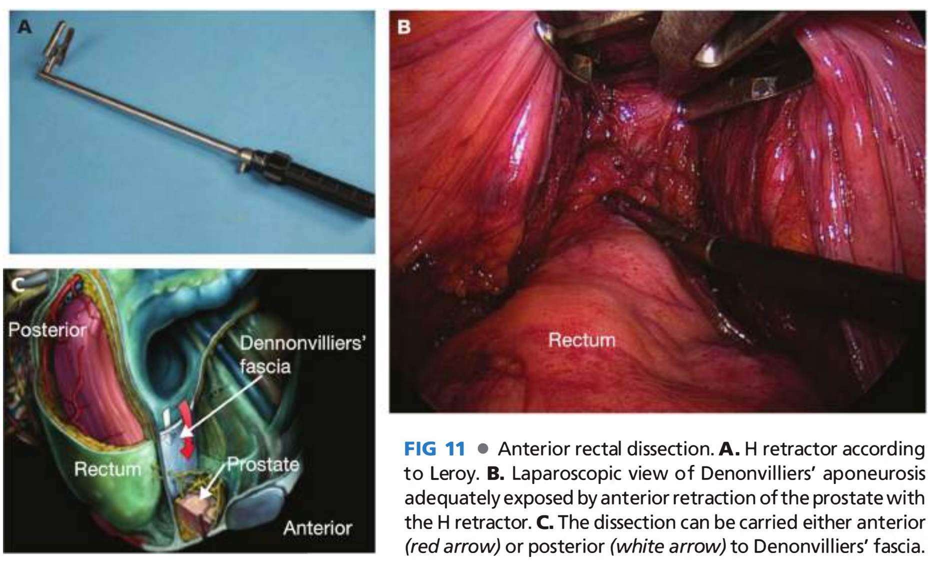


FIG 11 ● Anterior rectal dissection. **A.** H retractor according to Leroy. **B.** Laparoscopic view of Denonvilliers' aponeurosis adequately exposed by anterior retraction of the prostate with the H retractor. **C.** The dissection can be carried either anterior *(red arrow)* or posterior *(white arrow)* to Denonvilliers' fascia.

(3-D retraction), which ensures a safe dissection of the anterior aspect of the rectum.

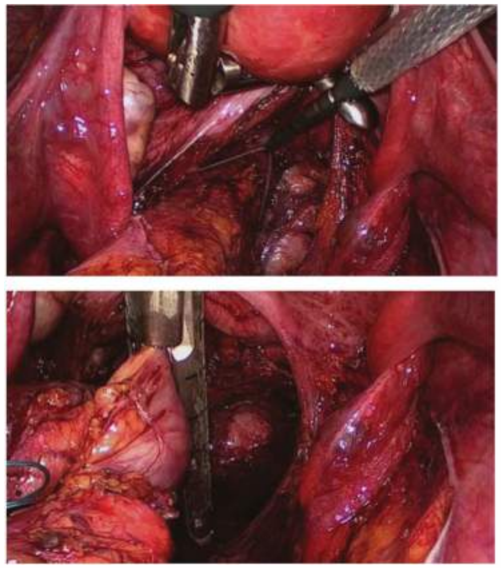
- The plane of anterior dissection can be carried either anterior or posterior to Denonvilliers' aponeurosis (FIG 11C). In advanced rectal cancer, it may be necessary to stay anterior to Denonvilliers' aponeurosis; in this case, the risk of genital nerve injury (impotence) is much higher.
- The dissection is then continued toward the pelvic floor.
- Posteriorly, it is recommended to free the last attachments of the lower rectum by dividing the sacrorectal ligament.
- Once the perirectal spaces have been dissected toward the pelvic floor, the rectum is free, surrounded by its meso, and the meso is entrapped within its fascia.
- This dissection technique is the recommended standard technique for oncologic surgery for cancer of the middle and lower rectum and is also becoming increasingly popular for the upper rectum.

Lower Rectum Division

- Division of the lower rectum must be performed at least 2 cm away from the inferior border of the tumor. For lesions of the middle third and of the upper rectum, respecting this distance is not difficult. For the upper rectum, TME resection is becoming increasingly more favorable, although theoretically, a partial resection of the mesorectum should be sufficient—in that case, a cylindrical division as opposed to a conical division of the meso and of the rectum must be located at least 5 cm away from the tumor.
- The distal end of the rectum is always excluded. To do so, a ligature is performed under the freed mesorectum by means of an extracorporeal ligature (FIG 12A). The rectal stump is then cleansed by means of a Betadine solution according to Balli's technique.
- Division of the rectum is performed, distal to the ligature, with a linear stapler (FIG 12B; Endo GIA™ with Tri-Staple™ technology [Covidien], purple cartridge, 30- or 45-mm long; more rarely, 60-mm long) introduced through the right lower quadrant port. The ligature prevents the spread of the rectal stump and allows applying upward traction on the rectum for a better positioning of the stapler.
- Once the division has been performed, an intact suture line should be visualized, and a patency test may also be performed by injection of a colored solution (Betadine) into the rectal stump.

Mobilization of the Left Colon and Division of the Sigmoid Colon

- The proximal division is performed either intracorporeally or extracorporeally.
- Extracorporeal division is performed after an atraumatic exteriorization of the rectum through a sufficiently large incision protected by a plastic sheath in order to prevent any risk of contamination to the abdominal wall.
- We prefer an intracorporeal transection, which allows reducing the size of the suprapubic abdominal incision.



A

B

FIG 12 ● Distal rectal transection. **A.** Ligation of the distal rectum prior to division. **B.** Division of the rectum with a linear Endo GIA™ stapler introduced through the right lower quadrant port site.

- Division of the sigmoid mesocolon is performed at this moment of the intervention as this will allow appreciating the vascularization of the proximal colonic segment later on after the left colon has been mobilized. The division with the LigaSure™ vessel-sealing device, removing the vascular pedicle and lymph nodes en bloc.
- The mesocolon is divided until contact is made with the proximal colonic segment chosen for the anastomosis.
- Mobilization of the left colon is continued toward the splenic flexure. It is important to have a good knowledge of the different mobilization techniques by means of lateral and posterior division of the splenic flexure attachments.
- In case of limited mobilization of the splenic flexure, we prefer to use a lateral approach by dividing the parietocolic gutter from caudad to cephalad, and then the phrenicocolic ligament and the colo-omental ligament (FIG 13A), thereby opening the lesser sac. Should it be necessary, the transverse mesocolon can be freed from the anterior aspect of the pancreas from lateral to medial.
- If an extensive mobilization of the splenic flexure is required, we prefer using a medial posterior transverse mesocolic approach. We open the transmesocolic axis of the IMV of the lesser sac. Once the lesser sac has been opened, the root of the transverse mesocolon should be divided anteriorly to the pancreas until the tail is reached. Lateral attachments will be freed as described in the previous paragraph (FIG 13B).
- Once the left colon has been mobilized, the sigmoid colon can be divided at the level previously chosen during the dissection of the mesocolon. If the proximal

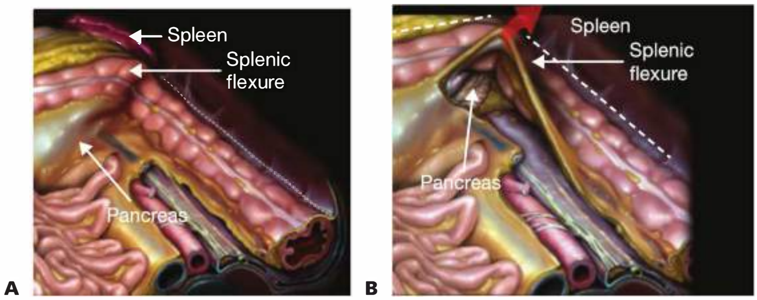


FIG 13 ● Splenic flexure mobilization. **A.** Limited mobilization: a lateral approach, by dividing the parietocolic gutter from caudad to cephalad and then the phrenicocolic ligament and the colo-omental ligament *(dotted lines)*, is used. **B.** Extensive mobilization: We prefer using a medial posterior transverse mesocolic approach, lifting the mesocolon of the tail of the pancreas from medial to lateral *(red arrow)*. The lateral colonic attachments and the phrenocolic and gastrocolic ligaments are then divided *(dotted lines)*.

colon appears to be well-vascularized, division is possible; otherwise, a more proximal division could be necessary. The division is performed intracorporeally with an endoscopic linear stapler (Endo GIA™, Covidien) (**FIG 14**).

Specimen Extraction and Anastomosis

- Specimen extraction is performed after the introduction of a large plastic bag (EndoCatch™ II, Covidien) through a Pfannenstiel's transverse suprapubic incision protected by a plastic sheath (Alexis® wound retractor, Vi-Drape® or SurgiSleeve™ wound protector) (**FIG 15**).
- The proximal colonic segment is then exteriorized through the suprapubic incision to evaluate its vascularization prior to the introduction of the anvil of a conventional circular stapler (DST PC EEA™), 28 mm in diameter. The colon is then reintroduced into the abdominal cavity with the anvil in place.
- Proper contact between the anvil and the rectal stump without tension should be feasible. An intracorporeal end-to-end colorectal mechanical circular anastomosis is then performed (**FIG 16A,B**).
- If the colonic segment does not reach the rectal stump without tension, it may be necessary to complete the colon's mobilization more proximally.

FIG 14 ● Intracorporeal proximal transection. The descending colon is transected with endoscopic linear stapler.

FIG 15 ● Double parietal protection for specimen extraction using a large EndoCatch™ II, introduced through a suprapubic incision protected by a plastic sleeve wound protector.

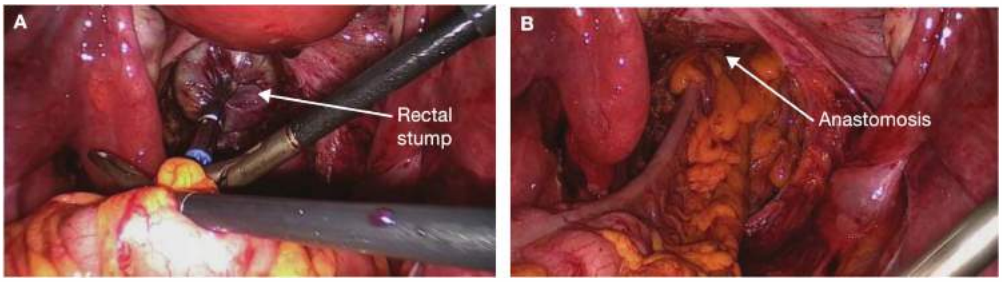


FIG 16 ● End-to-end distal colorectal anastomosis. **A.** Laparoscopic view of the connection between the anvil (placed in the colonic segment) and the shaft of the circular mechanical stapler (placed through the rectal stump). **B.** Pelvic view of a tension-free, end-to-end colorectal anastomosis.

FIG 17 ● Endoscopic inspection of an intact colorectal anastomosis.

- Two intact full-thickness doughnuts should also be obtained. The integrity of the anastomosis will be evaluated by means of an air test if the anastomosis is sufficiently cranial or by means of an endoscopic examination (FIG 17).
- A protective diverting loop ileostomy is recommended for very caudal anastomoses, especially after irradiation and in cases where risk factors such as morbid obesity, smoking, arteriosclerosis, undernourishment, and old age are present. This ileostomy will be reversed after 2 months.
- The intervention is completed with a final control of the abdominal cavity.
- A 14-Fr Blake drain is inserted into the pelvis through the port D's orifice.

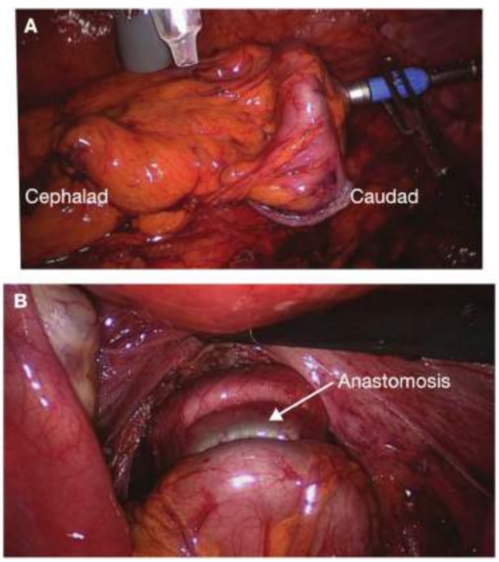


FIG 18 ● Side-to-end colorectal anastomosis. **A.** The anvil (exiting through the antimesenteric border of the colonic segment) has been mated with the end-to-end anastomosis (EEA) stapler shaft (placed through the rectal stump). **B.** Intracorporeal side-to-end anastomosis seen while firing the EEA stapler.

Alternative Anastomotic Techniques

- Side-to-end colorectal anastomosis (FIG 18A,B): It is a first-choice option for very distal anastomoses. It is simpler than J-pouch reservoir anastomoses and provides similar functional results.
- J-pouch colonic reservoir anastomosis (FIG 19A): potentially used in very distal anastomoses (<4 cm from the anal margin). The 5-cm tall reservoir is fashioned using the distal colon retracted upon itself and anastomosed via the antimesenteric border to the rectal stump/anus. The distal anastomosis may be performed by means of a circular stapler or hand sewn using a transanal route.
- The hand-sewn anastomosis is used for very distal tumors and may avoid the need for an abdominoperineal resection (APR) as long as it is possible to obtain a negative distal and radial margin of resection.
- The hand-sewn coloanal anastomosis is performed with interrupted 3-0 full-thickness, reabsorbable sutures placed through the colonic segment and through the internal anal sphincter with the assistance of a Lone Star retractor for exposure (FIG 19B).

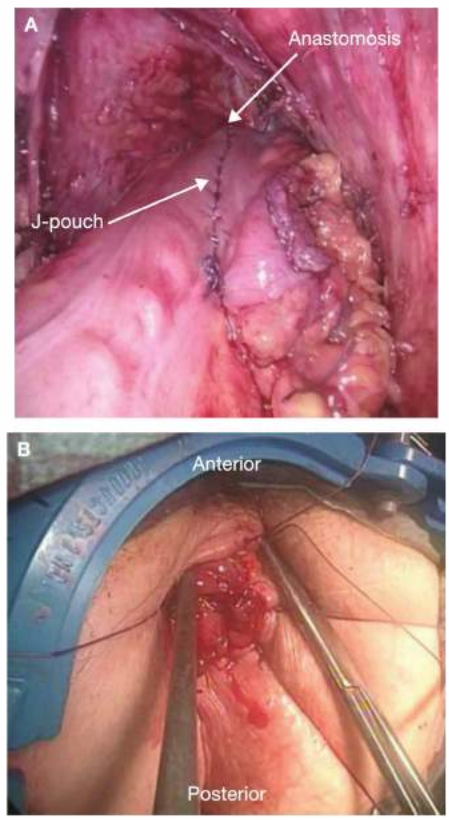


FIG 19 ● J-shaped colonic reservoir anastomosis. **A.** Stapled anastomosis. **B.** Hand-sewn coloanal anastomosis with a Lone Star retractor place to aid with the exposure.

PEARLS AND PITFALLS

Anatomy and embryology	■ Detailed knowledge of the pelvic fascial structures and tissue planes is essential.
Preoperative	■ Adequate staging with colonoscopy and appropriate imaging is important in determining the feasibility of an LAR.
Setup	■ Precise operating room (OR), patient, and team setup is critical to success.

Technique	■ Medial to lateral dissection of the mesocolon
	■ High IMA transection
	■ Pelvic dissection:
	  ■ Posterior first (along the presacral "holy plane")
	  ■ Lateral dissection/transection of the lateral rectal ligaments: Avoid injury to autonomic trunks and genital nerve branches that would lead to autonomic dysfunction postoperatively.
	■ Perform a circumferential dissection. Avoid "conization" of the specimen.
	■ The specimen should have an intact mesorectum.
	■ Anastomosis: Critical that they have excellent blood supply and that they are tension-free.
	■ There is no need to routinely perform J-pouch anastomosis.
	■ For very distal tumors, a hand-sewn coloanal anastomosis may avoid an APR as long as negative distal and radial margins can be obtained.

Postoperative care	■ Driven by a clinical pathway

POSTOPERATIVE CARE

- Postoperative care is driven by clinical pathways that include the following:
  - Pain control: Intravenous acetaminophen for 24 hours (start in the OR) followed by intravenous ketorolac for 72 hours (if creatinine is normal). The transversus abdominis plane (TAP) nerve block greatly reduces the need for narcotics.
  - Deep vein thrombosis (DVT) prophylaxis with enoxiheparin, starting within 24 hours of surgery
  - No additional antibiotics, judicious use of intravenous fluids
  - No nasogastric tube. Remove Foley catheter on postoperative day 1. Remove pelvic drains on postoperative day 2 or 3.
  - Early ambulation, diet ad lib, aggressive pulmonary toilet
  - Targeted discharge: postoperative day 3 or 4

OUTCOMES

- Laparoscopic LAR leads to improvements in short-term outcomes, including less pain, faster recovery, shorter hospital stay, and lower incidence of cardiac/pulmonary complications when compared to open surgery.
- For cancer resection, laparoscopic LAR oncologic outcomes are at least comparable to those of open surgery. TME with an intact mesorectum is critical to minimize locoregional treatment failures in distal rectal cancer.

COMPLICATIONS

- Wound infections and hernias
- Anastomotic leak: It is imperative that the anastomosis is tension-free and has excellent blood supply to prevent this complication.
- Urinary/sexual dysfunction: It is important to preserve autonomic nerves intact.
- Ureteral injury: critical to identify the left ureter prior to IMA transection
- DVT: lower risk with use of DVT prophylaxis

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Chapter **29**

Low Anterior Resection: Hand-Assisted Laparoscopic Surgery Technique

Matthew G. Mutch

DEFINITION

- The hand-assisted laparoscopic surgery (HALS) technique uses a hand-assist device that allows the surgeon to insert his or her hand into the peritoneal cavity while maintaining pneumoperitoneum. The location of the hand port is variable and is placed at the expected site of specimen extraction.
- HALS maintains all the short-term advantages of conventional surgery over open surgery.
- By reintroducing tactile feedback into the field, HALS results in higher usage rates, lower conversion rates, and shorter operative times, when compared to conventional laparoscopic surgery.

DIFFERENTIAL DIAGNOSIS

- The main indication for a HALS low anterior resection is rectal cancer. Patients with diverticulitis with inflammation extending into the mesorectum may also require a low anterior resection.

PATIENT HISTORY AND PHYSICAL FINDINGS

- A thorough history and physical examination are necessary prior to initiation of therapy for patients with rectal cancer.
- It is important to identify the distance of the tumor from the anal verge. Digital rectal exam and rigid proctoscopy are used for this purpose and to determine whether the tumor is mobile, tethered, fixed, or involving the sphincter complex.
- Prior abdominal surgery is not a contraindication to HALS approach. If the patient has had prior surgery, an incision can be made at the site of the hand port and if there are no or minimal adhesion, the hand port can be inserted. If the adhesions are prohibitive of the laparoscopic approach, the hand port incision can be extended into a full laparotomy incision.

IMAGING AND OTHER DIAGNOSTIC STUDIES

- All patients with rectal cancer should have a complete colonoscopy prior to surgery. If the patient has an endoscopically obstructing lesion, a computed tomography (CT) colonography and contrast enema study are acceptable alternatives.
- Preoperative staging of the tumor is paramount so the appropriate use of neoadjuvant therapy can be prescribed. This can be accomplished with either transrectal ultrasound (TRUS) or a rectal protocol magnetic resonance imaging (MRI). Both studies have equivalent accuracy for determining the T and N stages, which are 80% and 60%, respectively. The TRUS is operator dependent and is limited to examining only those nodes adjacent to the tumor. MRI has the advantage of assessing the tumor encroachment of the mesorectal fascia.
- Based on the preoperative T and N staging, the need for neoadjuvant radiation or chemoradiation therapy is determined. Typically, T3, T4, or N+ tumors receive neoadjuvant chemoradiation therapy. Surgical resection then occurs 8 weeks after completion of neoadjuvant therapy.

SURGICAL MANAGEMENT

Preoperative Planning

- Prior to taking the patient to the operating room, they should be marked for a possible diverting ileostomy. The patient needs to be assessed in the supine, sitting, and standing positions. The stoma should rest on the apex of skin fold and adequate distance from bony prominences, skin creases, and the waistline of their pants. The stoma should be brought through the rectus muscle to minimize the risk of developing a parastomal hernia.
- The use of ureteral stents is left to the discretion of the surgeon.

Positioning

- The use of a mechanical bed that is able to place the patient in the extremes of position is necessary.
- There are many methods by which a patient can be secured to the bed. A beanbag, a nonslip pad, shoulder braces, or foam pads can be used for this purpose.
- The patient should be placed in a modified lithotomy position with Allen or Yellofin stirrups (**FIG 1**). This allows access between the legs to assist with mobilization of the left colon and to the perineum for the anastomosis. The thighs

FIG 1 ● Patient positioning. The patient is placed on a lithotomy position with the hips slightly flexed and the legs in Yellofin stirrups. The thighs are placed parallel to the ground to avoid interference with the surgeon's arms and instruments. The patient is secured to the table with tape applied over a towel across the chest. The arms are tucked to the sides. All pressure points are padded to avoid neurovascular injuries.

are placed parallel to the ground to avoid conflict with the surgeon's elbows.

- Both arms are tucked to the patient's side with the thumbs facing up. This allows the surgeon, assistant, and camera driver plenty of room to maneuver during the case.
- A monitor should be placed off the patient's left shoulder during the mobilization of the left colon and splenic flexure. During the pelvic dissection, a monitor should be placed off the patient's left foot for the surgeon and another should be placed off the patient's right foot for the assistant.

PORT PLACEMENT AND OPERATIVE TEAM SETUP

- There are several options for the position of the hand port:
    - The hand port can be placed through either a Pfannenstiel or a midline incision. The suprapubic position allows for direct visualization into the pelvis. The hand port can then be used to facilitate the rectal dissection, for division of the distal rectum, for the performance of the anastomosis, and to address any pelvic complications such as bleeding or anastomotic failure.
    - The periumbilical position allows the surgeon to put his or her nondominant hand through the hand port.
    - A left lower quadrant (LLQ) position uses a muscle-splitting incision and allows for the right hand to be placed into the abdomen to facilitate the lateral and splenic flexure mobilizations of the left colon.
- For the purposes of this chapter, the suprapubic hand port position is discussed (**FIG 2**).
- The 5-mm or 12-mm camera port is placed in the supraumbilical position. The camera needs to be above the umbilicus, as the wound protector portion of the hand port extends several centimeters beyond the edges of the incision.
- The primary laparoscopic working port (12-mm port) is placed in the right lower quadrant (RLQ), at an equal distance between the hand port and the camera port and lateral to the rectus muscle.
- A 5-mm working port for the first assistant is placed in the LLQ. This will allow the assistant to help with the lateral and splenic flexure mobilization and the pelvic dissection. The lower the port is placed, the less time the assistant works in a reverse motion to the camera during the lateral and splenic flexure mobilization.
- The surgeon stands by the patient's right side with his or her right hand placed in the hand port. The camera operator stands to the left side of the surgeon. The assistant stands by the patient's left side (**FIG 3**).

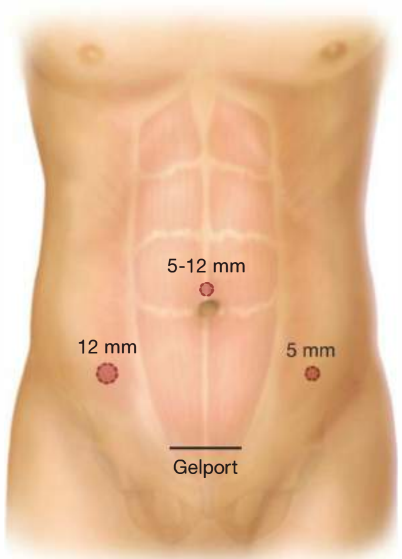


FIG 2 ● Port placement. The GelPort is placed through a 5- to 6-cm Pfannenstiel incision. A 5- or 12-mm supraumbilical port is used for the camera. Two working ports, a 12-mm RLQ and a 5-mm LLQ ports, are inserted.

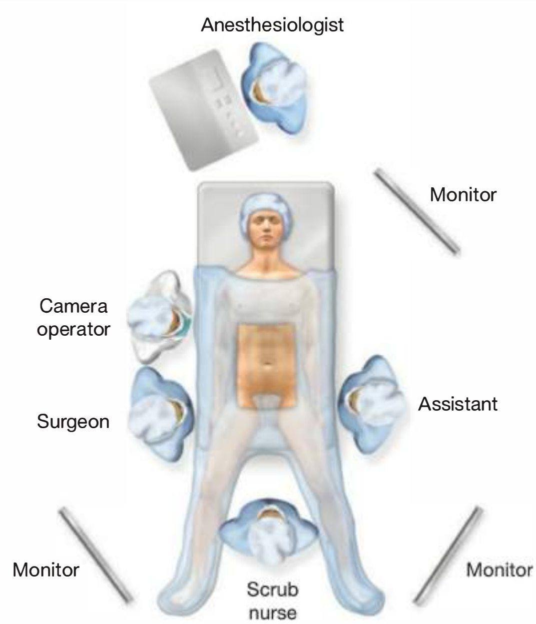


FIG 3 ● Operating team setup. The surgeon stands by the patient's right side with his or her right hand placed in the hand port. The camera operator stands to the left side of the surgeon. The assistant stands by the patient's left side. The scrub nurse stands between the patient's legs. A monitor should be placed off the patient's left shoulder during the mobilization of the left colon and splenic flexure. During the pelvic dissection, a monitor should be placed off the patient's left foot for the surgeon and another should be placed off the patient's right foot for the assistant.

TRANSECTION OF THE INFERIOR MESENTERIC ARTERY

- The patient is placed in a steep Trendelenburg position and in airplane position with the left side up to use gravity to place the small bowel in the right upper quadrant (RUQ) and the omentum in the upper abdomen to expose the transverse colon and splenic flexure. This helps to expose the inferior mesenteric artery (IMA) at its origin off the aorta and the inferior mesenteric vein (IMV) at the level of the ligament of Treitz.
- The surgeon's right hand is placed through the hand port and an energy source is placed through the RLQ working port.
- The retroperitoneum is accessed at the level of the sacral promontory. The superior rectal artery is grasped and elevated (**FIG 4**). A wide incision is made in the peritoneum dorsal to this artery; the wider the incision, the more the artery can be more elevated to obtain better exposure. Because of the curve of the pelvis at this point, the sigmoid mesentery curves up and away from the visual field. Therefore, the retroperitoneal plane is higher than expected, so the more mobile the arterial pedicle is, the easier it is to visualize the correct plane.

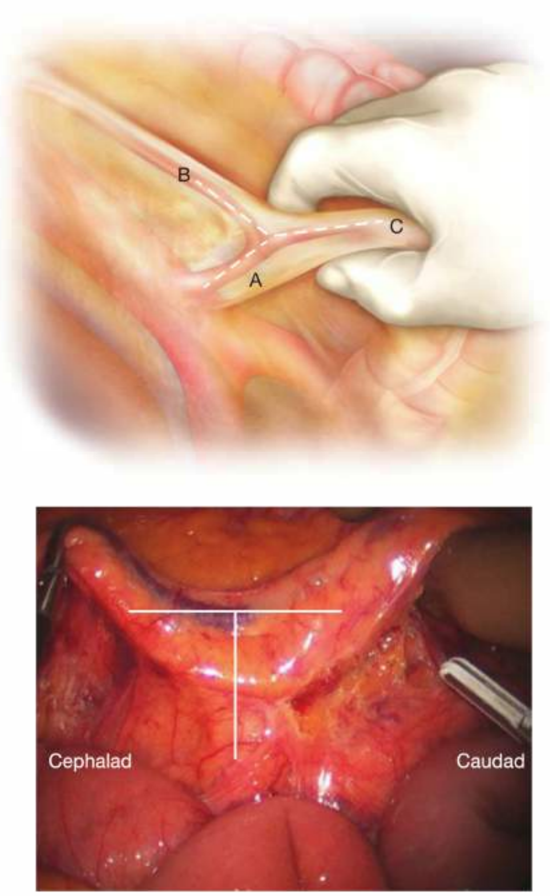


FIG 4 ● Identification of IMA and its branches. Identify the "letter T" formed between the IMA *(A)* and its left colic artery *(B)* and superior hemorrhoidal artery (SHA) *(C)* terminal branches. The IMA takeoff is just cephalad from the aortic bifurcation. The thumb and index finger are lifting the SHA off the groove located anterior to the right common iliac artery.

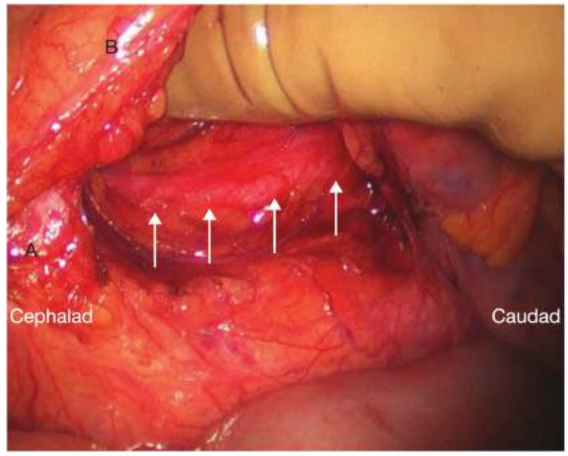


FIG 5 ● Identification of the left ureter. After the IMA *(A)* and superior hemorrhoidal artery (SHA) *(B)* have been lifted off the retroperitoneum, the left ureter *(arrows)* can be identified and preserved intact. Identification of the left ureter at this stage is critical in order to avoid injuring the ureter during the IMA transection.

- Identification of the left ureter is necessary before the IMA can be ligated (**FIG 5**). The following text is a four-step algorithm to identify the left ureter.
  - Mobilization of the superior rectal artery is as described earlier and the ureter is identified.
  - At the level of the IMV: The IMV is grasped and elevated. The peritoneum is incised dorsal to the IMV and the retroperitoneum is accessed. The retroperitoneum is flat in this area and is often more easily accessed. Once in the correct plane, the dissection is carried in a caudad fashion to meet up with the initial plane under the superior rectal artery.
  - If the ureter is still not identified, the sigmoid and left colon is mobilized in a lateral to medial fashion.
  - Finally, the top of the hand port can be removed and the left ureter can be located via an open fashion.
- After the left ureter is identified and swept into the retroperitoneum, the IMA can be isolated at its origin (**FIG 6**). The index finger elevates the superior rectal artery and the middle finger is used to sweep down the retroperitoneum along the course of the IMA. This motion continues until the bare area is exposed cephalad to the IMA and medial to the IMV.
- It is important to sweep down the retroperitoneal tissue in this area to help preserve the sympathetic plexus around the IMA. Once the IMA is safely isolated and the left ureter is clearly out of harm's way, the vascular pedicle can be ligated at its origin from the aorta with the surgeon's energy source of choice or with a linear stapler with a vascular cartridge (**FIG 7**).

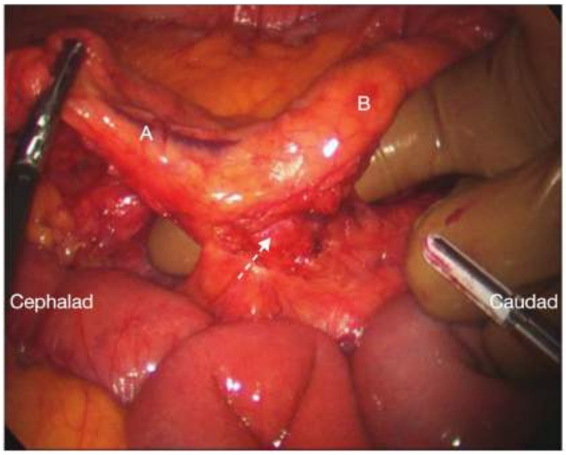


FIG 6 ● Circumferential dissection of the IMA. After the left ureter has been identified, the IMA *(arrow)* is circumferentially dissected at its origin of the aorta. Again, the "letter T" formed between the IMA and its terminal branches, the left colic artery *(A)* and the superior hemorrhoidal artery (SHA) *(B)* can be clearly identified.

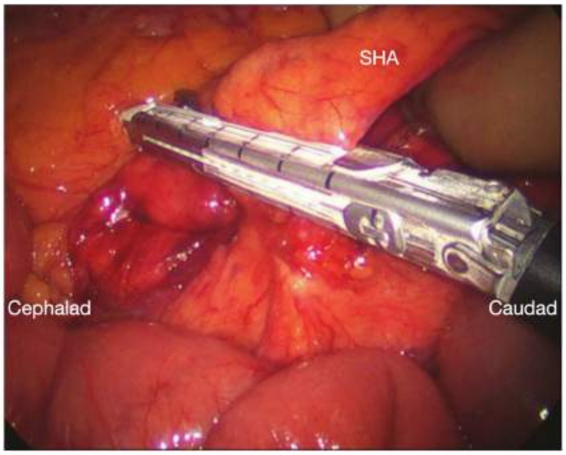


FIG 7 ● Transection of the IMA. With the left ureter safely dissected away into the retroperitoneum, the IMA is transected with a linear vascular stapler at its origin of the aorta. The surgeon's hand is holding the superior hemorrhoidal artery (SHA) anteriorly.

TRANSECTION OF THE INFERIOR MESENTERIC VEIN

- The IMV courses parallel to the left colic artery. The previous IMA dissection plane is carried cephalad with Endo Shears and 5-mm energy device (sweeping the retroperitoneal tissues dorsally) until the left colic artery separates from the IMV as it courses toward the splenic flexure at the level of the ligament of Treitz.
- Now that the IMV is elevated off the retroperitoneum, it is isolated at the inferior border of the pancreas and near the ligament of Treitz (**FIG 8**). It can be isolated with the same technique used for the IMA: The index finger and thumb elevate and create tension on the IMV and the middle finger and/or dissecting instrument sweeps the retroperitoneum dorsally along the course of the vein (**FIG 9**).
- A bare area is then created near the inferior border of the pancreas that allows the IMV to be safely isolated.
- Once isolated, the IMV can be safely transected with an energy device (**FIG 10**). The IMV should be transected cephalad to the left colic artery in order to preserve the marginal artery blood supply to the descending colon intact.

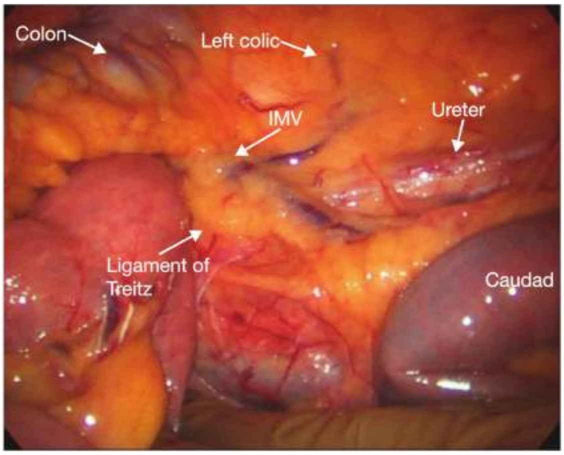


FIG 8 ● Identification of the IMV. The IMV can be identified at the root of the mesotransverse colon at the level of the ligament of Treitz. At this level, the IMV has separated from the left colic artery (which courses away from the IMV and toward the splenic flexure of the colon) and from the left ureter.

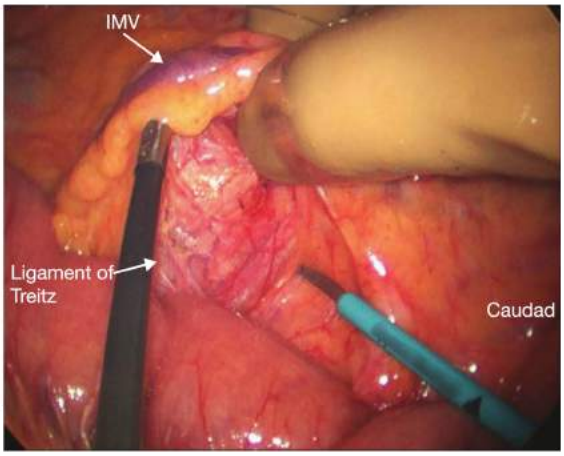


FIG 9 ● Dissection of the IMV. With the surgeon holding the IMV anteriorly, the retroperitoneal tissues are swept down (dorsally).

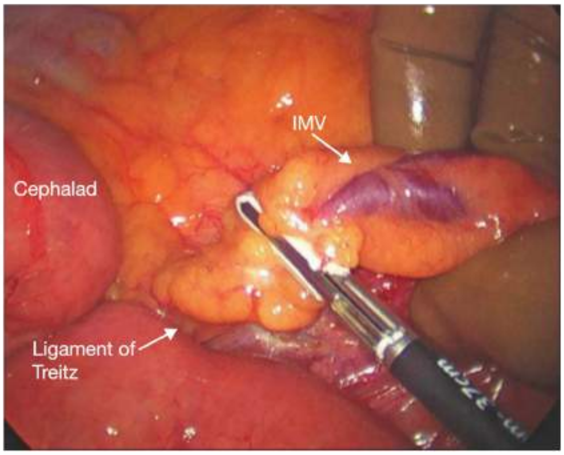


FIG 10 ● IMV transection. The IMV is transected with an energy device at the level of the IMV, cephalad of the left colic artery. This preserves intact the marginal artery of Drummond and ensures excellent blood supply to the descending colon segment for the anastomosis.

MOBILIZATION OF THE LEFT COLON

- The left colon mesentery is now dissected off the retroperitoneum using a medial to lateral dissection approach (**FIG 11**) all the way out to the lateral abdominal wall.
- The hand is placed palm down under the mesentery to elevate it as a fan-type retractor. The plane is dissected bluntly with an energy device from the sigmoid colon up to the splenic flexure. The further laterally and superiorly the dissection is carried, the easier the lateral dissection and splenic flexure mobilization will be later during the case. Care must be taken during mobilization near the inferior border of the pancreas, as it is very easy to carry the dissection deep to the pancreas.
- All that remains at this point are the lateral attachments. The hand is used to depress the sigmoid colon and lateral peritoneum is incised (**FIG 12A**). It is not uncommon for the hand to get in that way at this point, so it may be necessary to pass the energy source through the surgeon's fingers or the hand may be taken out and an instrument can be passed through the hand port to begin the dissection.
- Once the medial plane of dissection is accessed, the hand can be passed in the opening and the lateral attachments are elevated and exposed (**FIG 12B**). At this point, the surgeon uses a grasper for exposure and the first assistant uses the energy source through the LLQ port.

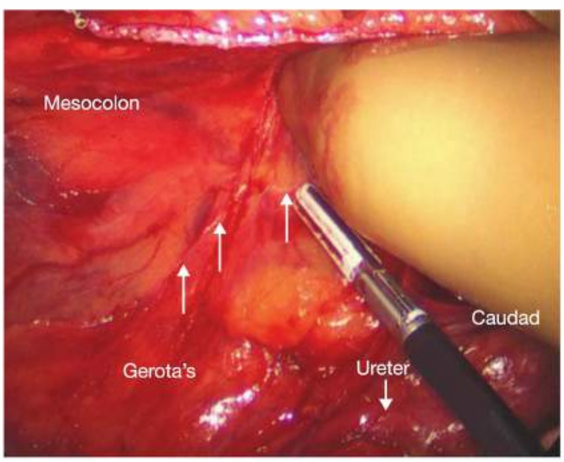


FIG 11 ● Medial to lateral dissection. With the surgeon holding the mesocolon anteriorly (notice the stapled transected IMA stump in between the surgeon's fingers), the retroperitoneal tissues are swept downward (dorsally) with an energy device. The dissection progresses along the transition of the two fat planes: mesocolon and Gerota's *(arrows)*.

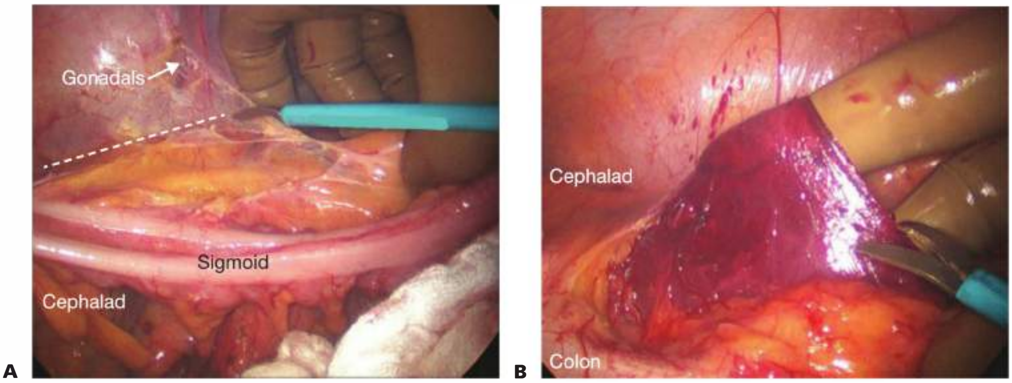


FIG 12 ● Lateral mobilization of the sigmoid and descending colon. **A.** The white line of Toldt *(dotted line)* is transected with an energy device. **B.** The medial to lateral dissection plane is readily entered, greatly facilitating the lateral mobilization of the descending colon.

MOBILIZATION OF THE SPLENIC FLEXURE

- As the splenic flexure is reached, a transition to separate the omentum from the transverse colon must be made. The surgeon's hand reflects the colon downward and the grasper elevates the omentum in a vertical fashion. Only the peritoneum is divided moving along the transverse colon. Eventually, the lesser sac is entered.
- Once the peritoneum attaching the omentum to the transverse colon has been divided to the extent of the dissection, the next layer of attachments of the omentum and the transverse colon mesentery can be divided. The gastrocolic ligament is transected in this way medial to lateral until the splenic flexure is reached (**FIG 13**).
- Returning to the splenic flexure, the colon is grasped laterally with the hand and medially with a grasper. The colon is put on stretch and pulled down and medial to identify the next level of attachment between the splenic flexure of the colon and the diaphragm and spleen. The splenodiaphragmatic and splenocolic ligaments are then transected with an energy device (**FIG 14**).
- All that remains are the posterior attachments to the inferior border of the pancreas. Division of these attachments to the midline allows for a full mobilization of the splenic flexure. This ensures adequate reach of the proximal colon for a tension-free anastomosis.

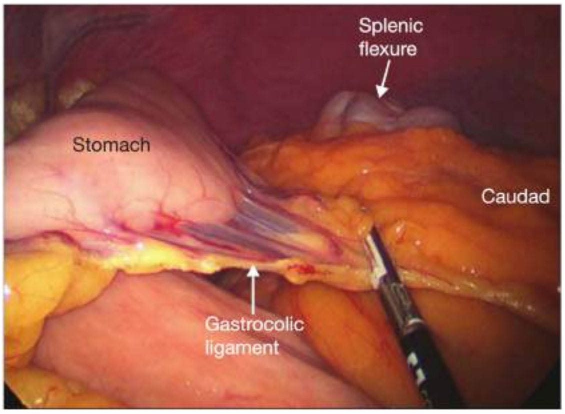


FIG 13 ● Transection of the gastrocolic ligament. After entering the lesser sac (between the stomach and the transverse colon), the gastrocolic ligament is transected from medial to lateral (toward the splenic flexure of the colon) with an energy device.

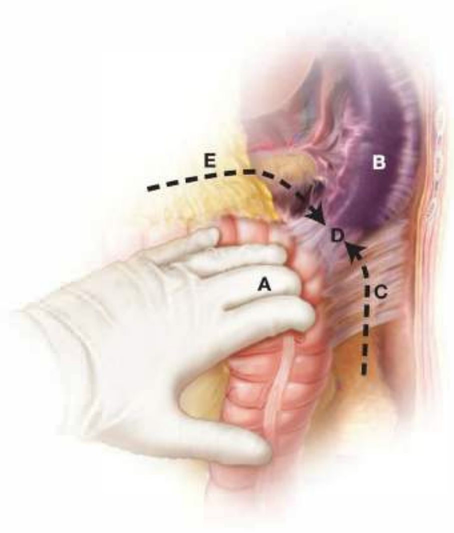


FIG 14 ● Mobilization of the splenic flexure. The surgeon retracts the splenic flexure of the colon *(A)* downward and medially, exposing the attachments of the splenic flexure to the spleen *(B)*. The phrenocolic *(C)* and splenocolic *(D)* ligaments are transected in an inferior to superior and lateral to medial direction, meeting the previously transected gastrocolic ligament dissection plane around the splenic flexure.

THE PELVIC DISSECTION AND DISTAL RECTAL TRANSECTION

- The pelvic dissection can be performed with either the hand used as a retractor, straight laparoscopically, or open through the suprapubic hand port.
- Conceptually, the rectum and mesorectum form a cylinder within the cylinder of the pelvis. This means the lines of dissection are circular and the ability to provide 360-degree exposure is necessary.
- The directions of retraction are anterior, posterior, medial, and lateral, with the goal being to make the plane of dissection perpendicular to the energy source. Avoid pulling the rectum and mesorectum out of the pelvis, as this does not optimize the exposure and space within the pelvis.
- The posterior dissection is performed first. The surgeon stands on the patient's right side with his or her right hand placed in the abdomen. With the thumb rotated medially and the palm up, the mesorectum is elevated and the presacral plane is entered (**FIG 15A**). Care is taken to identify and preserve the right and left hypogastric nerves intact.
- As the hand moves deeper into the pelvis, the fingertips are able to determine and expose the proper line of dissection. The mesorectum should be retracted anteriorly and not pulled out of the pelvis. The goal is to make the plane of dissection perpendicular to the energy source that is dividing the tissue.
- As the dissection proceeds on the right, posterior, and left, the hand subtly rotates the mesorectum to keep the plane of dissection perpendicular.
- Early on in the dissection, it is important to incise the peritoneum lateral to the rectum and mesorectum (Douglas pouch). The division should be carried all the way down to the peritoneal reflection. This helps to facilitate the lateral dissection and avoid carrying the lateral dissection too wide, minimizing the risk of injury to the parasympathetic nerves.
- The lateral dissection follows, with transection of the lateral rectal ligaments (**FIG 15B**).
- The posterior and lateral dissections are carried out down to the pelvic floor. All fat needs to be cleared off the levator muscles at the pelvic floor.
- The anterior peritoneal reflection is incised, with the hand retracting the uterus and cervix or prostate anteriorly. For the anterior dissection, the first assistant retracts the rectum posteriorly and rotates the direction of retraction as the dissection proceeds along Denonvilliers' fascia and behind the prostate/seminal vesicles in men (**FIG 15**) or the vagina in females. Once again, the

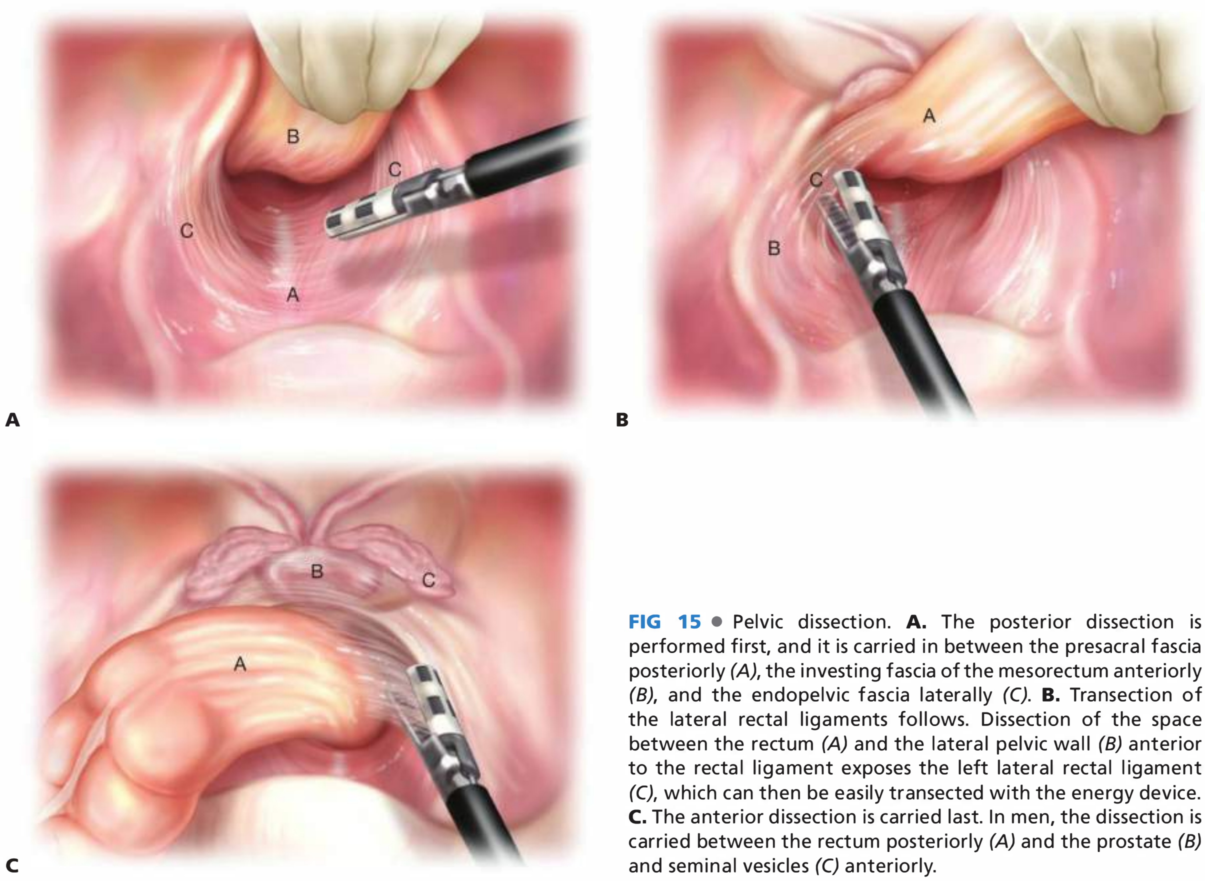


FIG 15 ● Pelvic dissection. **A.** The posterior dissection is performed first, and it is carried in between the presacral fascia posteriorly *(A)*, the investing fascia of the mesorectum anteriorly *(B)*, and the endopelvic fascia laterally *(C)*. **B.** Transection of the lateral rectal ligaments follows. Dissection of the space between the rectum *(A)* and the lateral pelvic wall *(B)* anterior to the rectal ligament exposes the left lateral rectal ligament *(C)*, which can then be easily transected with the energy device. **C.** The anterior dissection is carried last. In men, the dissection is carried between the rectum posteriorly *(A)* and the prostate *(B)* and seminal vesicles *(C)* anteriorly.

assistant should avoid pulling the rectum out of the pelvis, as this does not optimize exposure and space within the narrow confines of the pelvis.

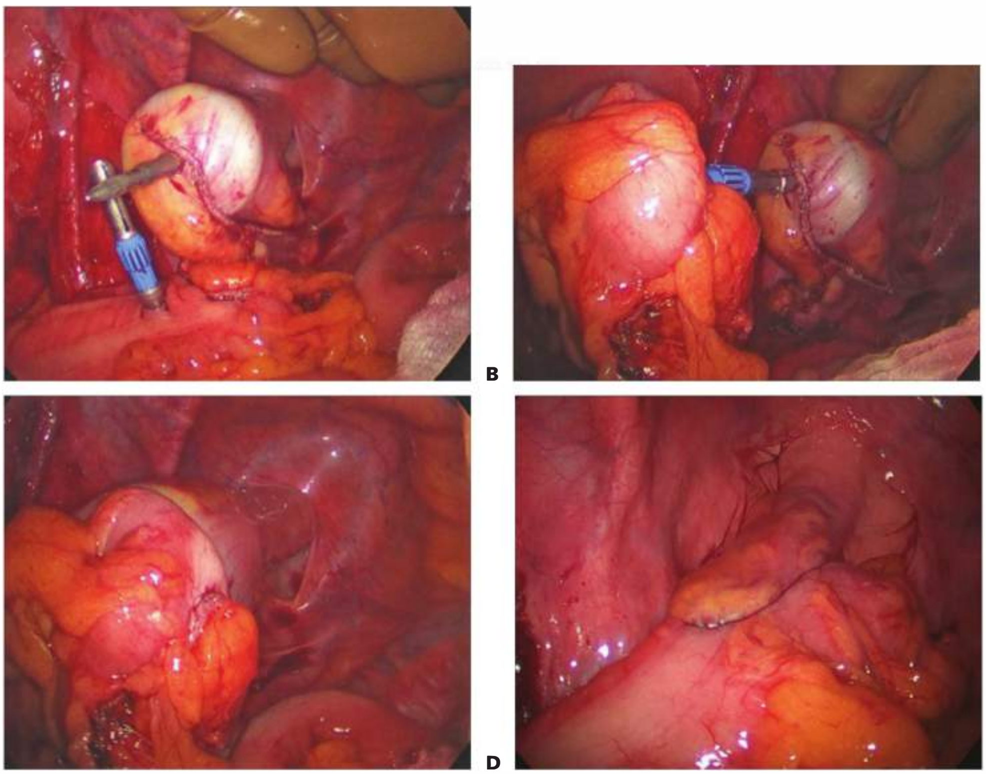
- For a tumor of the upper rectum, a tumor-specific mesorectal excision can be performed with a 5-cm distal margin. For a tumor of the mid to lower rectum, a total mesorectal excision should be performed.
- The rectum can then be stapled and divided with a linear stapler through the open hand port. This allows the rectum to be divided with a single firing of the stapler.

EXTRACORPOREAL PROXIMAL TRANSECTION

- The rectum and colon can then be extracted through the hand port and the proximal site of division of the colon can be selected. For rectal cancer, the ligated IMA pedicle should be resected with the specimen to ensure an adequate lymph node harvest.
- The colon is divided proximally at the desired level between clamps. The specimen is now completely disconnected.
- Once the specimen is removed, it should be inspected and the quality of the mesorectal excision (complete, near complete, incomplete) should be noted and documented.

ANASTOMOSIS

- If an end-to-end anastomosis (EEA) will be constructed, a purse string is then created, and the EEA stapling anvil is placed in the open proximal colotomy. If a side-to-end anastomosis will be constructed, the EEA anvil is introduced through the open end of the descending colon and is exteriorized with the spear through an antimesenteric location in the descending colon approximately 5 cm proximal to the open end of the colon. The open end of the colon is then closed with a linear stapler.
- The type of reconstruction of the neorectum is left up to the discretion of the surgery. Options include a colonic J-pouch, coloplasty, Baker-type anastomosis, and straight colorectal/coloanal anastomosis.
- Once the stapling cartridge is passed transanally to the top of the rectal stump, the spike is deployed and the anvil is reassembled. This can be performed either laparoscopically (FIG 16A–D) or open through the



A B C D

FIG 16 ● An intracorporeal side-to-end colorectal anastomosis. **A.** The anvil of the EEA stapler is in antimesenteric location in the distal descending colon. The spear of the EEA stapler can be seen protruding through the rectal stump. **B.** The anvil and the spear of the EEA stapler have been mated. **C.** While the EEA stapler is fired, care is taken to avoid getting the bladder (or vagina) trapped in the stapler. **D.** The completed side-to-end colorectal anastomosis is tension-free and has excellent blood supply.

hand port. As the anvil is cinched down, ensure that the posterior wall of the vagina or anterior tissue in a male is free from the stapler.

- The anastomosis should be assessed by inspecting the anastomotic doughnuts and by performing an air leak test (FIG 17) or endoscopic visualization of the anastomosis.
- A drain may be placed to drain whatever blood or fluid accumulates in the pelvis to minimize fibrosis of the neorectum.

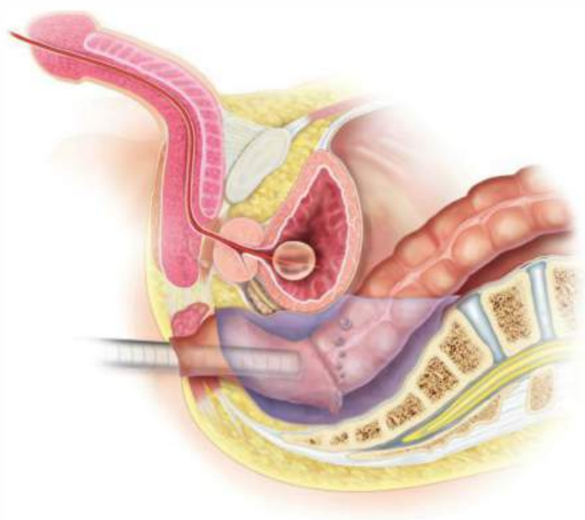


FIG 17 ● Air leak test. The anastomosis is tested under water. The presence of air bubbles would indicate an anastomotic disruption and should trigger a revision of the anastomosis.

CLOSURE OF THE ABDOMEN

- All 12-mm port fascial sites should be closed. The 5-mm port fascial sites do not need to be closed. Skin incisions are closed with subcuticular closure.
- The hand port can be closed with either interrupted or running stitch of no. 1 polydioxanone (PDS) suture.
- The indication for a diverting stoma is left at the discretion of the surgeon.

PEARLS AND PITFALLS

Indications	■ A complete history and review of preoperative staging is necessary to determine the need for neoadjuvant therapy. ■ The distance of the tumor to the anorectal ring needs to be clearly determined and documented. ■ T4 tumors, or those where there is concern for involvement of the circumferential margin, should not be approached laparoscopically.
Placement of the hand port	■ The suprapubic positions offers many advantages such as access to the pelvis to help with the dissection, division of the rectum, performance of the anastomosis, or management of bleeding or anastomotic complications.
Accessing the retroperitoneum	■ Different options include a medial approach, either at the level of the sacral promontory or at the IMV (by the ligament of Treitz), or alternatively, a lateral approach can be used.
Identification of the left ureter	■ A four-step technique was described above. Do not spend a lot of time with one approach if you are having difficulty, as the other steps described are anyway necessary to complete the case. Therefore, alternating your approach to identifying the ureter also helps complete other steps of the procedure.
Mobilization of the splenic flexure	■ The more extensive the medial to lateral dissection of the mesocolon is, the easier it is to mobilize the splenic flexure. ■ Be patient when entering the lesser sac. ■ Incise the peritoneum fusing the omentum to the transverse colon and dissect the omentum off the backside of the mesentery one layer at a time. ■ It is useful to alternate dissection between the lateral and medial aspects of the splenic flexure during this step.
Pelvic dissection	■ Creating space in the pelvis can be challenging. As a result, it is a natural reaction to pull the hand out of the pelvis. The exact opposite is necessary. The hand needs to be deeper in the pelvis; exposure is created by flexing the fingers and leaving the palm in place. ■ Small changes in the direction of tension are vital for increasing exposure and efficiency of the dissection.

POSTOPERATIVE CARE

- The patient can begin a liquid diet on the day of surgery. The diet can be advanced as tolerated. Solid food can be safely provided before the resumption of bowel function.
- A urinary catheter should remain in place for 3 to 4 days postoperatively to minimize the risk of urinary retention.
- Patients can begin ambulation as early as the day of surgery and by postoperative day 1; they are to be encouraged to spend more time out of bed than in bed.
- Venous thromboembolism (VTE) prophylaxis is important because most patients have rectal cancer and underwent a pelvic dissection. Low-molecular-weight heparin (LMWH), subcutaneous heparin, or pneumatic compression boots are all acceptable methods. There is data supporting the use of LMWH for 21 days postoperatively to decrease the risk of VTE.
- The drain can be removed on postoperative day 4 regardless of the volume of the output, unless it is draining urine, stool, or pus.

OUTCOMES

- There are currently three published trials of laparoscopic versus open resection of rectal cancer. The Conventional versus Laparoscopic-Assisted Surgery in Colorectal Cancer (CLASICC), COlorectal cancer Laparoscopic or Open Resection (COLOR II), and Comparison of Open versus laparoscopic surgery for mid or low REctal cancer After Neoadjuvant chemoradiotherapy (COREAN) trials have demonstrated equivalent outcomes for two approaches with regard to margins, lymph node harvest, recurrence, and survival.
- When HALS is compared to conventional laparoscopic-assisted colectomy, multiple prospective randomized trials have demonstrated no difference in short-term outcomes including length of stay, return of bowel function, or pain scores. Furthermore, HALS has been shown to decrease the operative time for a left colectomy by 33 minutes and a total abdominal colectomy by 57 minutes and the risk of conversion over straight laparoscopy as well as to significantly decrease conversion rates.
- Oncologically, recent studies have demonstrated comparable short-term outcomes, lymph node harvest, and margin status when HALS is compared to straight laparoscopic proctectomy.

COMPLICATIONS

- Bleeding
- Anastomotic leak
- Wound infection
- Pelvic abscess
- Ureteral injury
- Urinary and/or sexual dysfunction
- Incomplete mesorectal dissection
- VTE
- Incisional hernia

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Chapter 30

Low Anterior Rectal Resection: Robotic-Assisted Laparoscopic Technique

Mehraneh D. Jafari   Alessio Pigazzi

DEFINITION

- Low anterior resection (LAR) is most commonly performed for patients with mid to low non–sphincter-invading rectal adenocarcinoma. A simple surgical definition of LAR is full mobilization and division of the rectum at the level of the levators, leaving behind only a short or no rectal stump.
- LAR for rectal cancer requires a total mesorectal excision (TME) to ensure a radical resection with adequate radial margins.[1] The goal is to achieve an en bloc resection of the cancer with complete dissection of the pararectal lymph nodes contained within the mesorectum.
- Robotic-assisted laparoscopic LAR is a novel surgical technique that allows for a minimally invasive approach to TME. Robotic LAR can be performed via totally robotic or laparoscopic/robotic hybrid techniques. Our preferred method is a hybrid approach involving a laparoscopic medial to lateral mobilization of the colon and of the splenic flexure followed by a robotic TME.

PATIENT HISTORY AND PHYSICAL FINDINGS

- A full history and physical examination will allow the surgeon to determine if a sphincter-sparing operation is possible, whether a temporary ileostomy is likely, and will also aid in discussions regarding postoperative functional status.
- History elements elicited should include baseline functional status, bowel incontinence, sexual dysfunction, urinary dysfunction as well as pain with defecation or tenesmus. Previous history of pelvic radiation and pelvic surgery should also be noted.
  - History of incontinence should prompt discussions regarding postoperative quality of life with a low anastomosis.
  - History of pain or tenesmus suggests involvement of the anal sphincter or a larger tumor. This will alter the course of treatment, and a sphincter-sparing operation may not be possible in this subgroup of patients.
- Physical examination should include a digital rectal examination (DRE), vaginal examination, anoscopy, and a thorough abdominal examination.
  - DRE should assess tumor size, degree of fixation to rectal and pelvic wall, mobility, location (anterior/posterior/lateral), distance from the anorectal ring, and anterior extension into vagina/prostate. Anal sphincter involvement can also be determined by DRE in the majority of patients.
  - Anterior rectal tumors in female patients require a vaginal examination to rule out extension into the vagina.
  - Anoscopy for low rectal tumors may allow for better visualization of the tumor during the physical examination.
  - The abdominal examination should evaluate for liver metastasis. A bilateral groin examination should be performed to evaluate for potential inguinal lymphadenopathy.

IMAGING AND OTHER DIAGNOSTIC STUDIES

- The physical examination in conjunction with endoscopy and imaging modalities will aid in the preoperative surgical evaluation and staging. This preoperative workup will dictate the best surgical approach, the need for temporary diversion, and the need for neoadjuvant therapy.
- Colonoscopy must be performed in all patients with rectal cancer.
  - This will allow for assessment of tumor location and pathology.
  - It will also serve to rule out and possibly remove any synchronous colonic lesions. Malignant synchronous lesions have been reported in 2% to 8% of cases and benign synchronous polyps in 13% to 62% of cases.[2–4]
  - If a colonoscopy has already been done by another provider, it is our preference to perform a flexible sigmoidoscopy in all patients for documentation of the size, location, and distance of the tumor from the anal sphincter complex.
- The use of preoperative tattoos in rectal cancer patients undergoing anterior resection is unnecessary and unreliable to determine distal margins. The best assessment of the margin is obtained via frequent and thorough digital examinations, intraoperative flexible endoscopy, and adherence to the best TME surgery criteria.
- Accurate staging of rectal cancer should be able to determine depth of invasion, presence of lymph node metastases, and resectability of locally advanced tumors.
  - Endorectal ultrasound has an overall 80% to 95% staging accuracy.[5]
    - The ability to visualize the layers of the bowel wall allows for accurate T staging (**FIG 1**).
      - T1 stage is associated with 88% sensitivity and 98% specificity.
      - T2 stage is associated with 81% sensitivity and 96% specificity.
      - T3 stage is associated with 96% sensitivity and 91% specificity.
      - T4 stage is associated with 95% sensitivity and 98% specificity.[5]
    - Detection of lymph node metastasis is associated with 73% sensitivity and 76% specificity.[6]
  - High-resolution pelvic magnetic resonance imaging (MRI) delineates the layers of the bowel wall in T2 weighted images. It is associated with 93% to 97% sensitivity for T staging and 77% sensitivity for lymph node metastasis.[7,8]
  - Computed tomography (CT) scan of chest, abdomen, and pelvis should be obtained for preoperative evaluation metastases as per National Comprehensive Cancer Network (NCCN) guidelines.[9] It is associated with 40% to 86% accuracy in staging rectal cancers.[8,10,11]

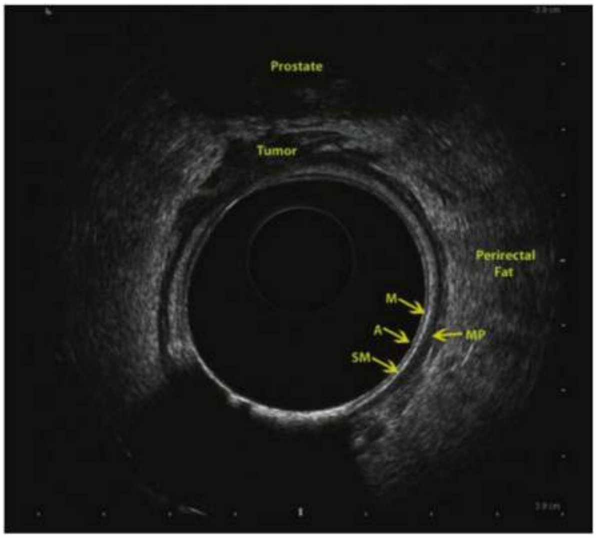

FIG 1 ● Endoscopic ultrasound (EUS) depicts the bowel wall layers: *A* indicates balloon interface, *M* indicates mucosa/muscularis mucosa, *SM* indicates submucosa, and *MP* indicates muscularis propria. This patient has an anteriorly located tumor with invasion of the perirectal fat but no direct extension into the prostate (EUS T3).

SURGICAL MANAGEMENT

Preoperative Planning

- Surgical decision is based on rectal cancer staging. As per NCCN guidelines, neoadjuvant chemotherapy and radiation therapy (CRT) should be considered for all N+ positive tumors based on preoperative imaging. The use of neoadjuvant CRT in T3N0 tumors is somewhat controversial. Proximal T3 tumors with no involvement of the circumferential resection margin (i.e., posterior lesions surrounded by abundant mesorectum) can selectively undergo radical resection without CRT.[9]
- Neoadjuvant CRT has been shown to reduce the local recurrence rate and increase the chances of sphincter-sparing surgery.[9]
- The decision for neoadjuvant chemotherapy should stem from a multidisciplinary discussion amongst the surgeon, oncologist, radiation oncologist, and patient.
- An enterostomal therapist should be involved for counseling and for potential stomal marking prior to operation.
- Despite the debate regarding bowel preparation, we routinely use mechanical bowel preparation at our institution for easier manipulation of the bowel during surgery. Our institution's standard bowel preparation is 510 mg of MiraLAX® in 128 oz of Gatorade®.
- Rectal irrigation via saline solution is performed in all patients.
- A Foley catheter is placed in all patients after induction for bladder decompression.
- Prophylactic ertapenem (Invanz®) antibiotic is administered prior to induction of anesthesia.
- Sequential compression devices are placed in all patients. However, the use of pharmacologic deep vein thrombosis (DVT) prophylaxis is not routinely used. The benefit of chemical prophylaxis remains controversial.[12,13]

Positioning

- The patient is placed in a modified lithotomy position with attention placed to correct technique to minimize injury:
  - The patient is ideally placed on a large high-density viscoelastic foam mat to prevent sliding.
  - The patient is brought to the edge of the table and the legs are placed into Yellofin® or Allen® stirrups with the hips slightly flexed and abducted, the feet flat within the stirrups, and pressure avoided along the lateral aspects of the legs. The ankle, knee, and contralateral shoulder should be aligned.
  - A Velcro belt is strapped over the chest to prevent side-to-side sliding.
- The perineum is prepped if a transanal extraction and or hand-sewn anastomosis is anticipated.

LAPAROSCOPIC MEDIAL TO LATERAL DISSECTION OF COLON

Port Placement

- Pneumoperitoneum is established via a Veress needle at Palmer's point (1 to 2 cm below the left costal border in the midclavicular line [MCL]).
- The ports are triangulated and placed at a minimum of one handbreadth apart (FIG 2).
- The camera (C) port is placed halfway between the xiphoid process and symphysis pubis.
- Three robotic (R) ports will be placed as follows (FIG 2):
  - R1 is a 12-mm trocar inserted in the MCL halfway in between C and the right anterior superior iliac spine (ASIS). This port can be used for ileostomy placement at the end of the surgery.
  - R2 is an 8-mm trocar inserted as a mirror image of R1.
  - R3 is an 8-mm trocar inserted 8 to 10 cm lateral to R2, usually directly above the left ASIS.
- Laparoscopic-assisted (L) ports (FIG 2):
  - L1 is a 5-mm trocar inserted in the MCL about 12 cm superior to R1.
  - L2 is a 5-mm port inserted halfway between MCL and midline about 12 cm superior to L1.
- Both surgeon and assistant stand on the right side of patient (FIG 3).
- R1, L1, L2, and C ports are used during the laparoscopic section.

Laparoscopic Transection of the Inferior Mesenteric Vein

- The peritoneal cavity is explored for evidence of metastatic disease.
- The patient is placed in a Trendelenburg position with the left side elevated.
- The small bowel is swept out of the pelvis. Nontraumatic bowel graspers are used to avoid injury.
- The dissection is begun at the inferior mesenteric vein (IMV), lateral to the ligament of Treitz (FIG 4).

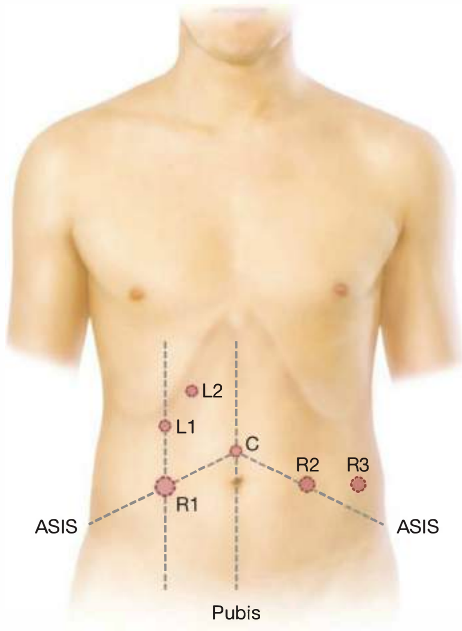

FIG 2 ● Placement of the laparoscopic ports. The ports are triangulated and placed at a minimum of one handbreadth apart. *C* denotes camera port; *L1* and *L2* denote the laparoscopic ports; and *R1*, *R2*, and *R3* denote the three robotic ports.

- The IMV is identified and dissected from its attachments to the left mesocolon.
- The peritoneum is scored with monopolar electrocautery.
- Blunt dissection is used to skeletonize the vessel. Once this is achieved, the vessel is clipped and divided via vessel sealer device just below the pancreas. This can also be accomplished with an Endo GIA vascular stapler.
- Transection of the IMV will serve as a lengthening maneuver, which in turn will decrease tension on the anastomosis.

FIG 3 ● Room setup with the robot docked from the left hip and surgeon and assistant surgeon on the right side of the patient.

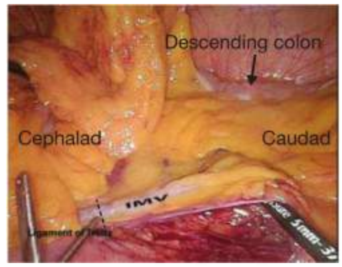

FIG 4 ● The IMV is visualized lateral to the ligament of Treitz and is skeletonized. The IMV will then be transected just below the pancreas *(dotted line)*.

Laparoscopic Transection of the Inferior Mesenteric Artery

- The sigmoid mesocolon is retracted toward the anterior abdominal wall, and the parietal peritoneum medial to the right common iliac artery at the sacral promontory is incised.
- Upward traction is maintained by the assistant and blunt dissection is used to enter the avascular retroperitoneal plane. This plane is developed under the superior hemorrhoidal artery (**FIG 5**).
- The left ureter and the hypogastric nerve are identified and swept posteriorly (**FIG 5**).
- This dissection is continued to the origin of the inferior mesenteric artery (IMA) at the aorta.
- The IMA is skeletonized using monopolar cautery. The junction of left colic artery and superior hemorrhoidal at the IMA can be visualized in a letter "T" configuration (**FIG 6A**).
- The IMA is clipped and divided at its origin from the aorta with a vessel sealer device (**FIG 6B**). This can also be accomplished via Endo GIA vascular stapler.
- The left colic artery is divided at its origin from the IMA (**FIG 6B**).
- Care is taken to avoid damage to the small nerve fibers of the preaortic sympathetic/superior hypogastric plexus.

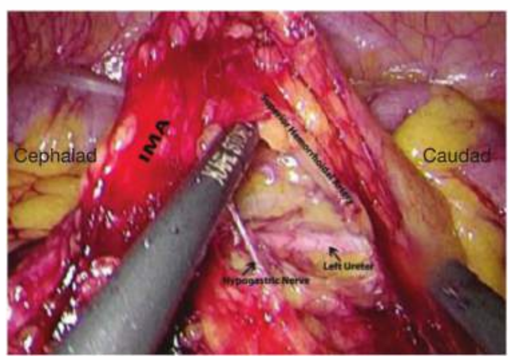

FIG 5 ● The retroperitoneal plane dorsal to the superior hemorrhoidal artery is dissected. The IMA is identified and left ureter and hypogastric nerve are swept posteriorly.

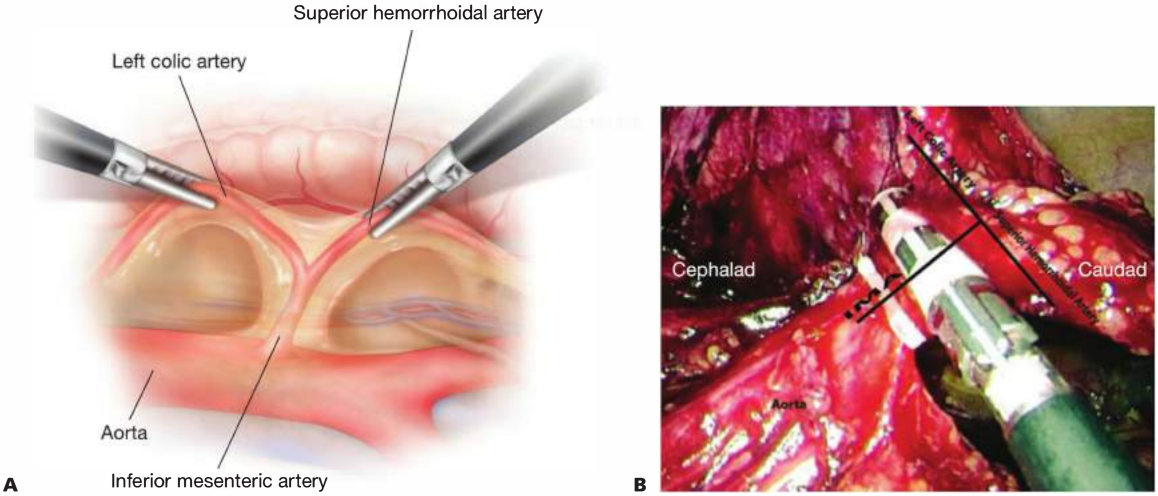

FIG 6 ● **A.** The T configuration formed between the IMA *(A)* and its terminal branches, the left colic *(B)*, and the superior hemorrhoidal artery *(C)* is visualized. Notice the left ureter *(D)* dissected posteriorly in the retroperitoneum. **B.** The IMA is clipped and divided at its origin from the aorta with a vessel sealer device. The left colic artery will be transected at its origin from the IMA also with a vessel sealer device.

Laparoscopic Mobilization of the Left Colon and Splenic Flexure

- The assistant surgeon retracts the colon medially, and with a combination of cautery and blunt dissection, the lateral peritoneal reflections are dissected.

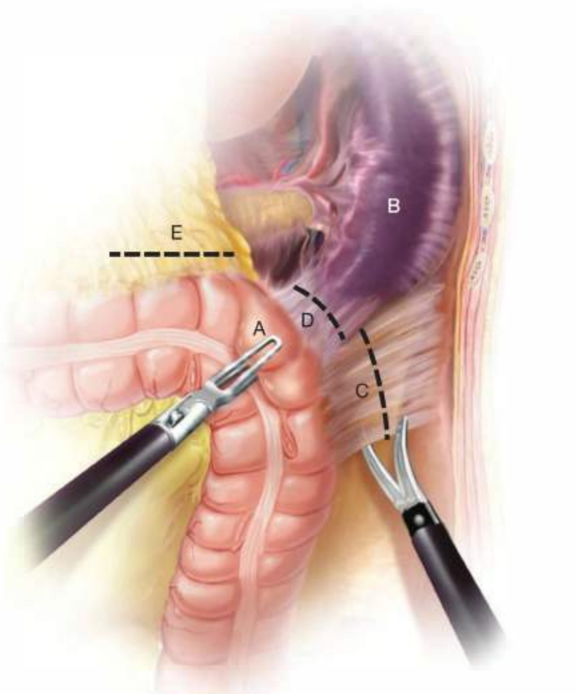

FIG 7 ● Mobilization of the splenic flexure. The phrenocolic *(C)*, splenocolic *(D)*, and gastrocolic *(E)* ligaments are transected. *A*, splenic flexure of the colon; *B*, spleen.

- The embryologic tissue plane between the descending colon mesentery and the retroperitoneum is entered. This bloodless areolar tissue plane is dissected toward the splenic flexure.
- The lateral dissection is continued cephalad by division of phrenocolic and splenocolic ligaments (**FIG 7**).
- The lesser sac is entered and the dissection is carried to the base of the mesentery (**FIG 8**).
- Care is taken to avoid injury to the tail of the pancreas in this location.
- The left and proximal transverse colon are now dissected free of their attachments.

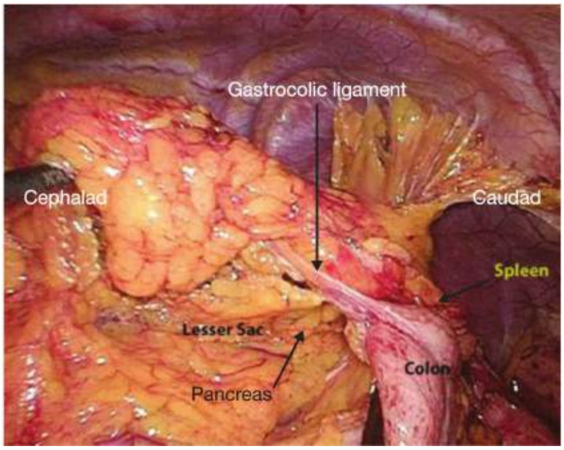

FIG 8 ● Transection of the gastrocolic ligament allows for entry into the lesser sac during the splenic flexure mobilization. The dissection is carried to the base of the mesentery.

ROBOTIC TOTAL MESORECTAL EXCISION

Robot Setup and Docking

- The patient is kept in a Trendelenburg position. A four-arm da Vinci robot is docked from a left hip approach (FIGS 3 and 9). This will allow for easy access to the anus during the case.
- A 0-degree scope is inserted in port C.
- Robotic arms are docked as follows (FIG 10):
  - Arm 1 is docked in R1. A hook cautery or monopolar scissors will be inserted in R1.
  - Arm 2 is docked in R2. A bipolar grasper will be placed in R2.
  - Arm 3 is docked in R3. A "prograsper" will be placed in R3.
- The assistant surgeon will stay on the right side of the patient and will use L1 and L2 to assist in retraction and suction/irrigation.

FIG 10 ● Configuration of robotic arms after docking.

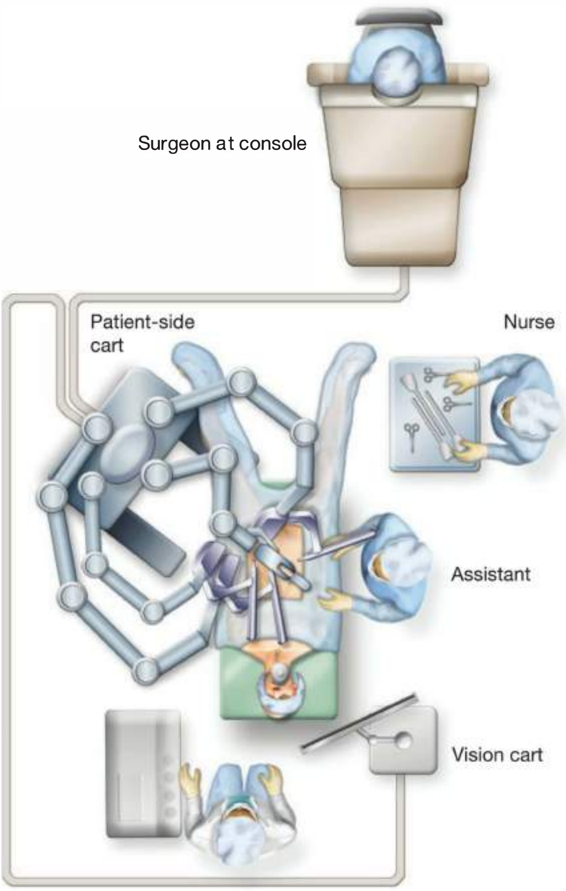

FIG 9 ● The robot is docked from a left hip approach. **A.** Illustration. **B.** Photograph.

Robotic Total Mesorectal Excision

- The following principles should be adhered to during a robotic TME:
  - Minimal manipulation of the rectum
  - Identification of embryologic tissue planes
  - Oncologic resection with negative radial and distant margins without violation of the mesorectal envelope
- The surgeon at the robot's console will start dissection at the sacral promontory dorsal to the superior hemorrhoidal artery, following this plane distally over the promontory and into the presacral space.
- Arm 3 is used for retraction, whereas arms 1 and 2 develop a plane of dissection within the avascular presacral space between the presacral fascia, posteriorly, and the mesorectal fascia, anteriorly.
- Arm 2 of the robot (left hand of the surgeon) should avoid grasping the mesorectum for the strong robotic arm may tear the mesorectum, which would cause bleeding.
- Monopolar scissors are preferred for rapid development of the plane of dissection with minimal use of electrocautery.
- The pelvic dissection proceeds posteriorly first, then laterally, and then anteriorly.
  - Posterior exposure is achieved with the assistant retracting the sigmoid colon cephalad and anteriorly (FIG 11). Waldeyer's fascia (rectosacral fascia) is entered distally at approximately the level of S3. This dissection is carried caudally to the level of levator muscles (FIG 12).
  - Laterally, the hypogastric nerves are identified and preserved. The lateral dissection plane is carried anterior and medial to these nerves (FIG 13A). The nerve fibers are carefully dissected toward the pelvic sidewall (FIG 13B).

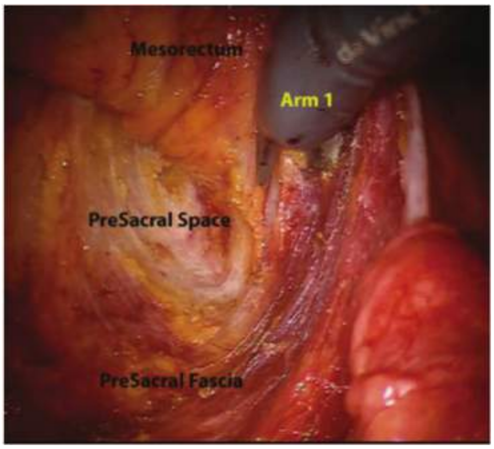

FIG 11 ● The posterior pelvic dissection is carried out within the presacral space, staying between the presacral fascia, posteriorly, and the mesorectal fascia, anteriorly.

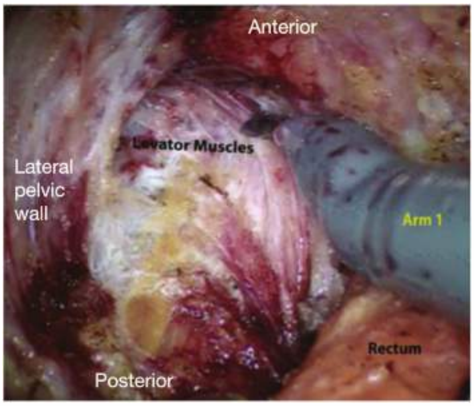

FIG 12 ● The posterior pelvic dissection is carried caudally to the level of the levator muscles.

- For the anterior pelvic dissection, exposure is achieved by the assistant retracting the rectum posteriorly and in a cephalad direction, as arm 3 anteriorly retracts the vagina (in females) or the prostate/seminal vesicles (in males). The Denonvilliers' fascia/pouch of Douglas (rectovesical/rectovaginal pouch) is entered by incising the peritoneal reflection between the anterior wall of the rectum and the posterior wall of vagina or the prostate/seminal vesicles (**FIG 14**). In case of large anterior tumors, Denonvilliers' fascia is resected en bloc with the rectum.

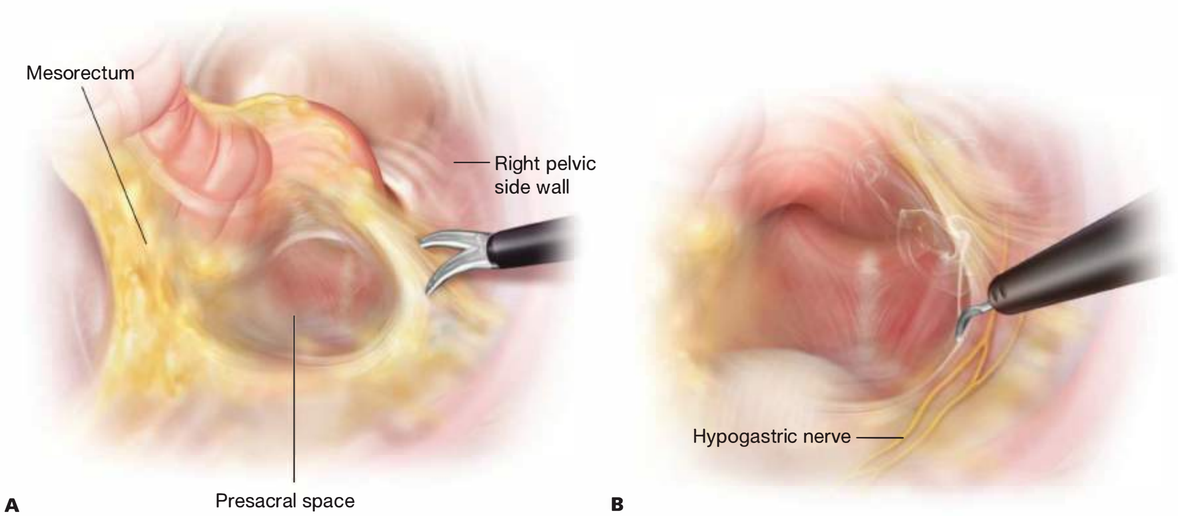

FIG 13 ● Lateral dissection of the mesorectum off the right pelvic sidewall: transection of the right lateral rectal ligament **(A)**. **B.** The hypogastric nerve can be seen posterolateral to the plane of the dissection.

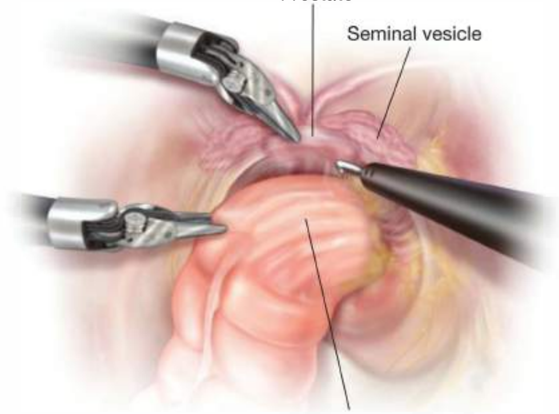

FIG 14 ● Anterior pelvic dissection. Exposure is achieved by the assistant retracting the rectum **(A)** posteriorly and in a cephalad direction, as arm 3 anteriorly retracts the prostate/seminal vesicles **(B,C)**, respectively. The anterior plane of dissection is carried along Denonvilliers' fascia, between the rectum posteriorly **(A)** and the prostate **(B)** and seminal vesicles **(C)** anteriorly.

DIVISION OF RECTUM AND CREATION OF ANASTOMOSIS

Division of Rectum

- DRE or flexible sigmoidoscopy under robotic vision is performed to establish the proper level of rectal division.
- In cases when the tumor is at least 2 to 3 cm from the anorectal ring, the distal rectum is transected with an articulating linear stapler.
  - An Endo GIA stapler is placed through the R1 port or in the lower assistant port (converted to a 12-mm port to accommodate the stapler).
  - The stapler is fired sequentially. Care is taken to avoid crossing staple lines during the sequential firing of stapler cartridges (**FIG 15**).
- For tumors that are less than 2 to 3 cm from the anorectal ring, an intersphincteric resection with hand-sewn coloanal anastomosis can be used (described in Part 4, Chapters 27 and 31).

Specimen Extraction

- Once the specimen is divided, the robot is undocked.
- The transected rectum and the contiguous sigmoid and descending colon are extracted through a 4- to 5-cm Pfannenstiel incision with a wound protector in place to protect the wound from potential oncologic contamination and soilage. The proximal transection is then performed with a linear stapler between the sigmoid and the descending colon. The specimen, including the rectum and sigmoid colon, is now completely disconnected and is sent to the pathologist for evaluation. The specimen should include the IMA pedicle and an intact mesorectum without any distal tapering (**FIG 16**).

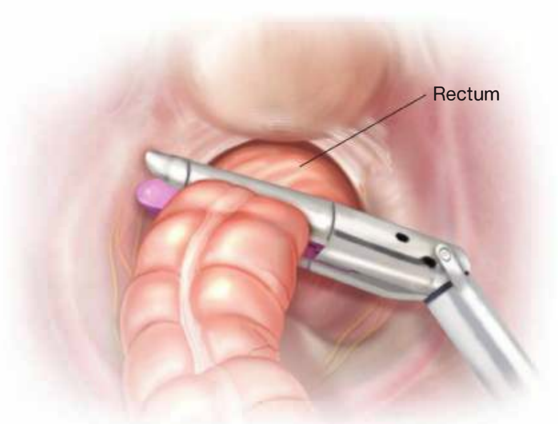

FIG 15 ● The distal rectum is transected with an Endo GIA. The stapler is fired sequentially. Care is taken to avoid crossing staple lines during the sequential firing of stapler cartridges.

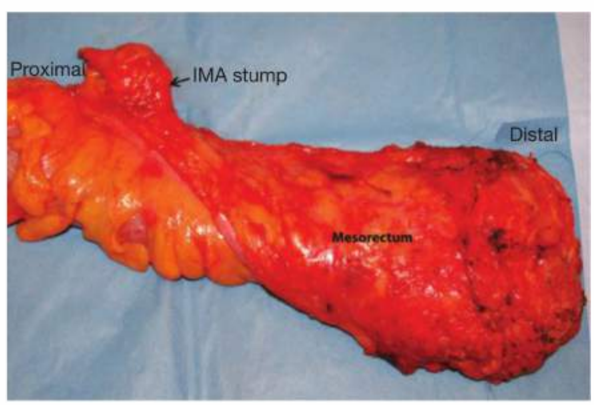

FIG 16 ● The extracted specimen demonstrates the IMA pedicle and an intact mesorectal envelope without any distal tapering.

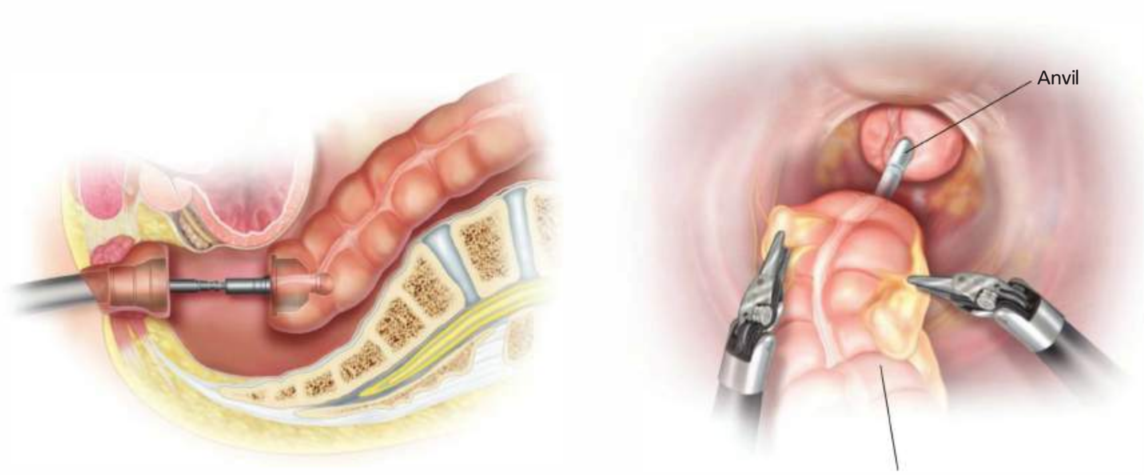

FIG 17 ● **A,B.** Intracorporeal laparoscopic anastomosis. The descending colon is anastomosed to the rectal stump with a 29F EEA circular stapler.

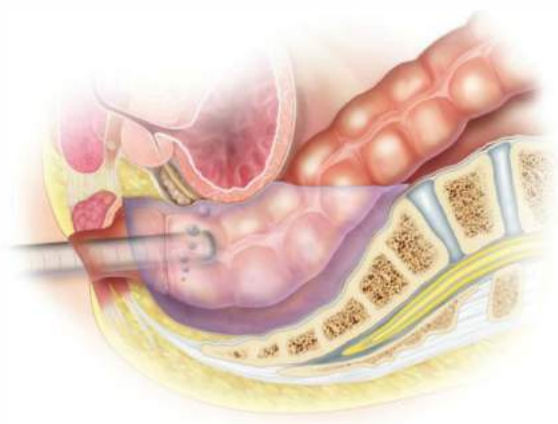

FIG 18 ● Assessment of anastomotic integrity by sigmoidoscopy. The completed colorectal anastomosis is tested underwater. Air bubbles identified during insufflation of the anastomosis indicate an anastomotic leak.

- The anvil of a 29F end-to-end anastomosis (EEA) stapler is secured with a purse-string suture in the descending colon and the colon is returned into the abdomen. A colonic J pouch can be created at this point if preferred.

Creation of Anastomosis

- Once the colon is returned into the abdomen, an end-to-end stapled anastomosis with a circular 29F EEA stapler is created laparoscopically (FIG 17A,B).
- A flexible sigmoidoscopy is then performed to assess the anastomosis integrity and to test for an air leak. If there is an air leak, this indicated the presence of an anastomotic leak (FIG 18). In this situation, and at the discretion of the surgeon, the decision is made to either redo the anastomosis or reinforce it with sutures.
- A round Blake drain is routinely placed within the pelvis near the anastomosis.

Creation of Ileostomy

- A temporary diverting loop ileostomy is created based on surgeon preference and patient factors. However, it is generally recommended for low anastomoses.

PEARLS AND PITFALLS

Preoperative workup	■ Obtain a complete and thorough history of urinary and bowel incontinence and sexual dysfunction. ■ Perform own endoscopy and verify the location of tumor.
Port placement	■ Maintain triangulation. ■ For narrower pelvic inlet, consider more medial robotic ports.
Division of IMA	■ Visualize the T configuration to assure high ligation.

Robotic TME	■ Avoid using arm 2 (surgeon's left hand) to grasp mesorectum. ■ Dissection should be within the avascular plane of the presacral space. ■ Avoid injury to hypogastric nerves laterally. ■ Identify bilateral ureters prior to proceeding.
Division of rectum	■ During repeated stapler firings, do *not* cross over previous transection points.
Anastomosis	■ Visualize anastomosis via endoscope to assure good blood supply and integrity.

POSTOPERATIVE CARE

- The Foley catheter should be continued for 48 to 72 hours given the high likelihood of postoperative urinary retention after low pelvic surgery.
- The pelvic drain is discontinued prior to discharge.
- Stoma teaching is performed by the enterostomal nurse prior to discharge.

OUTCOMES

- Given improved surgical technique and adjuvant therapy, overall survival rates of rectal cancer have improvement over the recent decades.[14,15]
  - Overall 5-year survival for patients undergoing curative resection is 80% with 10% local recurrence rates.[16]
- Robotic TME is comparable to laparoscopic TME in retrospective reviews of this technique. However, studies report lower conversion rates to open surgery compared to conventional laparoscopy.[17–21]

COMPLICATIONS

- Symptomatic anastomotic leaks after LAR have been reported to occur in 12% to 18% of patients with an associated risk of mortality of 15%.[16,22–26]
- Patients may complain of anorectal, sexual, and urinary dysfunction postoperatively. This may be due to dissection during surgery and/or secondary to pelvic radiation.
- LAR syndrome may occur and refers to a combination of symptoms including increased bowel frequency, fecal incontinence, and urgency.

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Chapter 31

Total Mesorectal Excision with Coloanal Anastomosis: Laparoscopic Technique

John H Marks Elsa B. Valsdottir

DEFINITION

- Total mesorectal excision with coloanal anastomosis via a transanal abdominal transanal proctosigmoidectomy (TATA) is defined as the complete removal of the embryologic tissue block of the rectum, leaving the sphincter muscles intact and thus avoiding a permanent stoma. Neoadjuvant chemoradiotherapy is an essential component to successful sphincter preservation. The abdominal part of the procedure can be performed with laparoscopic technique.

DIFFERENTIAL DIAGNOSIS

- Several conditions, both benign and malignant, can have similar presentation to rectal cancer. These include adenomatous polyps, solitary rectal ulcer, radiation injury, carcinoid tumor, and squamous cell carcinoma. Hence, a tissue biopsy confirming the diagnosis of rectal cancer is imperative.

PATIENT HISTORY AND PHYSICAL FINDINGS

- Careful patient selection is crucial for successful sphincter preservation in rectal cancer. A detailed history and physical examination are mandatory. Contraindications include inability to receive neoadjuvant chemoradiation therapy for distal rectal cancers, either because of comorbidities or previous radiation to the pelvis, previous radical surgery on rectum, distance of tumor from the dentate line, invasion of tumor into the sphincter muscles after completion of neoadjuvant chemoradiation therapy, and fecal incontinence on presentation.
- Detailed past medical history is obtained, emphasizing fecal continence, bowel habits, personal and family history of cancers and current medications and allergies, previous radiation to the pelvis, and previous abdominal surgeries.
- Prior radiation therapy for other cancers in the pelvis, such as cervical or prostate, is usually a contraindication. It is, however, helpful to review the previous records with regard to the dose and field treated and make decisions on individual basis.
- A detailed family history of cancers can help identify increased risk for other types of cancer as well as identify family members who are at an increased colon cancer risk. Recommendations should be given to first-degree relatives with regard to screening.
- Patient age, nodal status, or tumor size are not contraindications for sphincter preservation as long as the patient is a reasonable surgical candidate and negative margins (distally and circumferentially) can be obtained.
- Physical examination must include a thorough abdominal exam, including palpation of inguinal lymph nodes bilaterally. Most importantly, a careful digital rectal exam and a rectoscopy or flexible sigmoidoscopy are performed.
- The location of the tumor (anterior, posterior, or lateral), distance from the anorectal ring, size, fixity, circumference, configuration, and ulceration of the tumor need to be documented. This is imperative in preoperative planning as well as allowing for assessment of response to neoadjuvant treatment later (**FIG 1**).

IMAGING AND OTHER DIAGNOSTIC STUDIES

- All patients require preoperative staging of the disease with regard to the tumor, lymph node status, and distant spread, both clinically and radiographically.
- The most accurate way to determine size, length, and depth of the tumor invasion as well as any enlarged lymph nodes is with magnetic resonance imaging (MRI) or endoscopic rectal ultrasound (ERUS) (**FIG 2**).
- A computed tomography (CT) of the abdomen and chest should be obtained to evaluate for distant spread of the disease to the liver or lungs.
- Preoperative blood work should include a hemogram, blood chemistries, and a carcinoembryonic antigen (CEA) level.
- Full colonoscopy is needed to evaluate the entire colon for other pathology and synchronous malignant lesions or polyps.
- Histologic assessment with biopsy of the primary tumor is necessary and usually obtained at the time of colonoscopy.

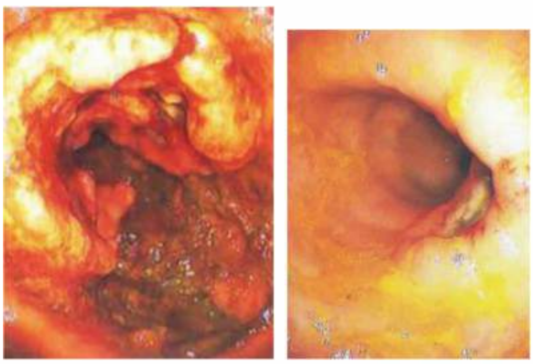

FIG 1 ● Rectal cancer before **(left)** and after **(right)** neoadjuvant chemoradiation. This patient had a good response to treatment.

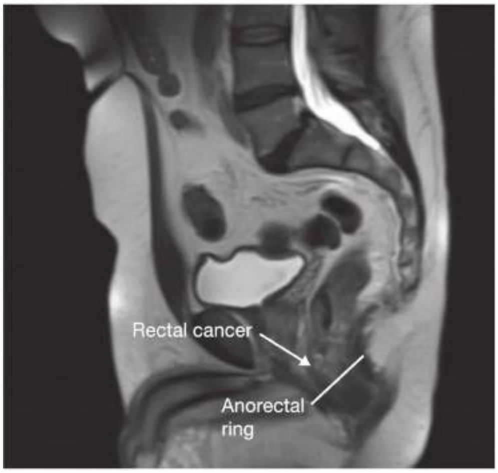

FIG 2 ● Pre–neoadjuvant treatment MRI of a rectal cancer suitable for TATA.

SURGICAL MANAGEMENT

Preoperative Planning

- Neoadjuvant chemoradiotherapy is the key to successful sphincter preservation. The radiation therapy is a high-dose, long-term treatment to maximize tumor downstaging. Preferred radiation dose is 5,580 cGy, with 4,500 cGy to the entire pelvis with a boost to the presacral area and tumor location, delivered over the course of 5 weeks. Concurrent chemotherapy based on 5-fluorouracil (5-FU) either orally or intravenously increases the sensitivity of the tissues to radiation, enhancing efficacy (**FIG 3**).
- Neoadjuvant chemoradiation apoptotic effect occurs only at cell division. Maximum cytotoxic effect is 8 to 12 weeks after completion of treatment. Extending the interval between completion of radiation therapy and surgery up to 8 to 12 weeks therefore gives the patient the fullest benefit of the treatment, maximizing downstaging and extending the options for sphincter preservation.
- Decision regarding sphincter preservation should be based on the status of the cancer *after* completion of chemoradiotherapy. All patients, except those whose cancers remain fixed at or below the 3-cm level are offered sphincter preservation.
- Accepting a distal margin of resection from the cancer as small as 5 mm is necessary for very low tumors. This does not adversely affect outcome. Dissection is started transanally to assure a known distal margin. This is particularly helpful in the postirradiated rectal cancer where there is often only a small scar left, making decisions as to where a stapler would be placed from above difficult.
- The patient should receive a bowel preparation the day before surgery.
- Perioperative antibiotics and deep vein thrombosis prophylaxis should be given.

Positioning

- The operation has both an abdominal part and perineal part. The surgeon and first assistant stand between the legs during the perineal part. For the abdominal part, which is performed laparoscopically, they stand at the patient's right side. It is important that the surgical team is free to move around the patient. The laparoscopic equipment and energy sources are positioned to patient's left (**FIG 4**).
- The patient is placed in the lithotomy position with the buttocks extending 2 cm over the padded table edge. Both arms are padded and tucked. The chest is taped to the table to further prevent slipping of the patient as the table is maneuvered. The Foley catheter is taped over the right thigh. The abdomen is prepped with Betadine and the perineum with povidone-iodine. In women, the vagina is prepped with povidone-iodine.

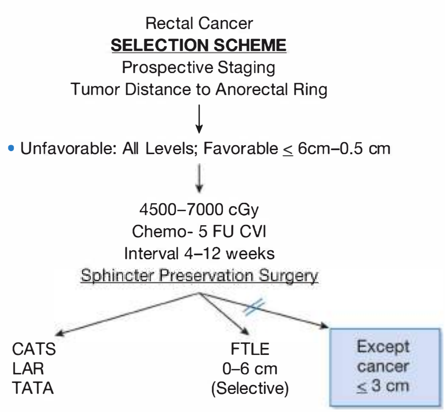

FIG 3 ● Author's treatment algorithm for low rectal cancers (distal 3 cm of the true rectum). cGy, centiGray; 5-FU, 5-fluorouracil; CVI, continuous venous infusion; CATS, combined abdominal trans-sacral rectal resection; LAR, low anterior resection; TATA, transanal transabdominal rectal resection; FTLE, full-thickness local excision.

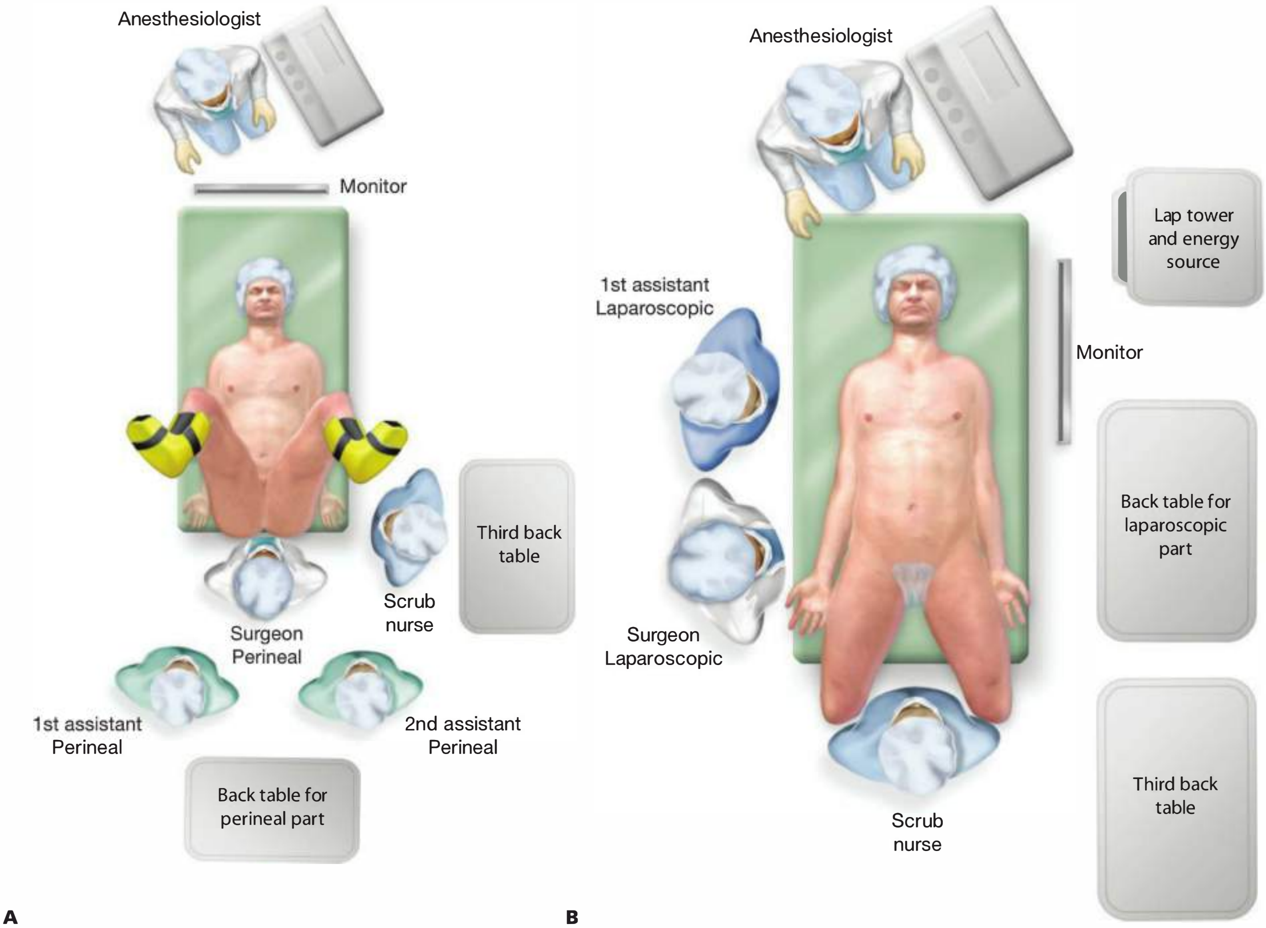

FIG 4 ● **A,B.** Operating room setup.

TRANSANAL, INTERSPHINCTERIC RESECTION OF RECTUM

- Place a sponge soaked in povidone-iodine in the anal canal or irrigate it with povidone-iodine. In order to minimize the possibility of dislodging tumor cells, avoid digitalizing the canal after this.
- To allow visualization of the dentate line, Alice-Adair clamps are placed circumferentially around the anal canal to evert the anal tissue (**FIG 5**).
- The dentate line is incised circumferentially with electrocautery through the mucosa, thus defining the distal resection margin. This is a critical step to avoid radial tearing later in the dissection (**FIG 6**).
- The Metzenbaum scissors are spread posterolaterally and slightly off the midline, perpendicular to the axis of the anus, to enter into the plane between the transected upper half of the internal sphincter and the underlying puborectalis. This plane is developed circumferentially (**FIG 7**).
- Alice-Adair clamps are applied to the transected distal portion of the rectum to facilitate retraction. One never applies more than four clamps at a time, as this is usually too bulky. The shiny, glistening white aspect of the puborectalis is identified using the scissors. Visualization of this white tissue is the key to ensuring that the dissection is carried out in the proper plane (**FIG 8**). Placing a small Deaver retractor allows development of the plane between the rectum and the levator ani complex. Once the proper plane is entered, the dissection is essentially bloodless.
- The sharp dissection is brought around anteriorly (**FIG 9**). In women, a finger in the vagina allows palpation of the vaginal wall, and it is generally not a problem to avoid this structure. In men, one has to be careful when proceeding anteriorly to avoid taking the dissection anterior to the prostate. The length of dissection cephalad is up to the seminal vesicles in men and to the cervix in women. This dissection is carried circumferentially until the rectum is fully mobilized (**FIG 10**).
- The rectum is oversewn in a watertight fashion with a 0-Vicryl stitch, turning the edges inward to avoid potential spilling of feces or tumor cells during the abdominal part of the procedure. The pelvis is irrigated from below with saline; a sponge is placed through the anus with an occlusive dressing in the perineum.

FIG 5 ● To allow visualization of the dentate line, Alice-Adair clamps are placed circumferentially around the anal canal to evert the anal tissue.

FIG 6 ● Line of incision of the mucosa at the dentate line.

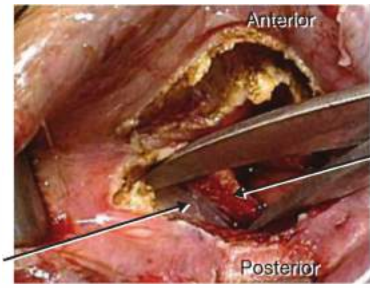

FIG 7 ● The Metzenbaum scissors are spread slightly off the midline, perpendicular to the axis of the anus, to enter into the plane between the transected upper half of the internal sphincter and the underlying puborectalis. This defines the circumferential resection margin.

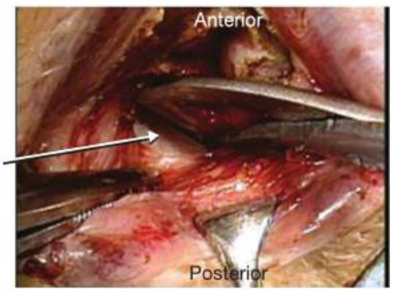

FIG 8 ● The shiny, glistening white aspect of the puborectalis is identified using the scissors. Visualization of this white tissue is the key to ensuring that the dissection is carried out in the proper plane.

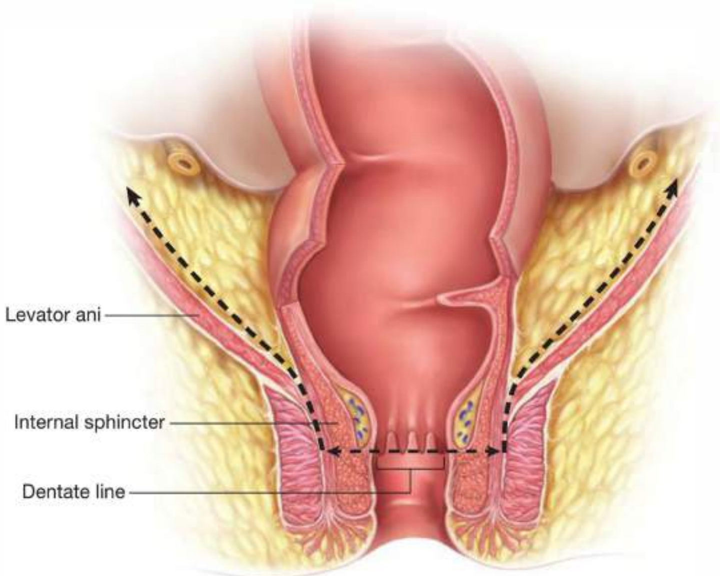

FIG 9 ● The drawing shows the lines of pelvic dissection.

FIG 10 ● The distal rectum is fully mobilized.

ABDOMINAL LAPAROSCOPIC PROCTOSIGMOIDECTOMY

- The patient's knees are lowered from full lithotomy so that they are flat to the abdomen to allow laparoscopic access to the abdomen and particularly the splenic flexure. The surgical team changes gowns and gloves. Five ports are placed as follows: (1) 5-mm port 20 cm above the pubic symphysis; (2) 12-mm port at the height of the umbilicus lateral to the rectus sheath; (3) 12-mm port in the right fossa, a hands width above the pubic tubercle; (4) 5-mm port suprapubically; and (5) 5-mm port in the left fossa (FIG 11).
- A careful exploration is carried out to rule out metastatic disease.
- The patient is placed in reverse Trendelenburg position of 15 degrees with the right side down 10 degrees. The monitor is placed at the left shoulder and the surgeon and assistant stand at the patient's right side (FIG 4).
- The first operative step is releasing the splenic flexure. The surgeon works with a bowel grasper in the left hand in port 2 and a LigaSure in the right hand in port 3. The 5-mm camera is in port 1. The gastrocolic ligament is identified and opened at the level of the middle epiploic perforating artery to enter the lesser sac. The gastrocolic ligament is divided laterally toward the lower pole of the spleen (FIG 12). Next, the lateral attachments of the flexure are taken down, using the epiploic to retract the colon medially. The splenocolic ligament is divided

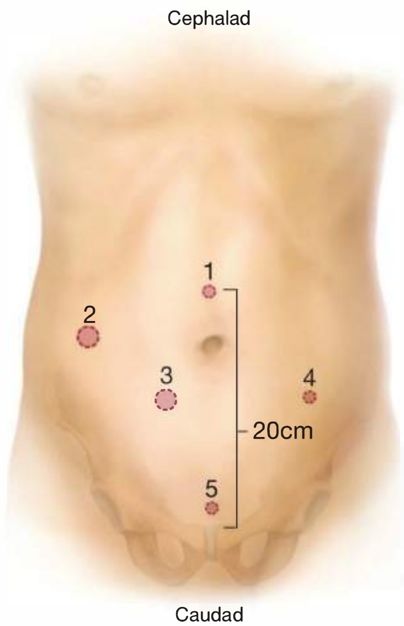

FIG 11 ● Port placement for the abdominal (laparoscopic) phase of the operation. Five ports are placed as follows: *(1)* 5-mm port 20 cm above the pubic symphysis; *(2)* 12-mm port at the height of the umbilicus lateral to the rectus sheath; *(3)* 12-mm port in the right fossa, a hands width above the pubic tubercle; *(4)* 5-mm port suprapubically; and *(5)* 5-mm port in the left fossa.

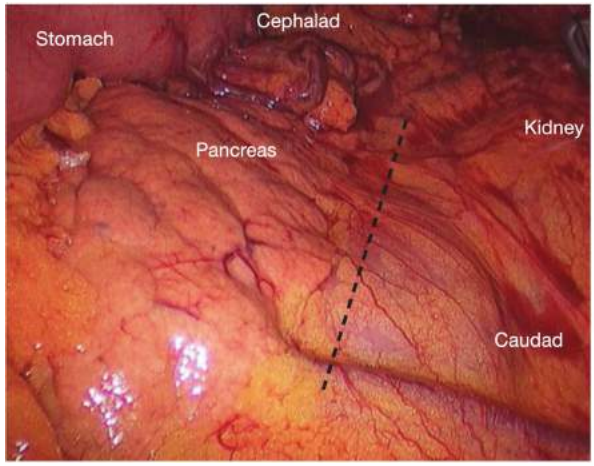

FIG 13 ● An incision is made in the peritoneal sheath of the mesentery of the transverse colon 1 cm below the inferior border of the pancreas.

and the tail of pancreas identified. Finally, an incision is made in the peritoneal sheath of the mesentery of the transverse colon 1 cm below the inferior border of the pancreas (**FIG 13**). The avascular space between the fascia of Toldt and Gerota's fascia is entered and the colonic mesentery is peeled off the Gerota's fascia. The splenic flexure is now fully mobilized and the retroperitoneal structures are visualized (**FIG 14**).

- The second step is repositioning the small bowel to gain access to the pelvis and vasculature. The patient is placed in steep Trendelenburg position (20 degrees); the right side remains down. The camera is changed to a 10-mm, 30-degree scope and moved to port number 2 and the surgeon's right hand to port number 1. The omentum is placed over the transverse colon; the small bowel is swept out of the pelvis and is placed in the right upper quadrant to expose the ligament of Treitz and the inferior mesenteric artery (IMA). The junction of the descending and sigmoid colon is marked with a suture to determine the level of transection to be performed later.

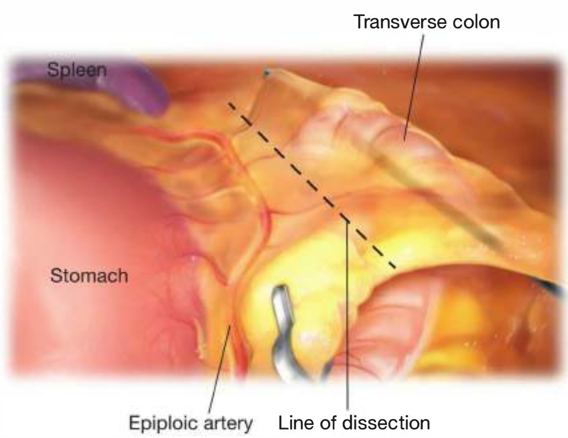

FIG 12 ● The gastrocolic ligament is identified and opened at the level of the middle epiploic artery to enter the lesser sac. The gastrocolic ligament is divided laterally toward the lower pole of the spleen.

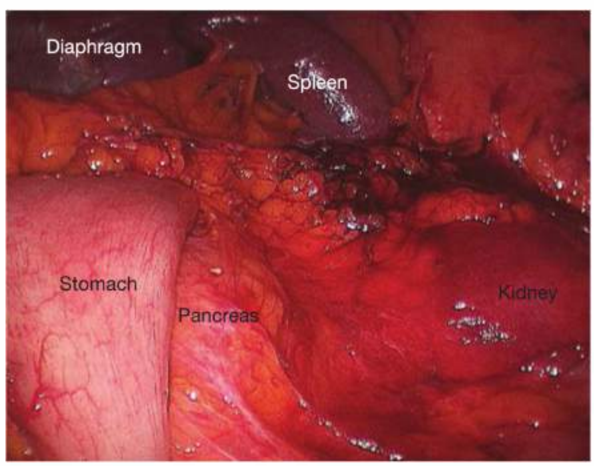

FIG 14 ● Once the splenic flexure is fully mobilized and the colonic mesentery is peeled off Gerota's fascia, the structures of the retroperitoneum can be visualized.

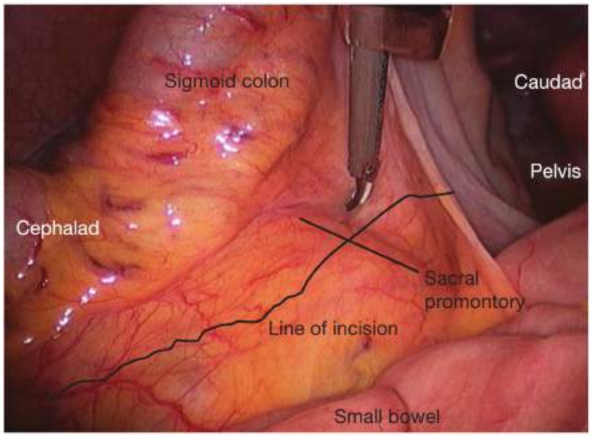

FIG 15 ● Point of incision at the sacral promontory. The peritoneum is incised at the level of the promontorium of the sacrum and opened down to the right pararectal sulcus and cephalad along the aorta toward the ligament of Treitz.

- The third step is a high ligation of the IMA. The right iliac artery and the left ureter are recognized. The peritoneum is incised at the level of the promontorium of the sacrum and opened to the right pararectal sulcus distally and then cephalad along the aorta toward the ligament of Treitz (**FIG 15**). Blunt dissection is used to lift the mesentery of the proximal rectum off the retroperitoneum, revealing the left ureter (**FIG 16**). The nerves of the hypogastric plexus are the key to the dissection. They are identified and preserved intact under the IMA and gently pushed down toward the aorta. The base of the IMA is skeletonized circumferentially and the artery is divided with an energy device, clips, or endovascular stapler (**FIG 17**).

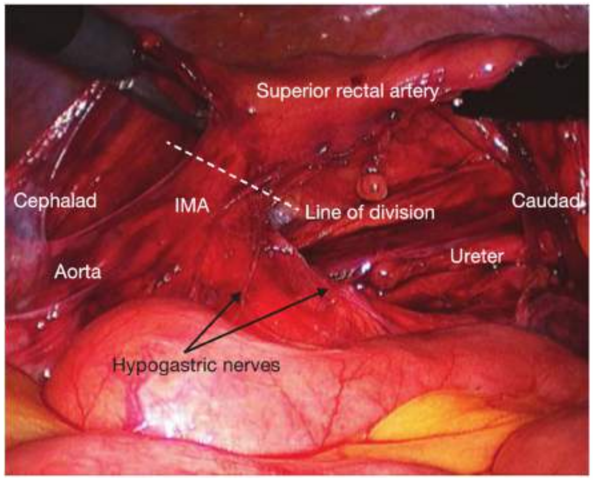

FIG 17 ● The nerves of the hypogastric plexus are the key to the dissection. They are identified under the IMA and gently pushed down toward the aorta and preserved. The base of the IMA is skeletonized circumferentially and the artery is divided along the *dotted line*.

- The fourth step is the high ligation of the inferior mesenteric vein (IMV) (**FIG 18**). The IMV is dissected and divided at the level of the ligament of Treitz, where it dives under the duodenum to join the splenic vein. The remaining mesentery of the descending and sigmoid colon is then lifted off the Gerota's fascia, completing the medial to lateral mobilization of the colon.
- The fifth step is the mobilization of the lateral attachments of the descending and sigmoid colon. This is relatively easy as the majority of the dissection has already

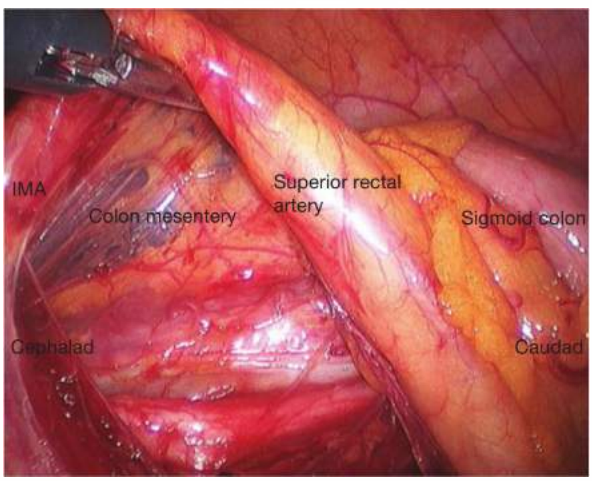

FIG 16 ● Blunt dissection is used to lift the mesentery of the proximal rectum off the retroperitoneum, revealing the left ureter.

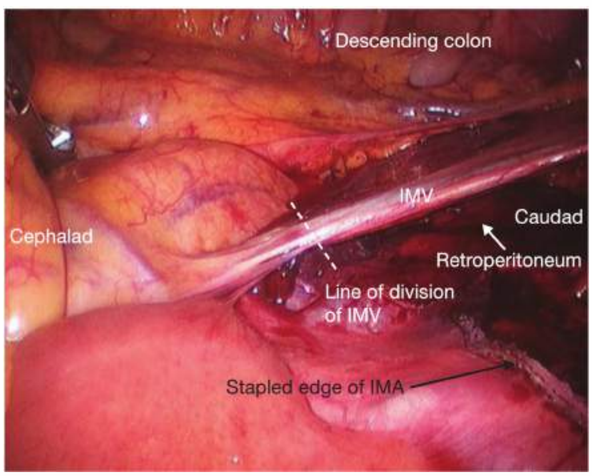

FIG 18 ● High IMV transection. The IMV has been lifted up along with the mesentery of the descending colon and is transected *(dotted lines)* at the level of the ligament of Treitz.

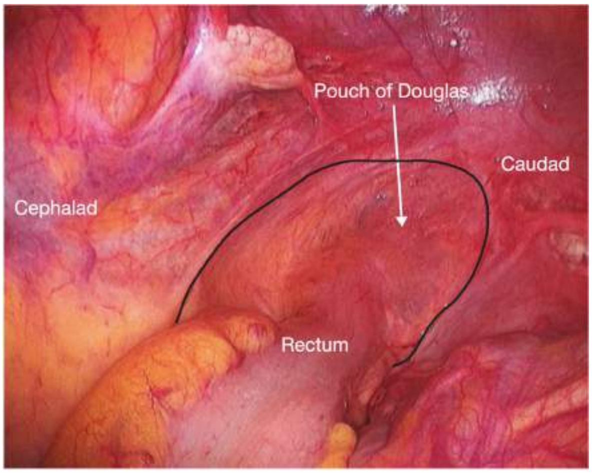

FIG 19 ● The peritoneum of the rectum is incised to open the box circumferentially, going down the left and right pararectal sulcus and anteriorly across the pouch of Douglas.

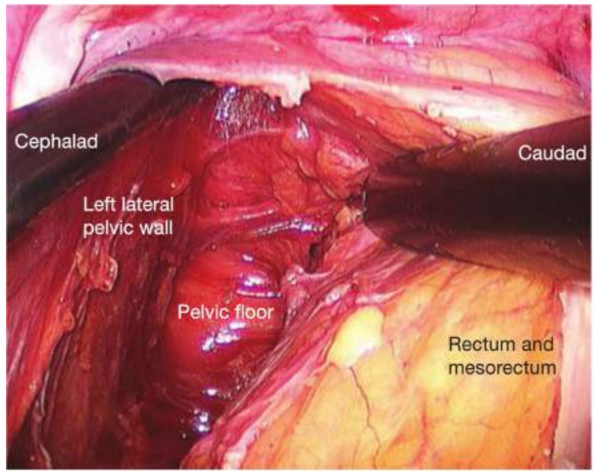

FIG 21 ● The lateral dissection is brought around the left (shown here) and right sides.

been done in a medial to lateral fashion. Starting at the pelvic brim, the peritoneum in incised up to the previous mobilization of the splenic flexure and a connection made with the dissection from the medial side.

- The sixth step is the total mesorectal excision (TME) of the rectum. To accomplish this laparoscopically, a few key points are made. First, the remaining peritoneum of the rectum is incised to "open the box" circumferentially, going down the left and right pararectal sulcus and anteriorly across the pouch of Douglas or the rectovesical fold (**FIG 19**). In anteriorly based lesions, this incision is a centimeter higher. The LigaSure is exchanged for Endo Shears with electrocautery attached to allow for finer dissection. The dissection is carried posteriorly along the mesorectal plane first (**FIG 20**), then brought around the right and the left sides (transection of the lateral rectal ligaments) (**FIG 21**), and is then finished anteriorly (**FIG 22**). This is repeated, alternating sides, as the dissection carries on deeper into the pelvis. To facilitate this, three-dimensional retraction is created by the surgeon retracting the rectum and assistants applying anterior and lateral retraction from the two 5-mm ports (**FIG 23**). The dissection is kept in the plane outside the mesorectal fascia, taking care not to taper the specimen and it is continued until it meets the previous perineal dissection from below. The sponge that was placed previously can be seen (**FIG 24**). The nerves are followed to direct the dissection in the proper plane.
- The rectum is delivered out the pelvis and the completeness of the dissection checked as well as the hemostasis (**FIG 25**).

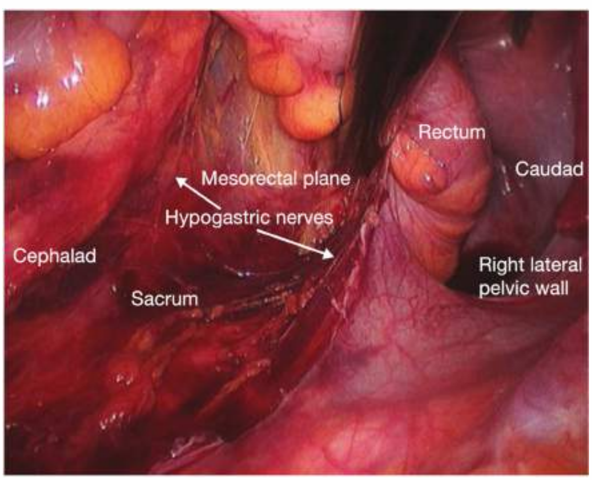

FIG 20 ● The dissection around the rectum is carried posteriorly first.

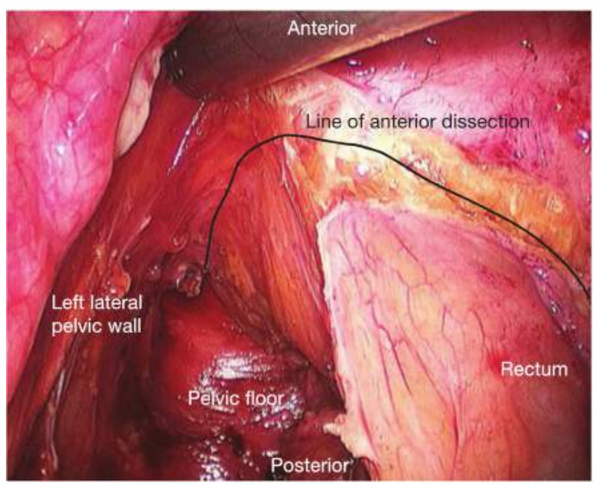

FIG 22 ● The dissection around the rectum is finished anteriorly.

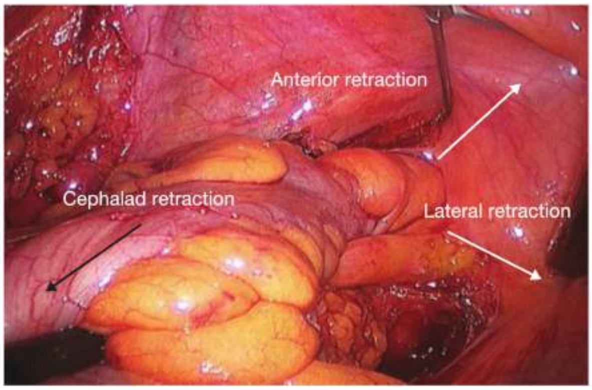

FIG 23 ● To facilitate the dissection around the rectum, three-dimensional retraction is created by the surgeon retracting the rectum with the left hand and assistants applying retraction from the two 5-mm ports toward the sides and anteriorly.

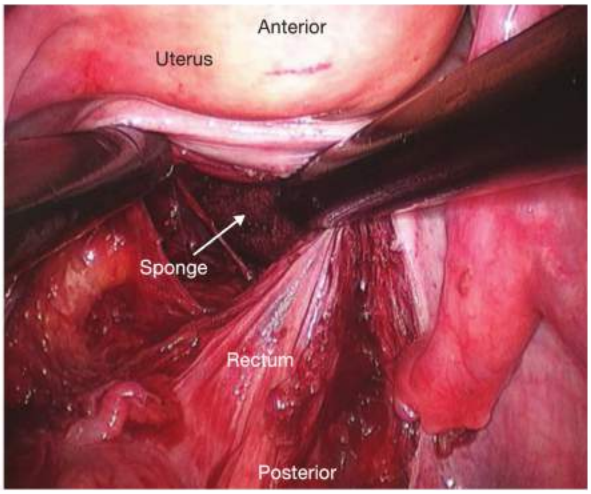

FIG 24 ● The dissection is continued until it meets the previous perineal dissection from below and the sponge that was placed previously can be seen.

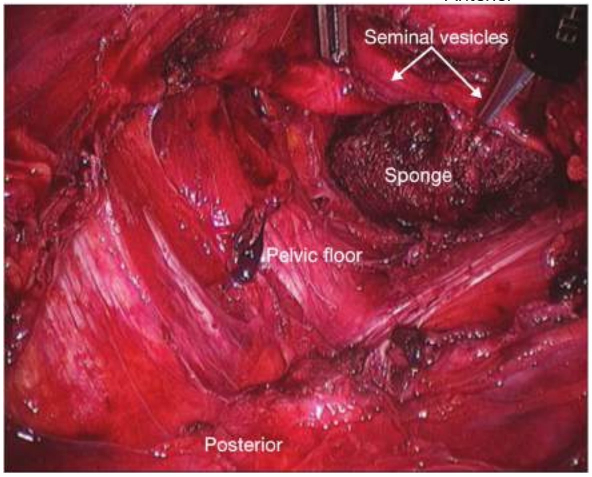

FIG 25 ● The rectum is delivered out through the pelvis and the completeness of the dissection and hemostasis are checked.

COLOANAL ANASTOMOSIS

- The surgeon moves back to the perineum. The patient's knees are raised again. The sponge and the perineal occlusive dressing are removed from the anus.
- The specimen is pulled through the anus carefully under direct laparoscopic visualization to assure orientation and is transected at the marking suture previously placed between the sigmoid and descending colon (**FIG 26**).
- The coloanal anastomosis is hand sewn. This can be direct, or a colonic pouch can be created if there is adequate length. Small Deaver retractors are used for exposure. Full-thickness bites are taken through the descending colon wall and the transected lower border of the internal sphincter, including the overlying anoderm. Four corner sutures are placed at 12, 3, 6, and 9 o'clock positions and left untied until one or two full-thickness bites have been placed between each corner suture (**FIG 27**).
- The anastomosis is either a direct coloanal, side-to-end or a colonic J-pouch, depending on the patient's body habitus and amount of fat (**FIG 28**).
- Digital examination is performed to ensure there are no gaps and the anastomosis is patent.

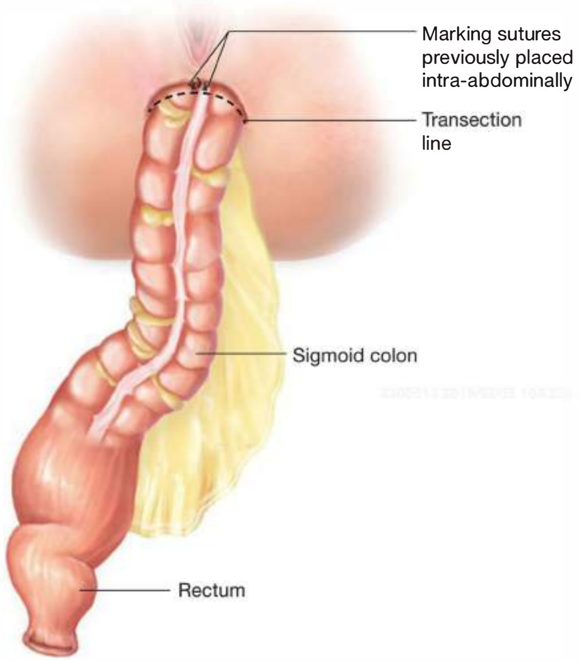

FIG 26 ● The specimen is pulled through the anus carefully under direct laparoscopic visualization to assure orientation and is transected along the *dotted line* at the previously placed marking suture.

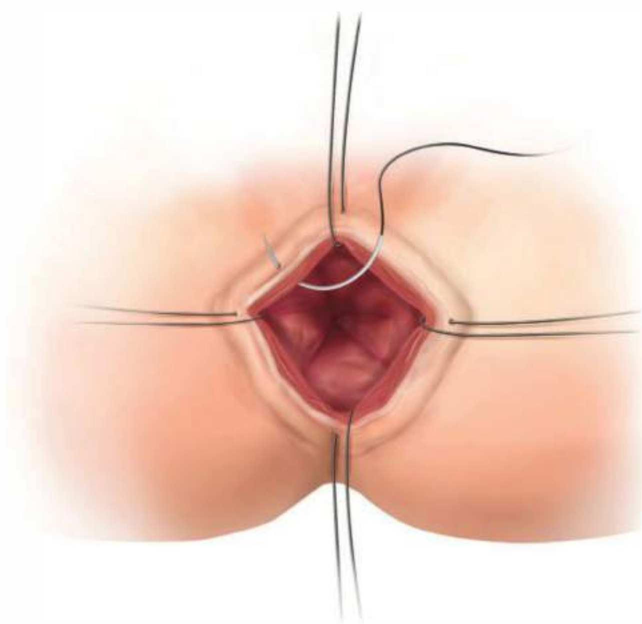

FIG 27 ● The coloanal anastomosis is hand sewn. This can be direct or a colonic pouch can be created if there is adequate length. Small Deaver retractors are used for exposure. Full-thickness bites are taken through the descending colon wall and the transected lower border of the internal sphincter, including the overlying anoderm. Four corner sutures are placed at 12, 3, 6, and 9 o'clock positions and left untied until one or two full-thickness bites have been placed between each corner suture.

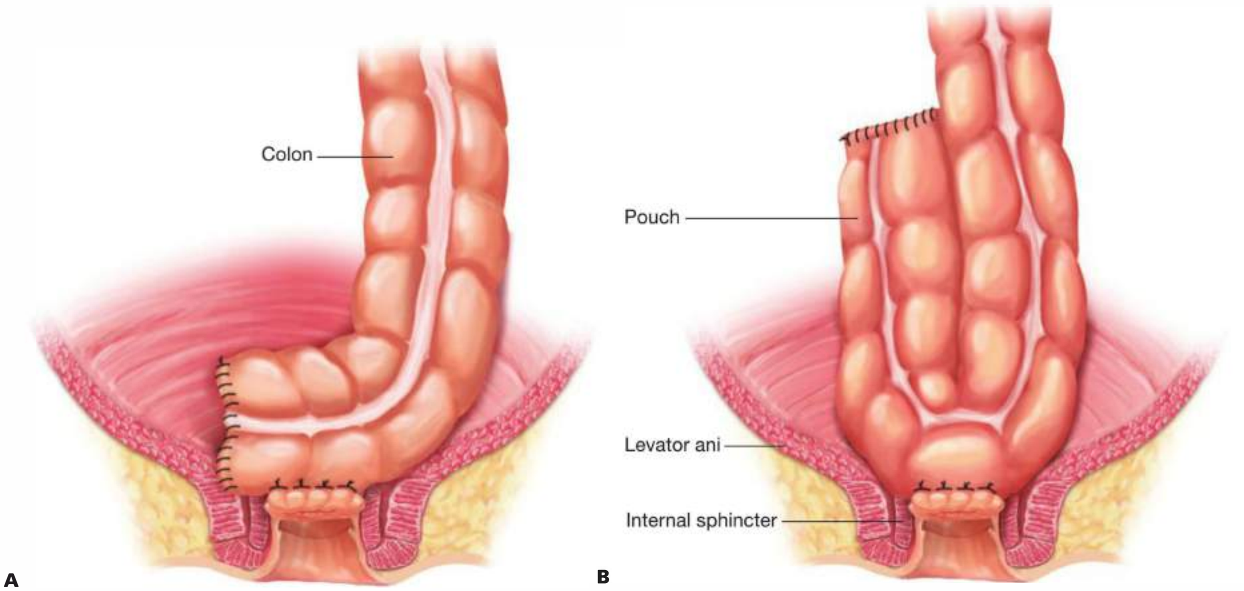

FIG 28 ● The anastomosis is either a direct coloanal (**A**), a side-to-end, or a colonic J-pouch (**B**).

CREATION OF STOMA

- The last step is bringing out a loop of ileum in preparation for a diverting loop ileostomy. A locked bowel grasper is used to grasp the ileum about 20 cm proximal to the terminal ileum. This loop is brought out at the site of port 3 or at the infraumbilical fat fold and a pin placed underneath it.
- The abdominal part of the procedure is then concluded. The insufflation air is evacuated through the trocars. The fascia at the 12-mm port sites is closed with 1-0 Vicryl suture and all skin incision with 4-0 Vicryl. Steri-Strips and dressings are applied. Finally, the diverting loop ileostomy is matured; stoma plate and bag applied (**FIG 29**).

FIG 29 ● The abdomen after all port sites have been closed and the diverting stoma has been matured.

PEARLS AND PITFALLS

Surgical decision making	■ Final decision on sphincter preservation based on *post* chemoradiation cancer characteristics
Patient selection	■ Patients whose cancer is not fixed to the levators in the distal third of the rectum after chemoradiation are offered sphincter preservation ■ Adequate baseline continence ■ Clinical staging and careful documentation of tumor location and size
Preoperative planning	■ Staging with MRI/ERUS, CT, physical exam ■ Full colonoscopy ■ Neoadjuvant chemoradiation therapy
Intersphincteric dissection	■ Incise mucosa at dentate line, marking distal margin ■ Stay in the plane between the internal sphincter and the puborectalis sling—identified by glistening white of the puborectalis ■ Carry the dissection cephalad to the cervix in women and to the seminal vesicles in men
Rectosigmoid resection	■ Wide mobilization of the splenic flexure with freeing of the distal transverse mesocolon from the retroperitoneum ■ Full medial to lateral mobilization of the left colon ■ High transection of the IMA and the IMV ■ TME resection of rectum ■ Avoid urethra or venturing anterior to the prostate in men
Anastomosis	■ Maintain orientation when delivering specimen through the anus ■ Full-thickness bites with interrupted sutures ■ Can be colonic J-pouch, side to end, or direct coloanal

POSTOPERATIVE CARE

- No nasogastric tube is needed. Oral diet is resumed on the first postoperative day. Intravenous pain medications are given for the first 24 hours, transition to oral after that as tolerated. Antibiotics are continued for 10 days postoperatively due to the poor vascularity of the radiated tissue and the ultralow anastomosis.
- The diverting stoma is closed at 3 months postoperatively, after flexible sigmoidoscopy, digital exam, and barium enema show that the anastomosis is intact. If the patient needs adjuvant chemotherapy, stoma closure is usually postponed until after completion of therapy.
- Close follow-up is mandatory for at least 5 years, with physical exam, flexible sigmoidoscopy, CT, and CEA measurements. Physical exam is performed every 3 months for 24 months, then every 4 months for 24 months, and then every 6 months for 12 months. Endoscopic evaluation (flexible sigmoidoscopy) is performed every 6 months for 24 months, then every 12 months for the next 3 years.

OUTCOMES

- Local recurrence is low and equivalent to best results after abdominoperineal resection, or 2.5% (at the author's institute) to 7.0%. The same holds for distant recurrence with metastasis (8% to 10%).
- Five-year survival for all patients undergoing sphincter preservation surgery for rectal cancer at the author's institution is 97%. Others have reported numbers from 71% to 82%.
- Sphincter preservation has been achieved in 90% of patients who have been considered for the procedure.
- Function is adequate in the majority of patients. In a survey among patients at the author's institute, more than half of patients report no or little inconvenience due to incontinence and 80% would not prefer to have kept their stoma.

COMPLICATIONS

- Infections
- Bleeding
- Anastomotic leak
- Ischemic neorectum
- Incontinence
- Rectal prolapse
- Bowel obstruction

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Chapter **32**

Abdominoperineal Resection: Open Technique

Curtis J. Wray   Stefanos G. Millas

DEFINITION

- The abdominoperineal resection (APR) refers to the operation for surgical treatment of distal rectal cancer. The APR, as originally described by Ernest Miles, involves the en bloc removal of the distal sigmoid colon, rectum, mesorectum, and anal canal. The operation uses both an abdominal and perineal approach.
- The APR requires a permanent end colostomy.

DIFFERENTIAL DIAGNOSIS

- This operation should be performed for those with a biopsy-proven diagnosis of malignancy (e.g., rectal or anal cancer, anal melanoma).

PATIENT HISTORY AND PHYSICAL FINDINGS

- Patients can present with tenesmus, rectal bleeding, rectal pain, and/or obstructive symptoms. Iron deficiency anemia is common at presentation and should always prompt a full colonoscopy in adult patients. Asymptomatic patients are typically diagnosed during screening colonoscopy.
- A thorough history should be obtained to assess the patient's functional status and to ensure sufficient physiologic reserve to undergo a major abdominal operation.
- A detailed family history is necessary to identify risk of an inherited colon and rectal cancer syndrome as well as risk for metachronous colorectal cancer.
- Digital rectal examination and rigid proctosigmoidoscopy can be performed in the ambulatory office and provide an accurate measurement of tumor distance from anorectal ring when compared to a flexible sigmoidoscopy. It also allows for evaluation of potential tumor fixation to the anal sphincter, pelvic side walls, sacrum, and/or urologic/gynecologic organs.

IMAGING AND OTHER DIAGNOSTIC STUDIES

- A complete colonoscopy is obtained to evaluate for potential synchronous lesions that may have to be addressed at the time of surgery.
- A computed tomography (CT) scan of the chest, abdomen, and pelvis with intravenous and oral contrast should be obtained to assess for the presence of metastatic disease and the extent of tumor involvement within the pelvis.
- A magnetic resonance imaging (MRI) of the pelvis with intravenous (IV) contrast, or endorectal ultrasound performed by a qualified endoscopist, should be obtained for local tumor staging that will guide neoadjuvant chemotherapy and radiation as per National Comprehensive Cancer Network guidelines. Endorectal ultrasound has a higher sensitivity and specificity for tumor depth rather than lymph node involvement as compared to MRI. MRI allows for a better assessment of the circumferential margin at the mesorectal envelope.
- Laboratory blood work should include a complete blood count, serum electrolytes, liver function tests, and a carcinoembryonic antigen level as a baseline measurement that will be the reference for future cancer surveillance.

SURGICAL MANAGEMENT

- Although controversial, a margin less than 2 cm between the tumor and the anorectal ring will typically require an APR to ensure adequate tumor clearance and a satisfactory functional outcome.
- The patient may be placed in the lithotomy position and two surgical teams can work simultaneously. Alternatively, one team can perform both portions of the operation sequentially.

Preoperative Planning

- The patient should take a mechanical bowel preparation (GoLYTELY) the day before surgery.
- Recent evidence suggests an oral antibiotic preparation reduces postoperative surgical site infections.
- The colostomy site should be marked preoperatively with the patient in a sitting and supine position to ensure skin folds and crevices do not interfere with the appliance. Ideally, this marking should be performed by a qualified enterostomal therapist (wound, ostomy, and continence nurse [WOCN]).
- The stoma is marked over the (left) rectus abdominus, typically below the level of the umbilicus, though it can be placed above the umbilicus to facilitate a large pannus or high belt line.
- Tumor fixation by rectal exam is unreliable in determining whether or not a low rectal tumor is resectable.
- Tumor fixation within the pelvis does not necessarily imply infiltration of tumor into surrounding structures.
- Inflammatory adhesions within the pelvis does not portend a worse prognosis with respect to local recurrence or overall mortality.
- Ultimate decision on whether to proceed with an APR is made at the time of laparotomy.

Positioning

- The patient is placed in a modified lithotomy position with Allen stirrups.
- The thighs are level with the abdomen as this allows efficient placement of a self-retaining retractor without creating excessive pressure between the retractor and the patient's thighs (**FIG 1**).
- The perineum is positioned flush with the edge of the operating room table.

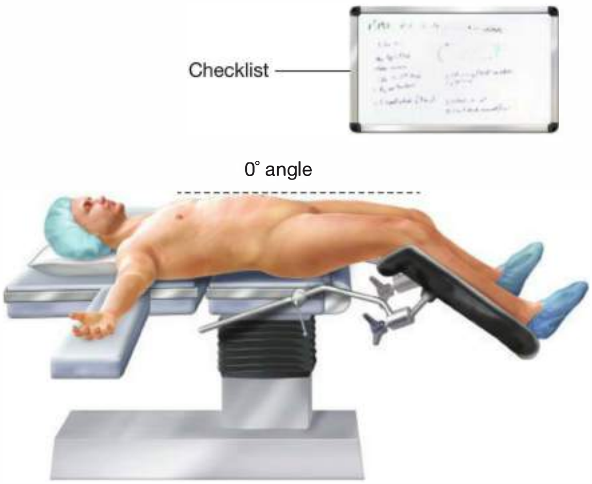


FIG 1 ● Patient positioning on the operating table. Note the horizontal position of the thighs to ensure free movement of surgeon's arms and hands. The perineum is flushed to the end of the table.

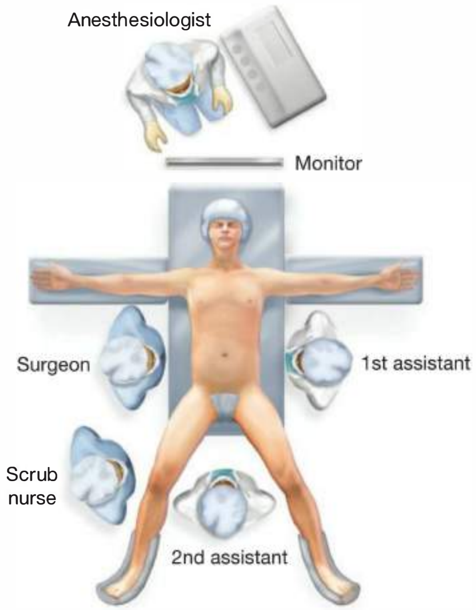


FIG 2 ● Team setup. For the abdominal phase of the operation, the surgeon stands by the patient's right side with his or her assistant standing at the patient's left side. A second assistant, if available, stands in between the patient's legs. The scrub nurse stands by the surgeon's right side.

- The pelvis is supported with a folded sheet to lift the entire perineum and facilitate exposure during the perineal dissection.
- The arms are placed in a neutral position and supported with suitable armrests.
- The anus is closed with a purse-string monofilament suture (0-Prolene with circle taper 1 [CT-1] Ethicon needle, or equivalent).
- For the abdominal phase of the operation, the surgeon stands by the patient's right side, with his or her assistant standing at the patient's left side. A second assistant, if available, stands in between the patient's legs. The scrub nurse stands at the surgeon's right side, by the patient's right leg (**FIG 2**). The surgeon and the first assistant will switch sides as necessary during the pelvic dissection.
- During the perineal phase, the surgeon and the first assistant will be situated in between the patient's legs, with the second assistant by the patient's right or left side.

EXPOSURE

- Exposure of the abdomen is obtained with a lower midline incision from the umbilicus to the pubic symphysis. A wound protector may be inserted to protect the wound from infectious and oncologic soilage (**FIG 3**).
- The abdomen should be fully explored for the presence of gross metastatic disease.
- Care should be taken to evaluate all peritoneal surfaces, the entire gastrointestinal tract, the omentum, and the liver.
- Any concerning lesions away from the primary tumor should be biopsied and evaluated by intraoperative cryosection.
- A self-retaining retractor is positioned to optimize exposure of the pelvis.
  - Two short Richardson attachments are used to retract the abdominal wall laterally, in a perpendicular orientation to the incision to avoid undue traction on the femoral nerves at the pelvic inlet (**FIG 4**).
  - A bladder blade is positioned at the inferior aspect of the incision to retract the bladder and uterus. A 2-0 silk, figure-of-eight suture through the fundus of the uterus can facilitate positioning the uterus behind the bladder blade.

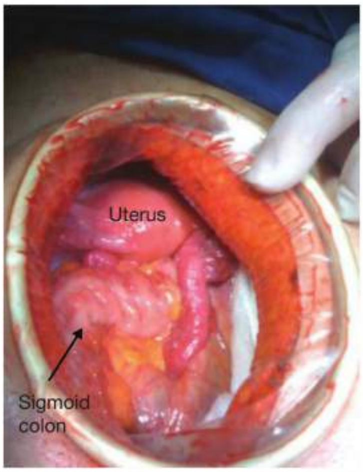


FIG 3 ● Placement of a wound protector protects the wound from infectious and oncologic soilage.

TECHNIQUES

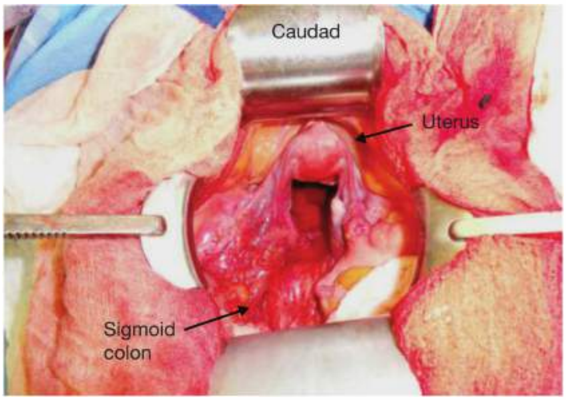


FIG 4 ● Exposure of the lower abdomen using a Bookwalter retractor. Two short Richardson attachments are used to retract the abdominal wall laterally, in a perpendicular orientation to the incision to avoid undue traction on the femoral nerves at the pelvic inlet. A bladder blade is positioned at the inferior aspect of the incision to retract the bladder and uterus. The small bowel is packed into the upper abdomen and held in place with malleable retractor.

- The small bowel is packed into the upper abdomen; this maneuver is facilitated by not extending the incision beyond what is required to access the origin of the inferior mesenteric artery.
- A malleable retractor attachment for the Bookwalter and moistened laparotomy pads aid in keeping the small bowel out of the pelvis.

Mobilization of Sigmoid Colon and Transection of the Inferior Mesenteric Artery

- The lateral peritoneal attachments to the sigmoid colon are divided, exposing the plane between the sigmoid mesocolon and the retroperitoneum (**FIG 5**).
- Mobilization of the sigmoid mesocolon allows for exposure and preservation of the left ureter and gonadal vessels, which should always be identified prior to dividing the inferior mesenteric artery at its origin (**FIG 6**).

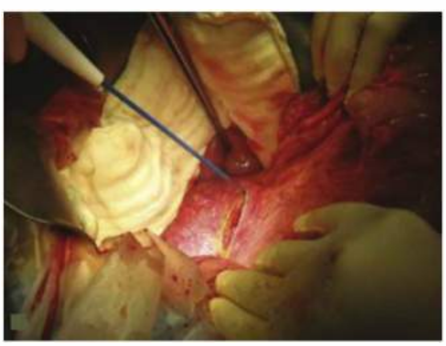


FIG 5 ● Sigmoid colon mobilization. With the descending colon retracted medially, the lateral peritoneal attachments are transected with electrocautery along the left paracolic gutter.

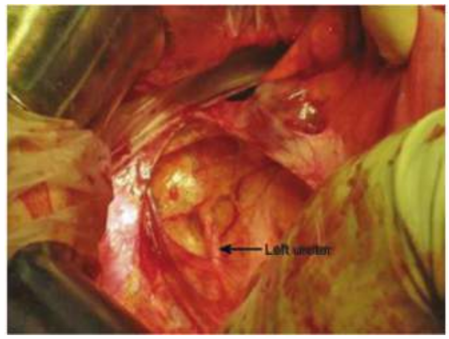
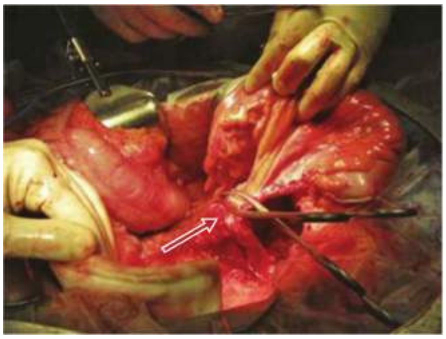


FIG 6 ● Identification of the left ureter. After full mobilization of the descending colon, the left ureter is exposed in the retroperitoneum. The surgeon is retracting the descending colon medially.

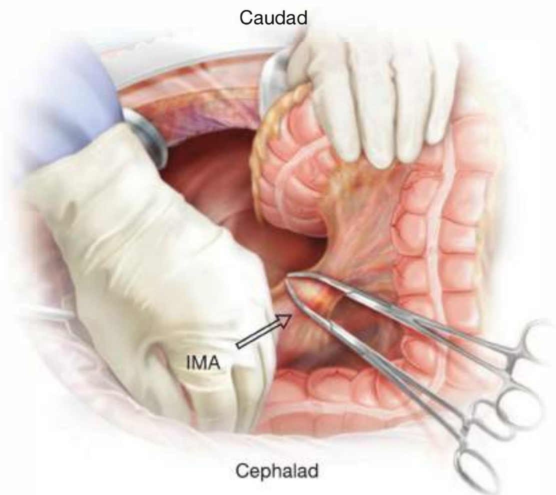
- The left ureter courses over the left psoas and is located medial to the gonadal vessels; it travels over the left iliac artery at its bifurcation at the pelvic inlet.
- Direct exposure of the left psoas often indicates an incorrect dissection plane where the ureter and gonadal vessels are mobilized medially with the sigmoid mesocolon.
- The peritoneal reflection on the right side of the sigmoid mesocolon is incised to complete the dissection of the mesentery away from the retroperitoneum. Again, care must be taken to maintain the ureter in its normal, anatomic position in the retroperitoneum.
- The origin of the inferior mesenteric artery (IMA) is identified at its origin off the aorta. The IMA is then ligated between Sarot clamps, incised, and doubly ligated with braided 2-0 suture (**FIG 7A,B**). High IMA ligation allows for an excellent lymph node harvest.
- The colon is then transected proximally between the sigmoid and descending colon segments with a linear stapler. The intervening mesentery is divided with an energy device.

Mobilization of the Rectum

- Once the sigmoid mesocolon is mobilized, dissection along the same anatomic plane between the mesentery and retroperitoneum is continued toward the pelvic inlet where the total mesorectal excision (TME) is initiated.
- The mesorectum is fully mobilized posteriorly using sharp dissection, typically with electrocautery. Care is taken not to injure the left and right hypogastric nerves posteriorly, as they can be intimately associated with the mesorectum (**FIG 8**).
- Dissection along the presacral plane is facilitated with anterior traction on the mesorectum provided by the St. Mark's retractors (**FIG 9A,B**).
- As the dissection proceeds posteriorly, the curve of the sacrum and coccyx needs to be followed (**FIG 10**), as inadvertent injury to the venous plexus of the sacrum posteriorly and hypogastric veins laterally can result that can be very difficult to control. Division of the rectosacral facia exposes the pelvic floor (levator ani).
- Once the rectum is fully mobilized posteriorly, the lateral mobilization can commence. This phase of the dissection



A



B

FIG 7 ● **A,B.** IMA division. The IMA is transected between clamps and will subsequently be ligated with heavy silk sutures.

is facilitated by the St. Mark's retractors, and the dissection proceeds along the avascular mesorectal plane that was initiated posteriorly. The lateral rectal ligaments are transected with an energy device (**FIG 11**).

- Care must be taken to avoid inadvertent entry into the mesorectum as well as injury to lateral pelvic sidewall structures, including the ureter at the pelvic inlet and branches of the internal iliac vein deeper within the pelvis. The appropriate plane is properly exposed with sufficient traction.

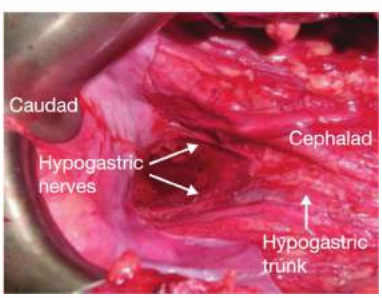
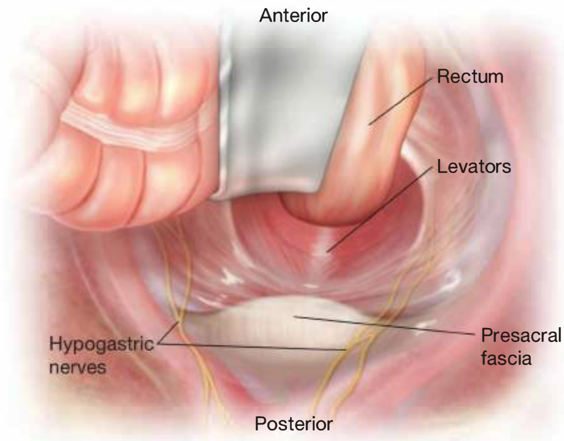
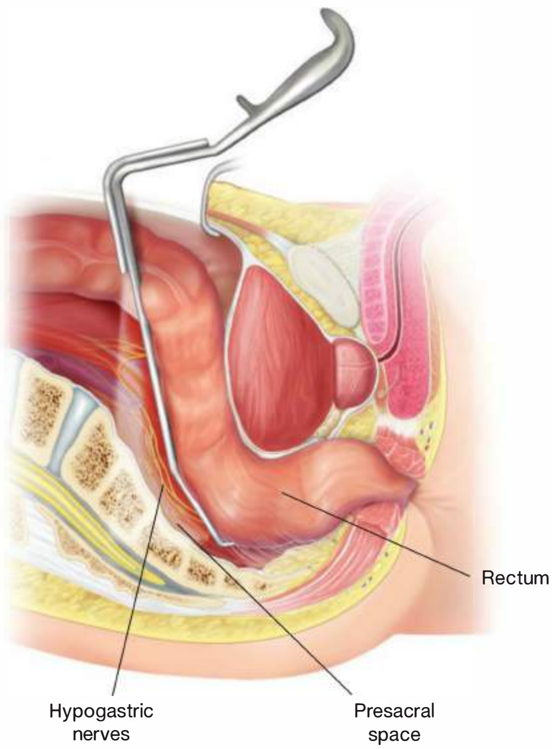


FIG 8 ● View of sympathetic plexus and origin of the left and right hypogastric nerves.



A



B

FIG 9 ● Posterior pelvic exposure with the lighted St. Mark's retractor. **A.** The rectum is retracted anteriorly, exposing the presacral space posteriorly. The hypogastric nerves are exposed and should be swept posteriorly and away from the mesorectum. This begins the superior and posterior portion of the total mesorectal excision. **B.** The presacral plane of dissection should be followed down to the levator muscles and the pelvic floor.

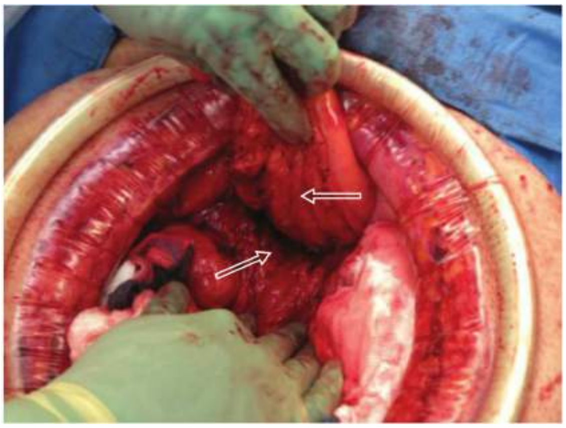


FIG 10 ● The posterior plane of dissection proceeds in a semicircular fashion to release the posterolateral rectal attachments and to allow a better anterior retraction on the rectum. This allows continued exposure of the posterior plane of dissection down to the pelvic floor and prevents vascular and nerve injuries along the lateral pelvic walls. Mesorectum *(top arrow)*; presacral fascia *(bottom arrow)*.

- The anterior dissection is initiated with division of the rectovesical reflection in men and rectovaginal reflection in women. Mobilization is continued anterior to Denonvilliers' fascia, exposing the seminal vesicles in men (**FIG 11**) and the vagina in women.
- For posterior tumors in men, consideration can be given to dissecting posterior to Denonvilliers' fascia as this may lower the risk of injury to the nervi erigentes with concomitant sexual dysfunction.
- For distal tumors overlying the anal canal, creating a "waist" near the tumor when dividing the levators has been associated with inadvertent bowel perforation, circumferential margin involvement, and local recurrence. An extended resection whereby the levators are resected at their origin can improve the aforementioned oncologic parameters.
- The posterior, lateral, and anterior dissections are carried down to the level of the levators circumferentially.

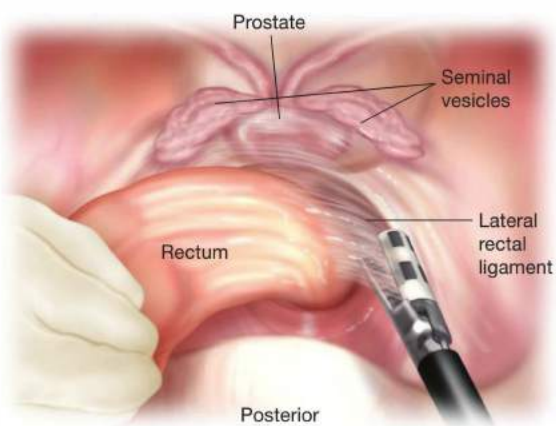


FIG 11 ● Transection of the lateral rectal ligaments and anterior pelvic dissection. Posterolateral retraction of the rectum allows for good exposure of the lateral rectal ligament (the right one is shown here), which can then be transected with cautery or with an energy device. The anterior dissection will then proceed behind Denonvilliers' fascia, in the space between the rectum posteriorly, and the prostate and seminal vesicles anteriorly.

Dissection of the Perineum

- This component of the operation can be performed concurrently with the abdominal dissection of the rectum.
- This technical description is applicable to a patient who has been placed in the lithotomy position and the legs are elevated in Allen stirrups. During the abdominal component of the operation, the Allen stirrups are lowered such that the thighs are level with the torso and abdomen, as this facilitates placement of the self-retaining retractor. For the perineal dissection, the Allen stirrups are elevated to fully expose the perineum. The self-retaining retractor should be repositioned if it places pressure on the thighs as they are elevated into position.
- The surgeon should have a separate electrocautery, with dedicated grounding pad, and a separate suction to allow the two operating teams to work independently. An instrument table should also be assembled for the perineal dissection, and the instruments should also be kept separate from those used in the abdomen and pelvis. The instrument set used is a major abdominal set, with the addition of two Gelpi retractors if they are not included in the set.
- A monofilament suture (0-Prolene) is used to close the anus prior to initiating the dissection; a large needle (CTX) is used to place two half-circle throws 1 cm lateral to the anal verge and the anus is closed by tying the suture (**FIG 12**). This helps prevent infectious and oncologic soilage of the perineal wound. The surgeon can perform this step at the beginning of the operation or when the decision to proceed with an APR is made.
- Two Gelpi retractors are placed in an "X" configuration such that the anus and perianal skin are adequately exposed for the incision and subsequent dissection (**FIG 12**).
- A circular skin incision is placed around the anal verge to include all of the anoderm as well as a margin of perianal

FIG 12 ● Closure of the anus with purse-string suture. This helps prevent infectious and oncologic soilage of the perineal wound.

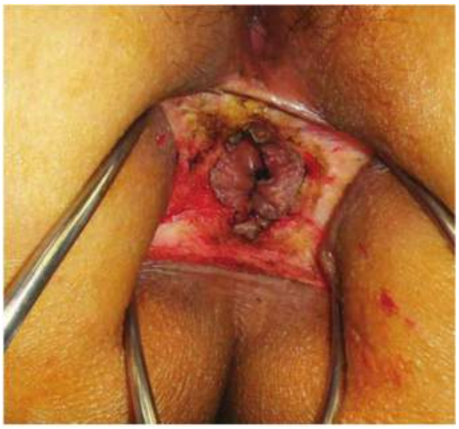


FIG 13 ● Perineal dissection: lateral incision around the anal canal. The incision is carried through the skin and subcutaneous tissues.

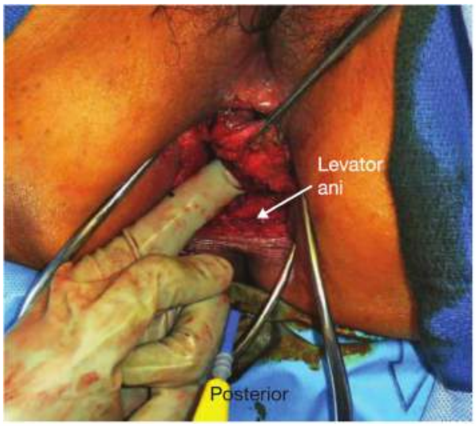


FIG 15 ● Perineal dissection: posterior palpation of coccyx during perineal dissection. The transection of the levators starts posteriorly anterior to the coccyx. The index finger of the surgeon is placed into the pelvis and hooked on to top of the levator muscle, pulling it into the field. This allows for safe transection of the levator muscle with electrocautery.

skin. The Gelpi retractors are repositioned inside of the skin incision to enhance exposure (FIG 13). A 3-cm margin (radius) around the closed anus is sufficient.

- Dissection should include the external sphincter muscle as the surgeon proceeds toward the levator ani (FIG 14). The lymphatic-bearing tissue surrounding the anal canal should be included with the specimen.
- The Gelpi retractors should be repositioned to maintain exposure. Handheld Richardson retractors can also be helpful and are held by the surgeon's assistant.
- As the external sphincter, perianal fat, and lymphatic tissue are mobilized, the coccyx should be palpated to ensure that dissection proceeds anterior to this structure. The surgeon in the abdominal field should place his or her hand posteriorly and serve as a guide for entry into the abdomen (FIG 15). A curved Mayo scissors is used to divide the anococcygeal ligament and levator ani muscle, which ultimately connects the abdominal and perineal dissections.
- The transection of the levators starts posteriorly anterior to the coccyx (FIG 15). The index finger of the surgeon is placed into the pelvis and hooked on to top of the levator muscle, pulling it into the field. This allows for safe transection of the levator muscle with electrocautery. The posterior and lateral component of the levator ani should be divided first, as the anterior dissection can be difficult, especially in anterior tumors.

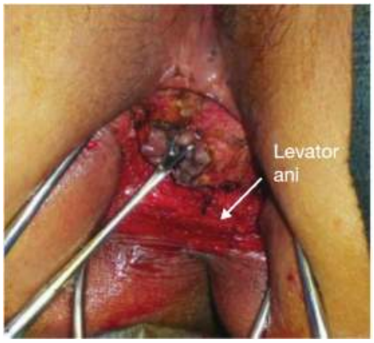


FIG 14 ● Perineal dissection: dissection through levator muscle complex.

- The surgeon's finger should then guide division of the perineal body anteriorly. In women, this component of the dissection is completed along the rectovaginal septum. In men, the surgeon should pay very close attention to the prostate gland anteriorly, as entry into the prostate can produce significant bleeding. Furthermore, if the dissection is too anterior, entry into the membranous urethra can occur. The appropriate plane of dissection is anterior to Denonvilliers' fascia as the abdominal and perineal dissections are connected.
- The specimen, now completely disconnected proximally and distally, is then extracted through the perineal wound. The rectum should exhibit an intact mesorectum with no distal "waisting" (FIG 16) in order to ensure excellent oncologic outcomes.
- Anterior tumors in men can lead to loss of the normal plane between the rectum and prostate or even invasion into the prostate. In this case, removing the prostate en bloc with the rectum may be the best way to achieve a satisfactory oncologic margin.
- Division of the levator ani circumferentially allows removal of the rectum through the perineum.
- The pelvis is irrigated with saline and hemostasis achieved before the perineal wound is closed. Persistent bleeding from the remaining levator ani, the prostate, or vagina may be controlled with well-placed suture ligatures.

Closure of Perineal Wound

- Once hemostasis is achieved, the levator ani are reapproximated with interrupted 0-Vicryl sutures. If the defect is large or insufficient levator ani muscle remains,

FIG 16 ● APR specimen. The rectum should exhibit an intact mesorectum *(A)* with no distal "waisting" *(B)* in order to ensure excellent oncologic outcomes.

consideration should be given to closure with a vertical rectus abdominus myocutaneous (VRAM) flap.

- The more superficial layers are sequentially closed with interrupted 2-0 Vicryl sutures and the skin can be reapproximated with interrupted 4-0 Monocryl sutures.
- A mobilized omental flap can be used to fill the pelvic cavity and help keep the small bowel in the upper abdomen. Closure of the peritoneum at the pelvic inlet can also facilitate keeping the small bowel in the upper abdomen.
- A closed suction drain is placed in the pelvis.

Creation of Descending Colostomy

- The site marked for the colostomy is identified. A Kocher clamp is used to lift the skin at the center of the mark and a circular skin incision is made approximately 2 cm in diameter.
- The subcutaneous fat is divided longitudinally, exposing the anterior rectus sheath, which is divided longitudinally as well. The rectus abdominus is bluntly separated and the posterior rectus sheath is divided longitudinally. Handheld Army-Navy retractors can facilitate exposure. The opening for the colostomy site should snugly accommodate two fingerbreadths.
- The descending colon should be sufficiently mobilized to allow a tension-free anastomosis between the colon and the skin. In patients with a thick layer of abdominal fat, additional length can be obtained by mobilizing the splenic flexure. If excessive tension at the skin persists, maturing the stoma as a loop-end can be the best option.
- Reinforcing the colostomy site with a retrorectus biologic mesh can decrease the incidence of parastomal hernia formation.
- The abdominal facia is closed in a standard manner.
- The staple line on the colon is removed with cautery and the stoma is matured to the dermis with interrupted 3-0 absorbable suture.
- Sterile dressings and a stoma appliance are placed such that the skin surrounding the stoma is completely protected with the wafer of the appliance.

PEARLS AND PITFALLS

Digital rectal exam and rigid proctoscopy	■ Should always be performed at initial consultation as lesion may decrease in size after neoadjuvant chemoradiation
Ureteral stent placement	■ Bulky pelvic tumors present a challenge and ureteral stents may assist in the identification of the ureters.
Pelvic dissection	■ Posterior first (along the presacral plane) ■ Lateral dissection/transection of the lateral rectal ligaments: Avoid injury to autonomic trunks and genital nerve branches that would lead to autonomic dysfunction postoperatively. ■ Anterior dissection: Staying inside of Denonvilliers' fascia reduces the incidence of injury to autonomic nerves to the prostate. Bulky anterior lesions may necessitate dissection anterior to Denonvilliers' fascia.
Perineal phase	■ Perform a circumferential dissection. Avoid "conization" of the specimen. The specimen should have an intact mesorectum without a "waist" effect distally.
Colostomy site	■ A location lateral to the rectus musculature increases the likelihood of peristomal hernia.
Perineal closure	■ Following neoadjuvant chemoradiation, a pedicled flap closure to the perineum warrants consideration in patients at high risk for wound breakdown (i.e., obese, diabetes, history of tobacco use).
Position in stirrups	■ Padded and positioned to avoid peroneal nerve injury
Omental flap	■ Save the omentum, mobilize the omental pedicles, and place omental flap into pelvic defect. This may prevent small bowel from becoming entrapped in the new "potential" space created in the pelvis.

POSTOPERATIVE CARE

- Recent evidence has demonstrated enhanced recovery after surgery pathways to improve a number of important postoperative outcomes following colorectal surgery.

OUTCOMES

- Survival from rectal cancer after multimodality treatment is dependent on disease stage. Overall 5-year survival is approximately 90% for stage I, 74% to 65% for stage II, and 81% to 33% for stage III of disease. Development of distant metastasis occurs in less than 10% in patients with stage I disease but increases up to 28% and 50% in patients with stages II and III rectal cancers, respectively.
- Local pelvic recurrence of rectal cancer is also dependent on tumor and nodal stage. Local recurrence is 5% or less for patients with stage I rectal cancer but increases to 15% for stage II disease and 22% for stage III disease. If a pelvic recurrence can be treated with a margin-negative surgical resection, 5-year survival can approach 40%. Often, this requires a pelvic exenteration, which demands a multispecialty surgical approach.

COMPLICATIONS

- Wound infections
- Incisional hernias
- Urinary/sexual dysfunction: important to preserve hypogastric nerves and parasympathetic ganglia intact
- Ureteral injury: critical to identify the left ureter prior to IMA transection
- Deep vein thrombosis (DVT): lower risk with use of adequate DVT prophylaxis
- Cardiac and pulmonary complications
- Pelvic abscess: reduced incidence with placement of an omental pedicle flap in the pelvis.
- Perineal wound breakdown is a notorious problem, especially in high-risk patients.

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Chapter **33**

Abdominoperineal Resection: Laparoscopic Technique

Joël Leroy Didier Mutter Jacques Marescaux

DEFINITION

- An abdominoperineal resection, or APR, involves removal of the anus, the rectum, and part or all of the sigmoid colon along with the associated regional lymph nodes, through incisions made in the abdomen and perineum. The end of the remaining colon is brought out as a colostomy.
- The laparoscopic abdominoperineal amputation of the rectum is a totally laparoscopic intervention, as specimen removal is performed through a perineal excision without compromising the oncologic aspect of the surgical procedure.

INDICATIONS

- Indications for laparoscopic APR:
  - Rectal cancer: when unable to obtain a negative distal margin and/or in patients with poor sphincter function or severe comorbidities
  - Anal cancer: after failure of chemotherapy/radiation therapy or in the palliative setting
  - Inflammatory bowel disease (i.e., Crohn's with severe perianal disease)

PATIENT HISTORY AND PHYSICAL FINDINGS

- Most patients with rectal tumors generally present after an incidental finding during screening colonoscopy or with occult bleeding and anemia.
- A thorough history and physical examination should include the following:
  - Presence of rectal pain and/or tenesmus
  - Presence of obstructive symptoms
  - Description of anorectal function, with any fecal incontinence or leakage documented preoperatively
  - Documentation of urinary and erectile function/dysfunction
  - A detailed personal and family history of colorectal cancer, polyps, and/or other malignancies
- Physical examination should include the following:
  - Routine abdominal examination, noting any previous incisions
  - Digital rectal examination with assessment of sphincter function
  - Bilateral inguinal nodal examination
  - Rigid proctoscopy is arguably the most critical portion of the physical examination and is the key to proper patient selection of patients for an APR.
- Proctoscopy should be standardized and documented at minimum.
  - The distal and proximal extent of the lesion measured from the anal verge
  - Exact position of the lesion and extent of the rectal circumference involved
  - Presence or absence of fixation to perirectal structures

IMAGING AND OTHER DIAGNOSTIC STUDIES

- A colonoscopy with documentation of all polyps should be performed. Suspicious lesions should be tattooed to facilitate localization during surgery.
- Staging with endorectal ultrasound or rectal magnetic resonance imaging (MRI) should be performed to determine the need for neoadjuvant therapy and to plan operative strategy. A computed tomography (CT) of the chest, abdomen, and pelvis evaluates for potential metastases.
- A preoperative carcinoembryonic antigen level should be obtained.

SURGICAL MANAGEMENT

Preoperative Planning

- Informed consent is obtained preoperatively. The patient has been informed of the necessity to perform a definitive colostomy.
- The colostomy site is marked by a skin tattoo the evening before the intervention.
- We follow the Society of American Gastrointestinal and Endoscopic Surgeons' (SAGES) bowel preparation guidelines.
- Appropriate intravenous antibiotics are administered within 1 hour of skin incision.

Equipment and Instrumentation

- 10-mm, 0-degree camera (30-degree camera is optional) with high-resolution monitors
- Laparoscopic endoscopic scissors and a blunt tip, 5-mm energy device (10-mm in obese patients)
- Laparoscopic linear staplers

Positioning and Port Placement

Patient setup

- Patient setup is a major operative step.
- The patient should be adequately secured to the table.
- Adequate padding is essential to prevent nerve and venous compressions.
- The patient is placed in a supine position with a cushion placed underneath the left flank in order to obtain a moderate lateral decubitus, which will retract bowel loops toward the right part of the abdomen.
- A rotation to the right and a caudal head tilt (Trendelenburg position) will help to retract bowel loops by means of gravity.
- The patient's legs will then be spread apart in a semiflexion using adjustable leg supports to allow for a double abdominal and perineal access.
- One should control the perfect positioning of the buttocks at the distal edge of the table to allow for an easy access to the anal and perineal area.

FIG 1 ● Team setup. Surgeon *(1)*. First assistant *(2)*. Second assistant *(3)*. Scrub nurse *(4)*. Anesthesiologist *(5)*.

- The arms are padded and tucked alongside the body.
- An orogastric tube is inserted; it will be removed at the completion of the surgery.
- A Foley catheter is inserted; it will be left in place for 24 hours.

Team positioning

- This procedure is performed with two assistants and a scrub technician.
- A table is prepared for the abdominal part of the intervention.
- A second table is used for the peritoneal part of the operation.
- During the abdominal part of the procedure (**FIG 1**), the surgeon stands on the right flank of the patient, his or her first assistant lateral to the patient's right shoulder, and the second assistant in between the patient's legs. The scrub technician is then located to the right of the surgeon lateral to lower limbs.
- During the perineal part of the procedure, the entire team shifts toward the extremity of the table once the perineum has been exposed.
- The monitors are placed in front of the operating team and at eye level to improve ergonomics.

Port placement

- One 12-mm supraumbilical port (port A) is introduced first using a mini-open technique. It will be used to accommodate the camera (**FIG 2**).
- Two other ports, a 5-mm port in the right flank (port B) and a 12-mm port in the right iliac fossa (port C), are used as operating ports (**FIG 2**).
- The fourth port in the left flank at the level of the umbilicus is inserted through the rectus muscle (port D, 5 mm in diameter), where the colostomy will be performed (**FIG 2**).
- The last port introduced in the suprapubic area (port E, 12-mm in diameter) is used for pelvic retraction and for exposure of the sigmoid colon's root (**FIG 2**).
- Port fixation in the wall should be perfect in order to prevent any risk of parietal injury and to prevent increased operative times due to a loss in abdominal pressure. One should not hesitate to fix ports to the skin.
- Additional ports may be used in case of difficulty in exposure. In this case, a port will be positioned in the right hypochondrium (port F) to retract the ileocecal area. This is particularly useful in obese patients.

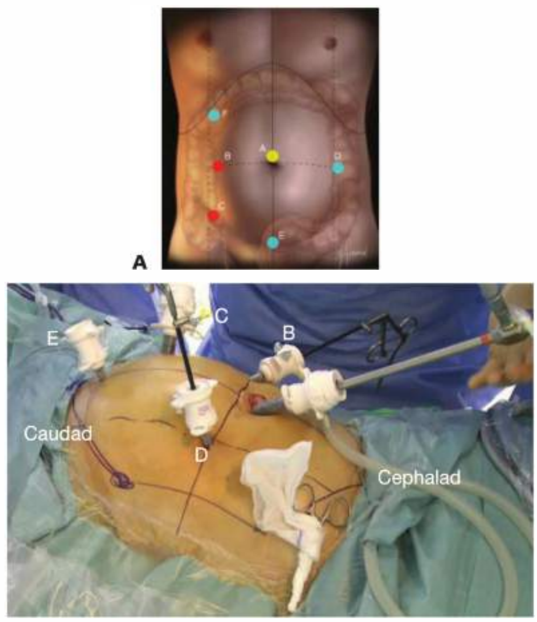

FIG 2 ● Port placement. **A.** Optical port *(A)*. Working ports *(B,C)*. Retracting ports *(D,E)*. Additional retracting port *(F)*. **B.** External view from the left side of the patient.

LAPAROSCOPIC ABDOMINOPERINEAL RESECTION

Exploration and Exposure

- The intervention is begun by an exploration of the abdominal cavity to locate the tumor and evaluate for possible metastases. It also allows to expose the pelvis and to evaluate the length and quality of the sigmoid loop, which will allow determining the type of mobilization of the left colon and of the splenic flexure.
- The tumor's identification may be necessary and especially so for tumors located proximally. Combined endoscopy may be required in cases where an effective preoperative marking could not be performed on the day before the intervention.
- Exposure is improved by placing the patient in a Trendelenburg position with the table tilted to the right.
- In women, exposure of the posterior pelvis and of the rectovaginal (Douglas') pouch can be obtained by direct or indirect suspension of the uterus by means of the T'Lift™ (VECTEC, France) tissue retraction device (**FIG 3A,B**) or suprapubic transparietal sutures (**FIG 4A,B**).
- Visceral obesity (in male patients) is more incapacitating than subcutaneous obesity (in female patients). The use of retractors is very helpful.

Primary Vascular Oncologic Approach to the Sigmoid Colon

- As for any oncologic surgical procedure, a primary vascular approach is the rule.

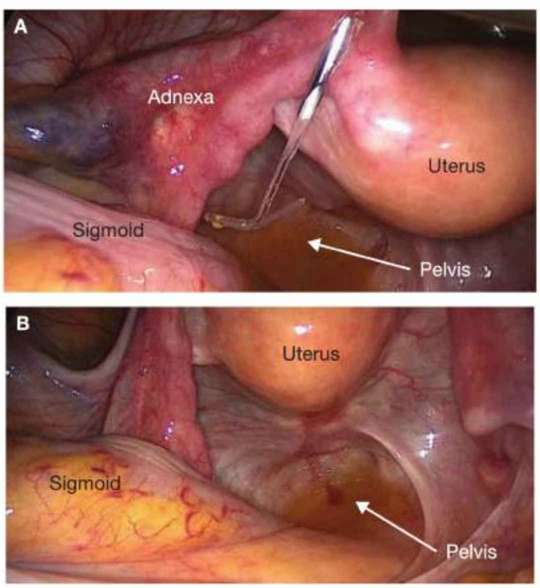

FIG 3 ● T'Lift™ tissue retraction system. **A.** T'Lift™ tissue retraction system passed through the round ligament. **B.** Pelvic exposure in women after bilateral uterine suspension with T'Lift™ tissue retraction system.

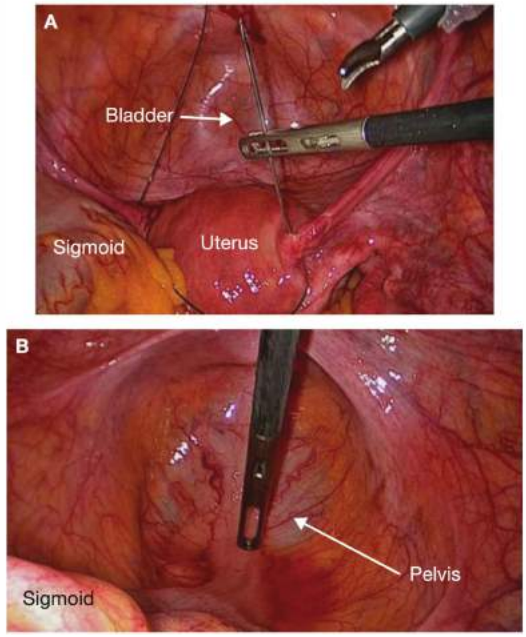

FIG 4 ● **A.** Transparietal suprapubic sutures for uterine suspension. **B.** Exposure of the pelvis in women after transparietal suprapubic suture uterine suspension.

- In rectosigmoid cancer, one should approach the inferior mesenteric vessels at their origin in order to perform an "en bloc" removal of all lymph nodes associated with the rectosigmoid junction (D3 resection). It does not prevent the potential preservation of the proximal inferior mesenteric artery (IMA) and of the left colic artery (LCA).
- We always start with a primary approach to the IMA. The inferior mesenteric vein (IMV) is then approached in order to prevent any venous overload related to the late ligation of the IMA.
- Once the root of the sigmoid mesocolon has been exposed, the left retroperitoneal space is opened by incising the posterior peritoneum from the anterior aspect of the promontory up to the left border of the duodenojejunal junction (ligament of Treitz) (**FIG 5A**).
- Once the retroperitoneum has been opened, dissection is initiated opposite the promontory on the posterior aspect of the inferior mesenteric vascular sheath (i.e., the superior rectal artery at this level). This step is facilitated by the anterior traction on the mesocolon, which induces the pneumodissection of the retrovascular space, thanks to intraabdominal carbon dioxide pressure.
- Dissection is carried on in contact with the vascular sheath cranially until the origin of the IMA on the aorta.
- The dissection is continued from caudad to cephalad in contact with the artery, which is skeletonized over approximately 2 cm in order to achieve ligation and division 1 or 2 cm away from the aorta (**FIG 5B**).

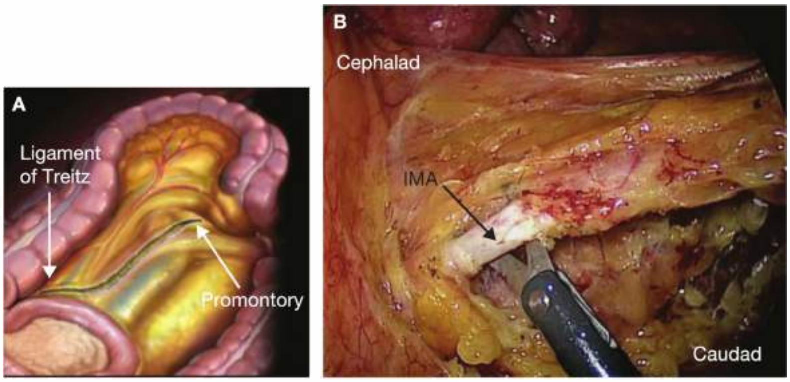

FIG 5 ● Dissection of the IMA. **A.** Opening of the left retroperitoneal space by incising the posterior peritoneum from the anterior aspect of the promontory to the ligament of Treitz. **B.** The IMA has been dissected 1 to 2 cm from the aorta.

- This technique allows preserving sympathetic nerve plexuses, which course along the aorta on its right anterior aspect.
- Division of the IMA is performed with the LigaSure™ vessel-sealing device using a ligation with a loop on the IMA stump.
- Once the IMA has been divided, the assistant standing between the patient's legs will grasp the artery using an atraumatic forceps introduced into the suprapubic port (port D) and apply anterior traction to ideally expose dissection planes in contact with the left posterior and lateral aspects of the artery.
- It helps to preserve the nerve plexus in contact with the artery, and notably the left sympathetic trunk of the neurovegetative system that will be progressively freed and parietalized.
- The next operative step will be to identify the IMV lateral to Treitz's flexure underneath the inferior edge of the pancreas (**FIG 6A**).
- The IMV is then transacted at the level of the ligament of Treitz with the LigaSure™ vessel-sealing device or in between clips.

Mobilization and Division of the Sigmoid Colon

- Our main objective is to perform a medial to lateral mobilization of the mesocolon.
- A medial to lateral mobilization of the sigmoid colon allows for traction on the upper rectum with a perfect exposure of the anterior, posterior, and lateral aspects of the rectum.
- Mobilization of the mesocolon is performed using a medial to lateral approach (**FIG 6A,B**) by opening the plane between Toldt's fascia anteriorly and Gerota's fascia posteriorly.
- The dissection is carried laterally until the posterior aspect of the descending colon is reached laterally.

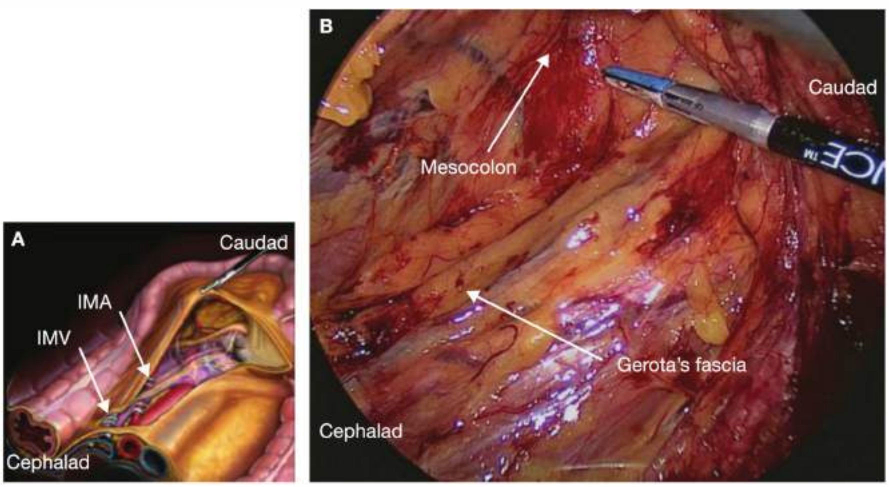

FIG 6 ● Medial to lateral mobilization of the mesocolon and IMV transection. **A.** IMV transection at the level of the ligament of Treitz. The IMA was previously transected off the aorta. The retroperitoneal structures are exposed. **B.** The mesocolon is separated from the retroperitoneum (Gerota's fascia) using a medial to lateral approach.

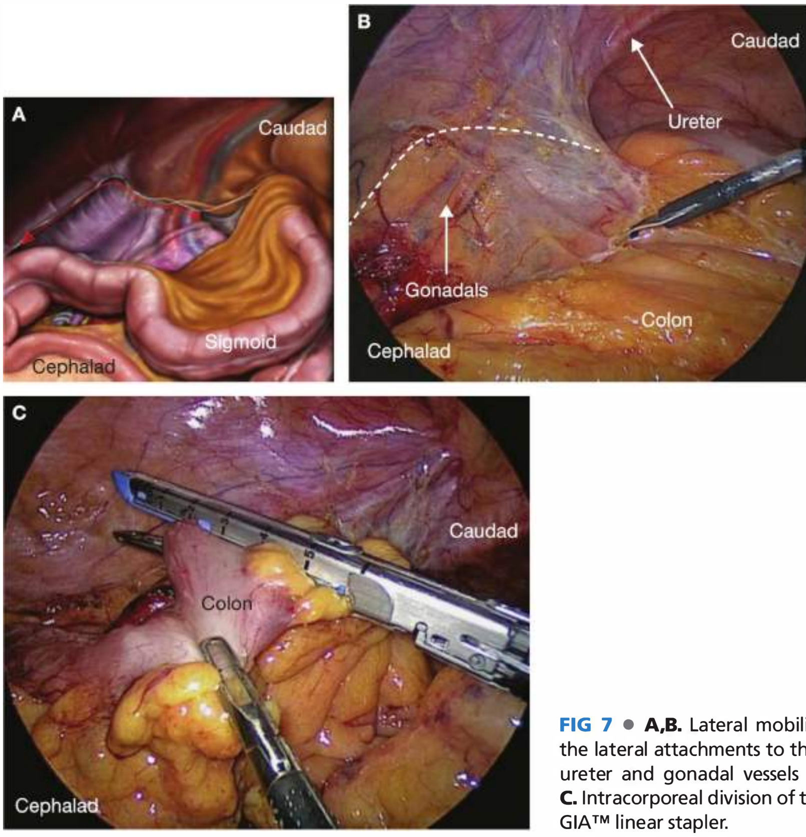

FIG 7 ● **A,B.** Lateral mobilization of the sigmoid loop by dividing the lateral attachments to the abdominal wall *(dotted line).* The left ureter and gonadal vessels are visualized in the retroperitoneum. **C.** Intracorporeal division of the proximal sigmoid colon with an Endo GIA™ linear stapler.

- Caudally, the dissection is carried toward the pelvic inlet. One should be cautious when in contact with the aorta as well as with the left iliac vessels where nerve rami of the superior hypogastric sympathetic plexus courses.
- The left ureter is identified during the dissection. It is located between the aorta and the genital vessels, well protected by Gerota's fascia.
- Mobilization of the sigmoid colon is completed with a division of its lateral attachments to the abdominal wall (**FIG 7A,B**).
- Division of the sigmoid loop is then performed intracorporeally with an Endo GIA™ linear stapler (**FIG 7C**).
- Mobilization of the splenic flexure is not performed routinely in APR cases.

Dissection of the Rectum According to the Total Mesorectal Excision (Heald's) Technique

- The principle of total mesorectal excision (TME) relies on the study of the embryologic development of the pelvis and of organs located within it. A surgical intervention cannot be envisaged without a detailed knowledge of pelvic and fascial anatomy (**FIG 8A**) that is essential to obtaining appropriate surgical specimens.
- Heald's principles rely on the dissection of the space located between the fascia propria of the rectum and the presacral fascia posteriorly, the lateral pelvic fascia laterally, and Denonvilliers' fascia anteriorly.
- In APR, the inferior limit of the dissection will depend on tumor's size and on its distal location.
- It is not recommended to dissect in contact with the tumor in a conical way but rather in a cylindrical manner. That is why distal dissection is performed using a perineal approach as proposed by Miles.

Posterior Dissection of the Rectum

- Once the sigmoid colon has been mobilized, a cranial and anterior traction is exerted on the rectum in order to expose the posterior aspect of the upper rectum.
- The presacral space (**FIG 8B,C**) is opened under the effect of traction and of pneumoperitoneum pressure, along with an atraumatic anterior retraction of the posterior rectal wall—a small swab at the tip of an atraumatic grasper is used. The tracts, which cross the space, are divided by means of a 2-mm electrode located at the tip of a LigaSure Advance™ vessel-sealing device.
- Dissection should be continued toward the pelvic floor. When progressing downward, dissection should continue

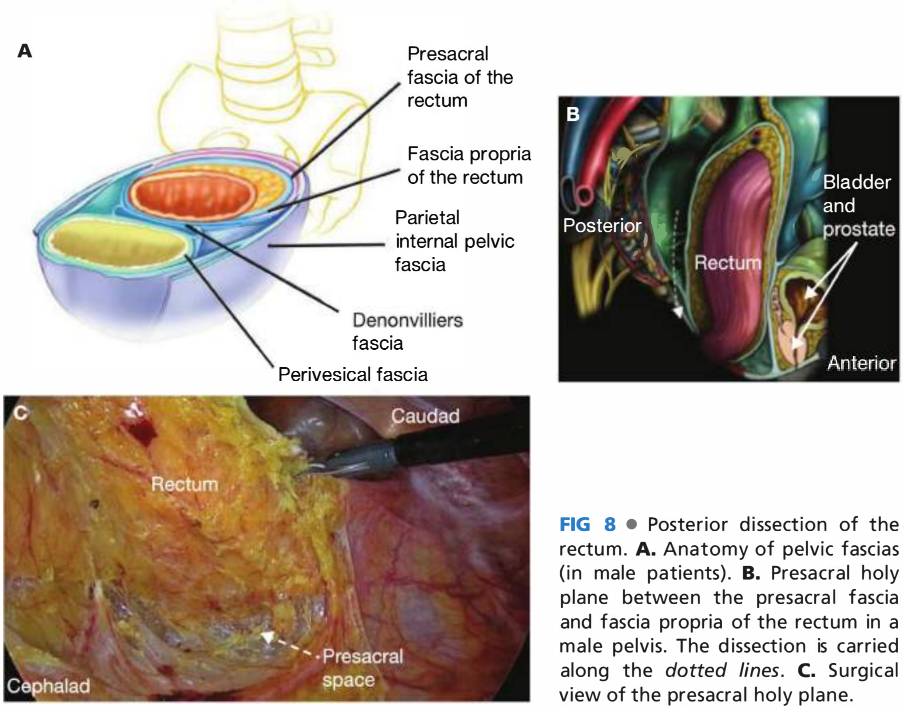

FIG 8 ● Posterior dissection of the rectum. **A.** Anatomy of pelvic fascias (in male patients). **B.** Presacral holy plane between the presacral fascia and fascia propria of the rectum in a male pelvis. The dissection is carried along the *dotted lines*. **C.** Surgical view of the presacral holy plane.

along the presacral fascia until it fuses with the fascia propria (Waldeyer's fascia).

- During this dissection, left and right branches of the inferior hypogastric plexuses can be observed. The lateral pelvic fascia protects them along the pelvic side walls (**FIG 9A**).

Lateral Dissections of the Rectum

- Cranial and medial retraction is maintained on the rectum in order to open the lateral pelvic space. This step is begun on the right side.
- The peritoneum is incised until seminal vesicles are reached. Under the effect of pneumoperitoneum pressure and of medial retraction, parietalization of the inferior hypogastric plexus and especially of the sacral branches (3rd and 5th sacral nerves, parasympathetic nerves responsible for male erections) is carried on (**FIG 9A**). Care is taken to avoid violating the parietal endopelvic fascia.
- Between three and five nerve branches can be observed crossing the space between the fascia and the rectum (**FIG 9B**). These branches will be divided after skeletonization in order to preserve the trunks and prostatic branches as much as possible (**FIG 9C**).
- The least traumatic dissection seems to be the one performed by means of the LigaSure Advance™ device with a 2-mm monopolar electrode, an energy level of 15 Watts being considered sufficient.

Anterior Dissection of the Rectum

- In order to open and dissect the space between the anterior aspect of the rectum and Denonvilliers' aponeurosis, minimal cranial and posterior traction should be maintained on the rectum; Denonvilliers' aponeurosis should be retracted anteriorly.
- Retraction is usually easy to perform in female patients. In male patients, especially obese ones, this step is more difficult. We recommend the use of specific retractors developed by KARL STORZ (Endo-Retractors™) in order to reproduce the technique used in open surgery with St. Mark's retractor. It is the use of the three-directional retraction described by Heald's (3-D retraction), which ensures a safe dissection of the anterior aspect of the rectum.
  - The plane of anterior dissection can be carried either anterior or posterior to Denonvilliers' aponeurosis (**FIG 10A,B**). In advanced rectal cancer, it may be necessary to stay anterior to Denonvilliers' aponeurosis; in this case, the risk of genital nerve injury (impotence) is much higher.
- Dissection is not pursued farther than the inferior pole of the prostate.

Extraperitoneal Colostomy Technique

- Prior to initiating the perineal part of the procedure, the sigmoid colon is divided using the Endo GIA® linear stapler after en bloc division of the mesocolon.

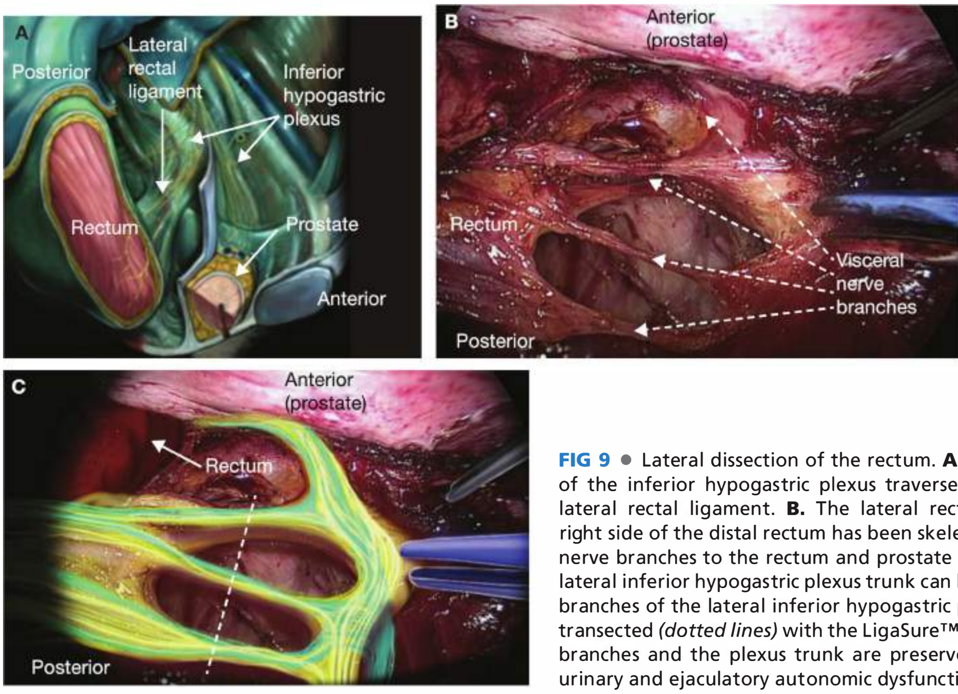

FIG 9 ● Lateral dissection of the rectum. **A.** The rectal branches of the inferior hypogastric plexus traverse along the so-called lateral rectal ligament. **B.** The lateral rectal ligament on the right side of the distal rectum has been skeletonized. The visceral nerve branches to the rectum and prostate originating from the lateral inferior hypogastric plexus trunk can be seen. **C.** The rectal branches of the lateral inferior hypogastric plexus are selectively transected *(dotted lines)* with the LigaSure™ device. The prostatic branches and the plexus trunk are preserved in order to avoid urinary and ejaculatory autonomic dysfunction.

- Patient quality of life will depend on an adequate colostomy technique. We prefer a preperitoneal terminal colostomy technique proposed in open surgery by Goligher.
- The objective is to limit the risk of peristomal eventration and stomal prolapse, which is all the more frequent in laparoscopic surgery as the risk of intraabdominal adhesions is low.
- Once colostomy location has been determined, preferably in the left transrectal space at the level of the umbilicus, the skin is incised over 5 to 6 cm, and the subcutaneous tissue is incised until the aponeurosis of the rectus sheath is reached.
- Muscular fibers are then retracted to expose the posterior leaflet of the aponeurosis that is incised vertically to visualize the peritoneum, which is preserved.
- It is then necessary to detach the peritoneum from the posterior aspect of the rectus sheath aponeurosis, moving toward the left paracolic gutter and staying posteriorly to the aponeurosis of the transverse and oblique abdominis muscles.

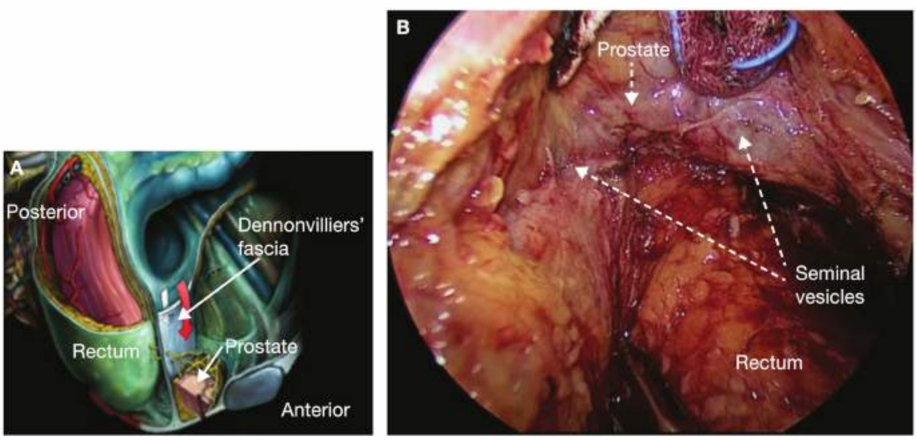

FIG 10 ● Anterior dissection of the rectum. **A.** The dissection can be carried either anterior *(red arrow)* or posterior *(white arrow)* to Denonvilliers' fascia. **B.** Surgical field after anterior dissection.

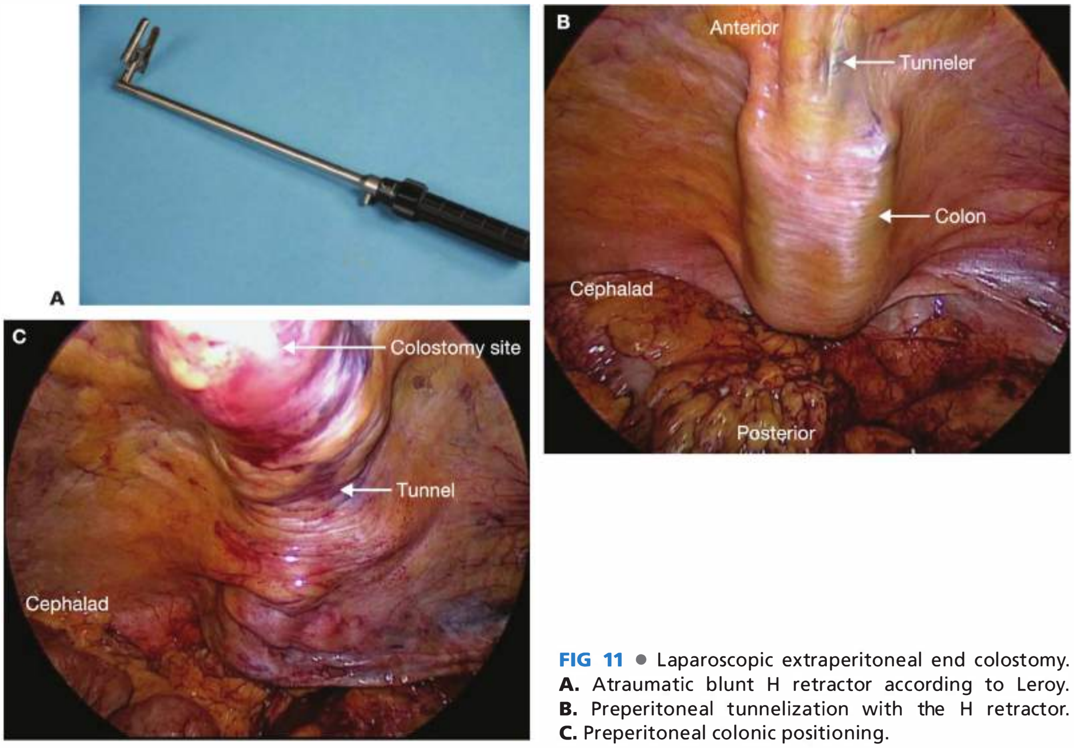

FIG 11 ● Laparoscopic extraperitoneal end colostomy. **A.** Atraumatic blunt H retractor according to Leroy. **B.** Preperitoneal tunnelization with the H retractor. **C.** Preperitoneal colonic positioning.

- A tunnel is then created. It joins the intraabdominal detachment of the left flank peritoneum performed during mobilization of the sigmoid and left colon.
- The tunnel is fashioned with a bougie or, even better currently, using an atraumatic blunt H retractor according to Leroy (KARL STORZ, Tuttlingen, Germany), the extremity of which may be angulated and enlarged to obtain a tunnel more adapted to the size of the colon (**FIG 11A**).
- During dissection, a permanent laparoscopic control helps to check the route and the width of the tunnel (**FIG 11B,C**).
- In order to retrieve the colon, a long laparoscopic forceps is introduced into the tunnel. The extremity of a Vicryl® purse string (Ethicon™) is grasped and taken out through the colostomy skin incision. Control is performed to make sure that the colon is perfectly positioned.
- The colostomy will be matured as usual after closure of all wounds by fixing the colonic serosa to the dermis with either interrupted or running sutures using a rapid resorption suturing material (Monocryl® 3-0, Ethicon™). Stitches transfix the dermal layer and extramucosal layer of the colon.

Perineal Dissection

- Once the perineal region has been perfectly exposed, the entire team is positioned opposite the perineum.
- The anal opening is closed by a purse string (**FIG 12A**). The skin incision is generally vertical and elliptical, away from the tumoral area in case of sphincteric invasion.
- Once a retracting system (either a Gelpi retractor [**FIG 12B**] or the self-retaining Lone Star™ [CooperSurgical Inc] retractor system) has been placed on the incision margins, dissection of deep structures is performed in a circular fashion first using the electrocautery and then using the LigaSure Atlas® vessel-sealing device or ultrasonic scissors.
- It is essential to maintain dissection along a vertical axis in order to prevent any conical route. Therefore, the inferior rectal vessels and the levator ani muscles should be divided as laterally as possible.
- Posteriorly, the dissection is directed toward the coccyx and to the presacral area to find the posterior pelvic plane.
- Anteriorly, the dissection is more subtle. In male patients, it is recommended to stay dorsal to the urethra without injuring or devascularizing it.
- More cranially, the dissection is carried dorsal to the prostate until reaching the anterior pelvic dissection plane.
- In female patients, the dissection is easier and it proceeds dorsal to the vagina.
- Some authors suggest an extension of the lateral dissection, also called "extended APR," "extralevator abdominoperineal excision (ELAPE)," "cylindrical APR," or "Holm cylindrical abdominoperineal excision." This may be unnecessary, especially after radiochemotherapy.

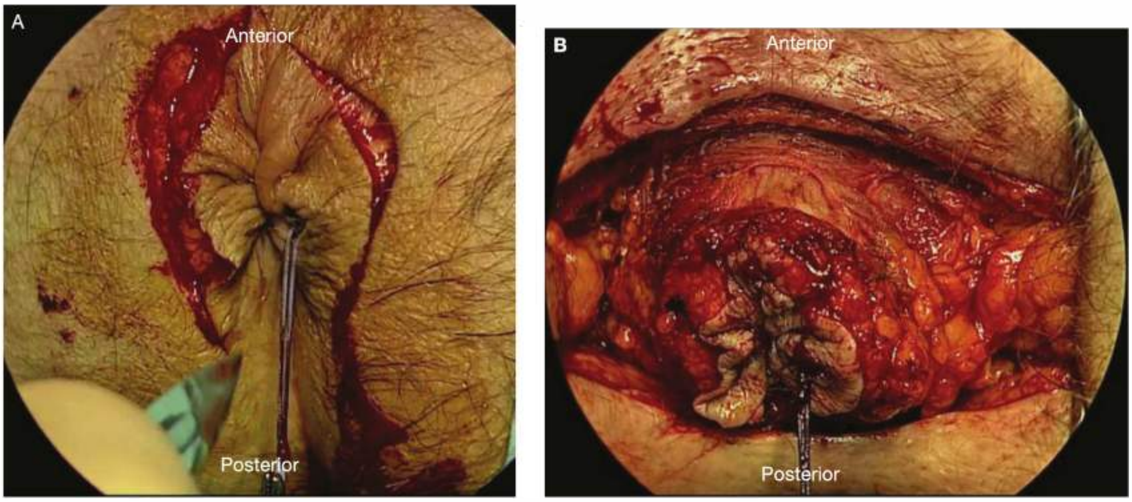

FIG 12 ● Perineal dissection. **A.** Closure of anal canal with a purse-string and elliptical skin incision. **B.** Cylindrical dissection of the distal rectum is facilitated by the use of Gelpi retractors.

Specimen Extraction, Perineal Closure, and Colostomy Completion

- Specimen extraction is performed through the perineal incision.
- In order to obtain a good oncologic outcome, it is necessary to obtain a cylindrical specimen with an intact mesorectum and without a waist effect, removing the specimen along with the levator ani fixed to the anus (**FIG 13**).
- Total hemostasis of the pelvis is then controlled through the perineal incision.
- Once two suction drains have been placed (either 12-Fr Redon drain or 14-Fr Blake drain) in the presacral space, the perineal incision is then closed in layers.
- The deep cellular adipose plane is reapproximated using an absorbable suture.
- An omentoplasty may be used to fill the pelvic space and to limit the risk of perineal hernia and urinary dysfunction due to a posterior falling of the urinary tract (**FIG 14**).
- The extensive cylindrical rectal resection does not allow to reapproximate the muscular plane of the levator ani.
- The skin is closed using interrupted sutures.
- The intervention is always completed with a final laparoscopic examination of the abdominal and pelvic cavity.

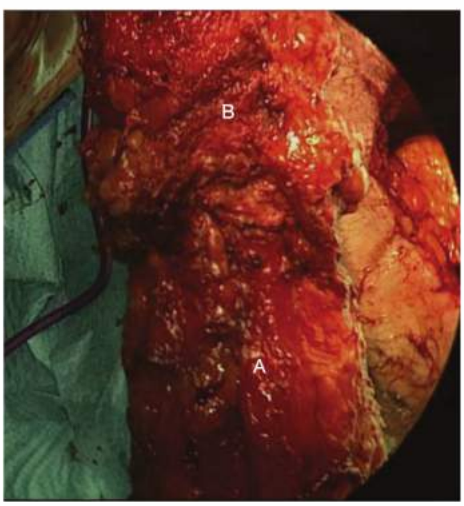

FIG 13 ● Cylindrical specimen with an intact mesorectum (A) without a waist effect (B).

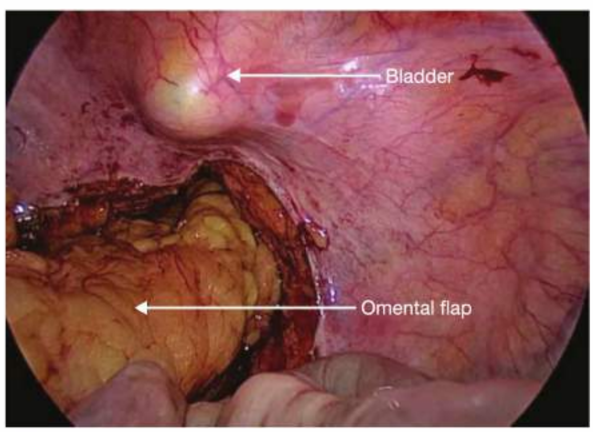

FIG 14 ● An omental pedicle flap is used to obliterate the pelvic space after resection.

PEARLS AND PITFALLS

Anatomy and embryology	▪ Detailed knowledge of the pelvic fascial structures and tissue planes is essential.
Preoperative	▪ Adequate staging with colonoscopy and appropriate imaging is important in determining the need for an APR.
Setup	▪ Precise operating room (OR), patient, and team setup is critical to success.

Technique	▪ Medial to lateral dissection of the mesocolon
	▪ High IMA transection
	▪ Pelvic dissection:
	  ▪ Posterior first (along the presacral "holy plane")
	  ▪ Lateral dissection/transection of the "lateral rectal ligaments": Avoid injury to autonomic trunks and genital nerve branches that would lead to autonomic dysfunction postoperatively.
	▪ Perineal phase: Perform a circumferential dissection.
	▪ Avoid "conization" of the specimen.
	▪ The specimen should have an intact mesorectum without a "waist" effect distally.
	▪ "Tunnelization" of the colostomy in the abdominal wall minimizes parastomal hernias.

Postoperative care	▪ Driven by a clinical pathway

POSTOPERATIVE CARE

- Postoperative care is driven by clinical pathways that include the following:
  - Pain control: Intravenous acetaminophen for 24 hours (start in the OR) followed by intravenous ketorolac for 72 hours (if creatinine is normal). The transversus abdominis plane (TAP) nerve block greatly reduces the need for narcotics.
  - Deep vein thrombosis (DVT) prophylaxis with enoxiheparin, starting within 24 hours of surgery.
  - No additional antibiotics, judicious use of intravenous fluids
  - No nasogastric tube. Remove Foley catheter on postoperative day 1. Remove pelvic drains on postoperative day 2 or 3.
  - Early ambulation, diet ad lib, aggressive pulmonary toilet
  - Use soft pillow/jelly doughnut while seating.
  - Targeted discharge: postoperative day 3 or 4

OUTCOMES

- Laparoscopic APR leads to improvements in short-term outcomes, including less pain, faster recovery, shorter hospital stay, and lower incidence of cardiac/pulmonary complications when compared to open surgery.
- For cancer resection, laparoscopic APR oncologic outcomes are at least comparable to those of open surgery. TME with an intact mesorectum is critical to minimize locoregional treatment failures.

COMPLICATIONS

- Wound infections and hernias
- Perineal wound infection/dehiscence and pelvic abscess incidence are reduced with the use of an omental pedicle flap to fill the pelvis.
- Urinary/sexual dysfunction: It is important to preserve autonomic nerves intact.
- Ureteral injury: critical to identify the left ureter prior to IMA transection
- DVT: lower risk with use of DVT prophylaxis

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Chapter 34

Hand-Assisted Laparoscopic Abdominoperineal Resection

Daniel Albo

DEFINITION

- An abdominoperineal resection, or APR, involves removal of the anus, the rectum, and part or all of the sigmoid colon along with the associated regional lymph nodes, through incisions made in the abdomen and perineum. The end of the remaining colon is brought out as a colostomy.
- Hand-assisted laparoscopic surgery (HALS) is a minimally invasive surgical approach that uses conventional laparoscopic-assisted (LA) surgery techniques with the addition of a hand-assist device (placed in the projected specimen extraction site) that allows for the introduction of a hand into the surgical field. HALS in colorectal surgery retains all of the same advantages of conventional LA surgery over open surgery, including less pain, faster recovery, lower incidence of wound complications, and reduction of cardiopulmonary complications, especially in the obese and in the elderly.
- Advantages of HALS over conventional LA colorectal surgery include the following:
  - Reintroduces tactile feedback into the field
  - Shorter learning curves; easier to teach
  - Shorter operative times and lower conversion to open rates
  - Higher usage rates of minimally invasive surgery

DIFFERENTIAL DIAGNOSIS

- Indications for HALS APR
  - Rectal cancer: when unable to obtain a negative distal margin and/or in patients with poor sphincter function or severe comorbidities
  - Anal cancer: after failure of chemotherapy/radiation therapy or in the palliative setting
  - Inflammatory bowel disease (i.e., Crohn's with severe perianal disease)

PATIENT HISTORY AND PHYSICAL FINDINGS

- Most patients with rectal tumors generally present after an incidental finding during screening colonoscopy or with occult bleeding and anemia.
- A thorough history and physical examination should include the following:
  - Presence of rectal pain and/or tenesmus
  - Presence of obstructive symptoms
  - Description of anorectal function, with any fecal incontinence or leakage documented preoperatively
  - Documentation of urinary and erectile function/dysfunction
  - A detailed personal and family history of colorectal cancer, polyps, and/or other malignancies
- Physical examination should include the following:
  - Routine abdominal examination, noting any previous incisions
  - Digital rectal examination with assessment of sphincter function
  - Bilateral inguinal nodal examination
  - Rigid proctoscopy is arguably the most critical portion of the physical examination and is the key to proper patient selection of patients for an APR.
- Proctoscopy should be standardized and documented at minimum.
  - The distal and proximal extent of the lesion measured from the anal verge
  - Exact position of the lesion and extent of the rectal circumference involved
  - Presence or absence of fixation to perirectal structures

IMAGING AND OTHER DIAGNOSTIC STUDIES

- A colonoscopy with documentation of all polyps should be performed. Suspicious lesions should be tattooed to facilitate localization during surgery.
- Staging with endorectal ultrasound or rectal magnetic resonance imaging (MRI) should be performed to determine the need for neoadjuvant therapy and to plan operative strategy. A computed tomography (CT) of the chest, abdomen, and pelvis evaluates for potential metastases.
- A preoperative carcinoembryonic antigen level should be obtained.

SURGICAL MANAGEMENT

Preoperative Preparation

- Patients undergo stoma marking by an enterostomal therapist.
- Clinical trials have shown no need for mechanical bowel preparation.
- We use two fleet enemas to evacuate the rectal vault prior to surgery.
- Intravenous cefoxitin is administered within 1 hour of skin incision.
- Use hair clippers if needed and chlorhexidine gluconate skin preparation.
- Preoperative time-out and briefing is performed.
- Ultrasound-guided, bilateral transversus abdominis plane (TAP) block reduces the need for postoperative narcotics.

Equipment and Instrumentation

- 5-mm camera with high-resolution monitors
- 5-mm and 12-mm clear ports with balloon tips. They hold ports in the abdomen and minimize their intraabdominal profile during surgery.
- Laparoscopic endoscopic scissors and a blunt tip 5-mm energy device
- 60-mm linear reticulating laparoscopic staplers with vascular and tan loads
- We use the GelPort hand-assist device due to its versatility and ease of use. This device allows for the introduction/removal of the hand without losing pneumoperitoneum and

allows for insertion of multiple ports through the hand-assist device. It also allows for the introduction of laparotomy pads into the field, which are very useful to retract bowel/omentum in obese patients.

Patient Positioning and Surgical Team Setup

- Place the patient on a modified lithotomy position, with the arms tucked and padded (to avoid nerve/tendon injuries). The patient is taped over a towel across the chest without compromising chest expansion (**FIG 1**).
- Place the legs on Allen stirrup with the heels firmly planted on the stirrups to avoid pressure on the calves and the lateral peroneal nerves.
- Keep the thighs parallel to the ground to avoid conflict between the thighs and the surgeon's arms/instruments.
- The coccyx should be readily palpable off the edge of the table. This will be critical for the perineal step of the operation.
- The surgeon starts at the patient's right lower side with the assistant to his or her left side.
- Align the surgeon, the ports, the targets, and the monitors in straight lines. Place monitors in front of the surgeon and at eye level to prevent lower neck stress injuries.
- Avoid unnecessary restrictions to potential team movement around the table. All energy device cables exit by the patient's upper left side. All laparoscopic (gas, light cord, and camera) elements exit by the patient's upper right side.

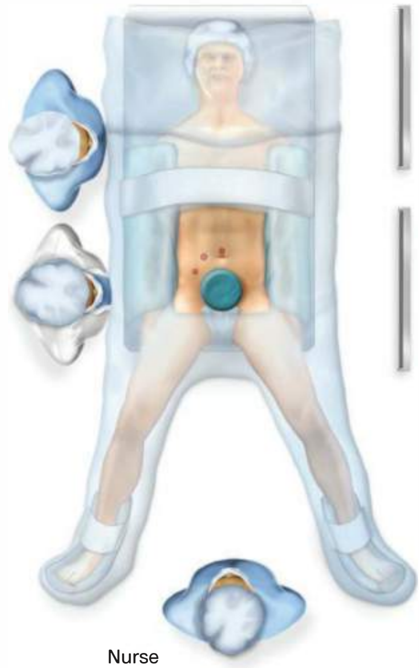


FIG 1 ● Team, patient, and monitor setup. The patient is on a modified lithotomy position. The team, ports, targets, and monitors are aligned.

PORT PLACEMENT AND OPERATIVE FIELD SETUP

- Insert the GelPort through a 5- to 6-cm Pfannenstiel incision. This incision will be also used for specimen extraction. It provides a better cosmetic result and lowers the incidence of wound infections and hernias. It also allows for more working space between the hand and the instruments. (**FIGS 1** and **2**).
- Ports: Insert a 5-mm working port in the right upper quadrant, a 12-mm working port in the right lower quadrant, and a 5-mm camera port above the umbilicus. These three ports are triangulated, with the camera port at the apex of the triangle. This setup avoids conflict between the instruments and the camera and prevents disorientation (avoids "working on a mirror").
- A 5-mm accessory working port may be inserted at the planned colostomy site in the left lower quadrant (LLQ). This port allows the surgeon to operate from the left side of the table (useful for the right-sided pelvic dissection, especially in males). It can also be valuable for the mobilization of the splenic flexure.

FIG 2 ● Ports and instrumentation setup. The GelPort is placed through a Pfannenstiel incision. All ports are triangulated. Notice the energy devices placed in a pouch in front of the surgeon to minimize instrument transfer.

OPERATIVE STEPS

- Our HALS APR operation is highly standardized and consists of eight steps:
  - Transection of the inferior mesenteric vein (IMV)
  - Transection of the inferior mesenteric artery (IMA)
  - Medial to lateral dissection of the descending mesocolon
  - Sigmoid colon mobilization off the pelvic inlet
  - Descending colon mobilization
  - Pelvic dissection

- Transection of the levator ani muscles
- Creation of colostomy and closure of abdominal wounds

Step 1. Transection of the Inferior Mesenteric Vein

- This is the critical "point of entry" in this operation. We favor it over starting dissection at the IMA level due to the IMV's constancy in location, the ease of its visualization by the ligament of Treitz, and the absence of structures that can be harmed around it (no iliac vessels or left ureter nearby). This will be the only time during the operation when a virgin tissue plane is entered. Every step will set up the following ones, opening the tissue planes sequentially.
- The patient is placed on a steep Trendelenburg position with the left side up. Using the right hand, move the small bowel into the right upper quadrant and the transverse colon and omentum into the upper abdomen. If necessary, place a laparotomy pad to hold the bowel out of the field of view, especially in obese patients. This pad can also be used to dry up the field and to clean the scope tip intracorporeally. Make sure that the circulating nurse notes the laparotomy pad in the abdomen on the white board.
- Identify the critical anatomy: IMV, ligament of Treitz, and left colic artery (**FIG 3**).
- If there are attachments between the duodenum/root of mesentery and mesocolon, transect them with laparoscopic scissors. This will allow for adequate exposure of midline structures.
- Pick up the IMV with the right hand. Dissect under the IMV and in front of Gerota's fascia with endoscopic scissors, starting at the level of the ligament of Treitz and proceeding with the dissection caudally toward the IMA. The assistant provides upward countertraction with a grasper.
- Transect the IMV cephalad of left colic artery (which moves away from the IMV and toward the splenic flexure of the colon) with the 5-mm energy device, thus preserving intact the left-sided marginal arterial arcade and maintaining the blood supply to the descending colon segment (**FIG 4**).

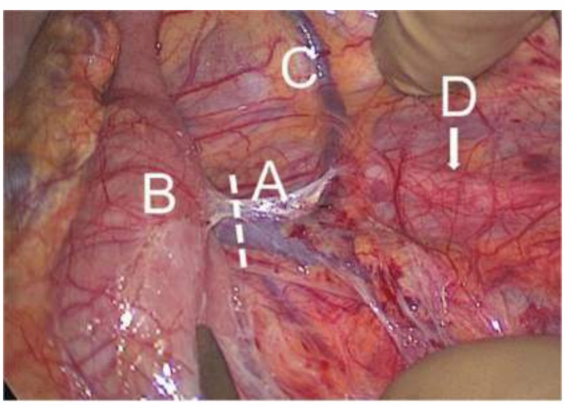


FIG 3 ● Step 1: Key anatomy. IMV *(A)*. Ligament of Treitz *(B)*. Left colic artery *(C)* as it separates from the IMV and goes toward the splenic flexure of the colon. The left ureter *(D)* is located far from the IMV projected transection *(dotted lines)*.

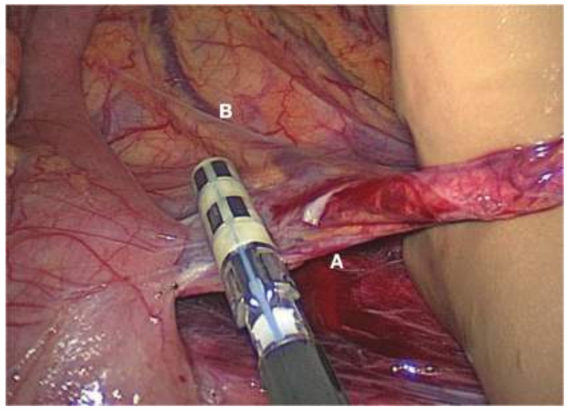


FIG 4 ● Step 1: Transection of the IMV *(A)* cephalad of the left colic artery *(B)*.

Step 2. Transection of the Inferior Mesenteric Artery

- Identify the critical anatomy: the "letter T" formed between the IMA and its left colic and superior hemorrhoidal artery (SHA) terminal branches (**FIG 5**).
- Holding the SHA up with the right hand, dissect the plane along the palpable groove between the SHA and the left iliac artery using laparoscopic scissors and a 5-mm energy device. Preserve the sympathetic nerve trunk intact in the retroperitoneum. Identify the left ureter in front of the left iliac artery and psoas muscle and medial to the gonadal vessels before transecting anything.

FIG 5 ● Step 2: Critical anatomy. Identify the letter T formed between the IMA *(A)* and its left colic artery *(B)* and SHA *(C)* terminal branches. The IMA takeoff is just cephalad from the aortic bifurcation. The thumb and index finger are lifting the SHA off the groove located anterior to the right common iliac artery.

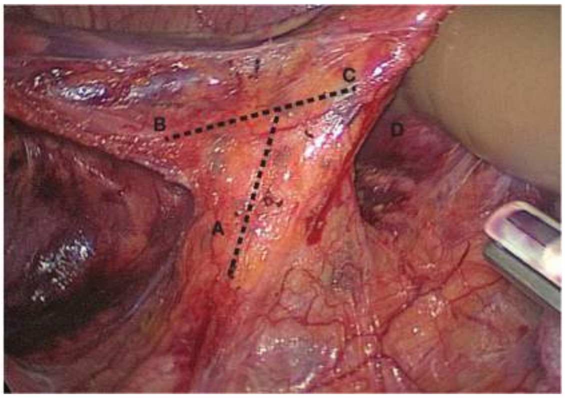
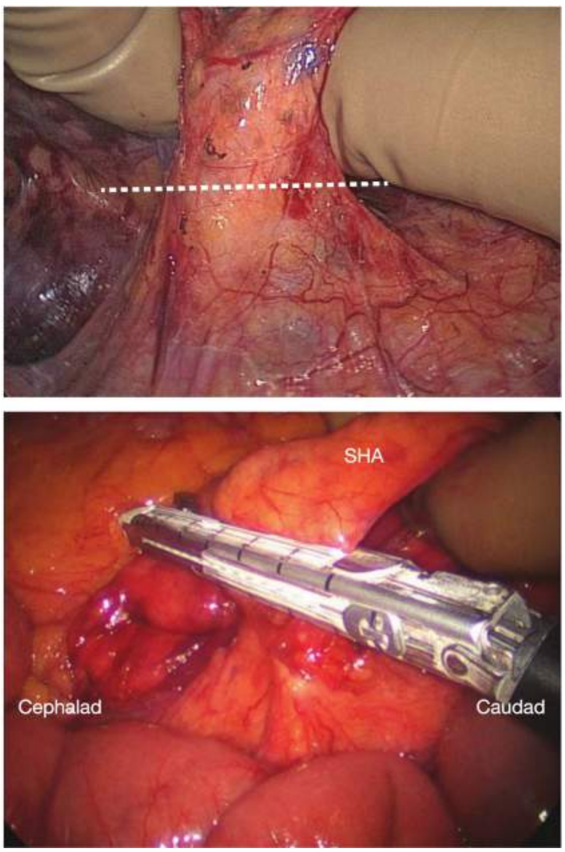


FIG 6 ● The letter T dissected: IMA *(A)*, left colic artery *(B)*, SHA *(C)*. Notice the left ureter *(D)* in the retroperitoneum.

- You can visualize the letter "T" formed between the IMA, the left colic artery, and the SHA (**FIG 6**). Dissect with your thumb and index finger around and behind the IMA and transect the IMA at its origin with a vascular load stapler or energy device (**FIG 7A** and **B**). This ensures excellent lymph node harvest and great exposure for step 3.

A



B

FIG 7 ● The IMA is now completely encircled; a high IMA transection will be perform along the dotted line (Panel **A**). The IMA is transected with a linear vascular stapler (Panel **B**) at it's origin off the aorta.

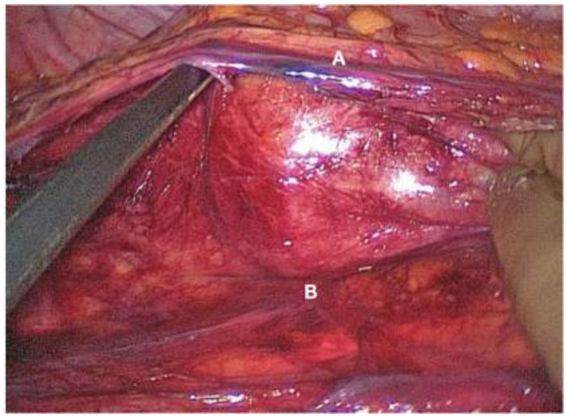


FIG 8 ● Step 3: Medial to lateral dissection of the descending mesocolon. The surgeon's hand is holding the descending mesocolon and colon anteriorly *(A)*, separating them from Gerota's fascia and other retroperitoneal structures *(B)*.

Step 3. Medial to Lateral Dissection of the Descending Mesocolon

- The surgeon's right hand and the assistant's grasper hold the descending mesocolon up, creating a working space between the mesocolon and the retroperitoneum (**FIG 8**). The plane between the mesocolon and Gerota's fascia, readily identified by the transition between the two fat planes, is dissected with the 5-mm energy device.
- Dissect caudally toward the pelvic inlet; this will greatly facilitate performance of steps 4 and 6. Dissect laterally until you reach the lateral abdominal wall; this will greatly facilitate performance of step 5.

Step 4. Sigmoid Colon Mobilization off the Pelvic Inlet

- The surgeon pulls the sigmoid colon medially, exposing the lateral sigmoid colon attachments (**FIG 9A**). Transect the attachments between the sigmoid and the pelvic inlet with laparoscopic scissors in your left hand, staying medially, close to the sigmoid and mesosigmoid, to avoid injuring the ureter/gonadal vessels.
- Dissect caudally until reaching the entrance to the left pelvic inlet.
- The left ureter and gonadal vessels, dissected in step 3, should be visible (**FIG 9B**).

Step 5. Descending Colon Mobilization

- The surgeon stands between the patient's legs. Retract the left colon medially with your hand to expose the white line of Toldt. The assistant holds the omentum/bowel out of way.
- Transect the white line of Toldt up to the splenic flexure using endoscopic scissors or energy device (**FIG 10**).

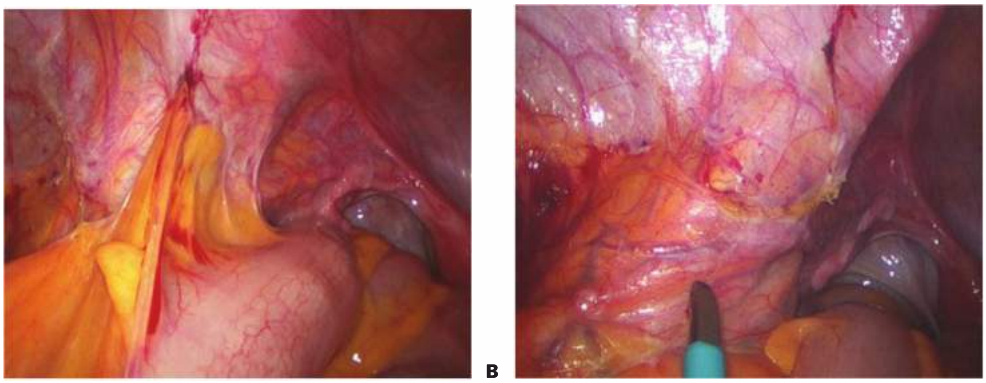


FIG 9 ● Step 4. Panel **A**: Medial traction on the sigmoid exposes its lateral attachments to the pelvic inlet. Panel **B**: After the sigmoid mobilization is completed, the left ureter is visualized as it crosses over the left iliac artery.

You should readily enter the retroperitoneal dissection plane dissected during step 2.

Step 6. Pelvic Dissection

- Start by following the dissection plane under the SHA, initiated during step 2, over the promontory and into the presacral space. Dissect the presacral space using a 5-mm energy device staying between the presacral fascia and the investing fascia of the mesorectum (**FIG 11A**). It is critical to preserve the mesorectum intact to avoid oncologic contamination of the pelvis.
- Transect the lateral rectal ligaments between the rectum and the lateral pelvic wall (**FIG 11B**). There is a space in front and behind the lateral rectal ligaments that can be easily dissected with the 5-mm energy device. Stay medial to the endopelvic fascia to avoid injuring the hypogastric vein and its branches as well as the parasympathetic ganglia.
- From the right side of the table and using his or her right hand, the surgeon retracts the rectum to the right side, exposing the left lateral rectal ligament. The ligament is then transected with a 5-mm energy device.

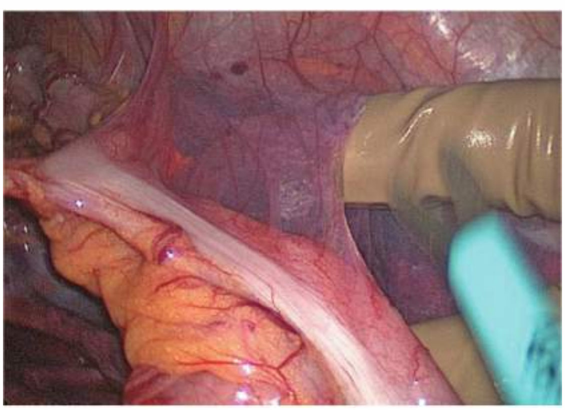
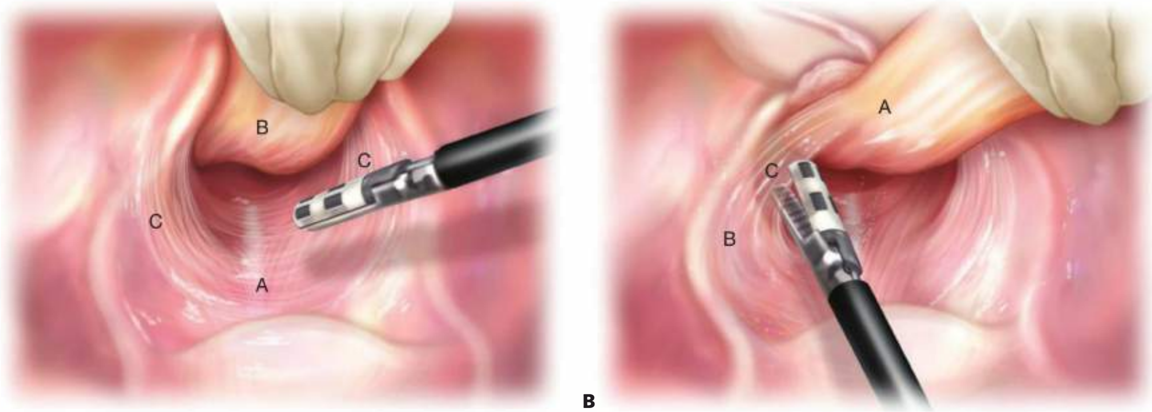


FIG 10 ● Step 5: Transection of the lateral descending colon attachments (white line of Toldt). Notice that the hand has entered the retroperitoneal dissection plane dissected during step 3.

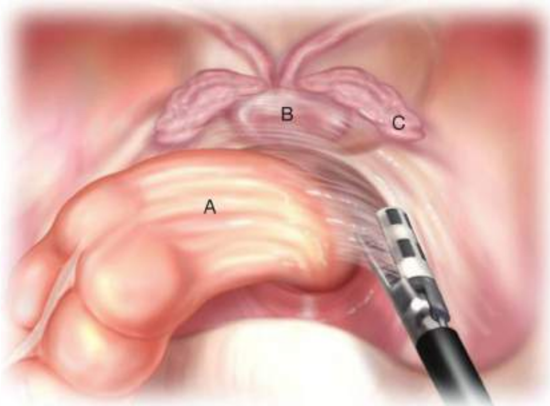
- From the left side of the table and using his or her left hand, the surgeon retracts the rectum to the left side, exposing the right lateral rectal ligament. The ligament is then transected with a 5-mm energy device.
- For the anterior pelvic dissection, the assistant pulls the rectum up into the abdomen with a grasper. The surgeon holds the bladder (in males) or the uterus (in females) anteriorly using his or her right hand and dissects between Denonvilliers fascia and the prostate/seminal vesicles (in males) (**FIG 11C**) or vagina (in females) with the 5-mm energy device. Continue with the circumferential dissection around the rectum until you can actually see pelvic floor (levator ani muscle) (**FIG 12A**).
- At this point, you are ready for the intracorporeal proximal transection of the specimen. Transect the mesocolon between the sigmoid and left colic vessels with the 5-mm energy device. Start at the stapled IMA stump on the specimen side, and move up toward the colon wall, transecting the left colic artery (at its origin, off the IMA stump) and the marginal artery (close to the colon wall).
- Transect the colon intracorporeally using a 60-mm tan load linear stapler.

Step 7. Transection of the Levator Ani Muscle

- There are two alternative techniques to accomplish this step:
  - Laparoscopic anterior circumferential dissection
    - This has become our preferred approach because it obviates the need for a perineal dissection, thus greatly reducing perineal wound complications. Without the use of the hand for exposure, this technique is extremely difficult to accomplish.
    - Very large tumors may impede proper visualization of the levator ani muscle, therefore necessitating a more conventional open transperineal approach.
    - We first transect the posterior aspect of the levator ani with the 5-mm energy device, staying anterior to the coccyx followed by



A B

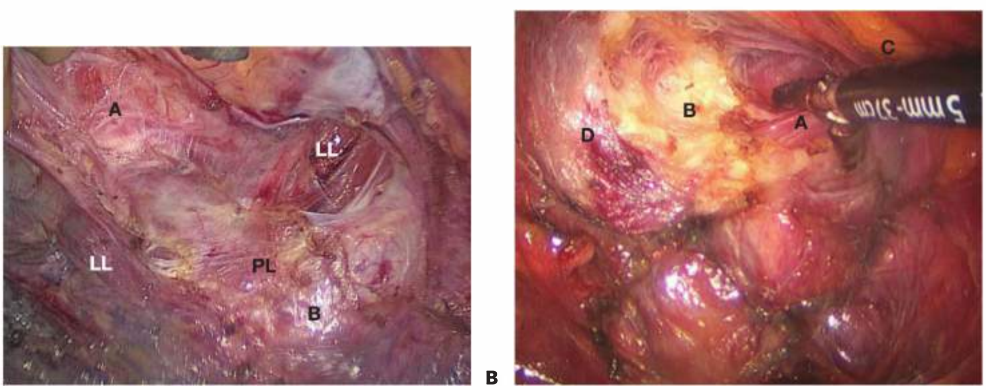


C

FIG 11 ● Step 6: Pelvic dissection. Panel **A**: The posterior dissection is carried in between the presacral fascia posteriorly *(A)*, the investing fascia of the mesorectum anteriorly *(B)*, and the endopelvic fascia laterally *(C)*. Panel **B**: Transection of the lateral rectal ligaments. Dissection of the space between the rectum *(A)* and the lateral pelvic wall *(B)* anterior to the rectal ligament exposes the left lateral rectal ligament *(C)*, which can then be easily transected with the energy device. Panel **C**: The anterior dissection is carried (in men) between the rectum posteriorly *(A)* and the prostate *(B)* and seminal vesicles *(C)* anteriorly.

transection of the levator ani laterally until we reach the fat of the ischiorectal fossa (FIG 12B).

- Finally, we perform the anterior transection of the levator ani muscles, staying posterior to the urethra (in males) or the distal vagina (in females).
- The rectum is now fully mobilized. By pulling up on the rectum, the anal canal comes up into the pelvis (FIG 13A,B). It is remarkable how far up into the pelvis the anal canal can be mobilized with this technique.
- While pulling up on the rectum with the left hand, the surgeon transects the specimen distal



A B

FIG 12 ● Panel **A**: After completing the rectal mobilization, the levators are now fully exposed. Rectum *(A)*. Coccyx *(B)*. Posterior levators *(PL)*. Lateral levators *(LL)*. Panel **B**: Circumferential anterior transection of the levators. Transected lateral levators *(A)*. Exposed ischiorectal fossa fat *(B)*. Rectum *(C)*. Lateral pelvic wall *(D)*.

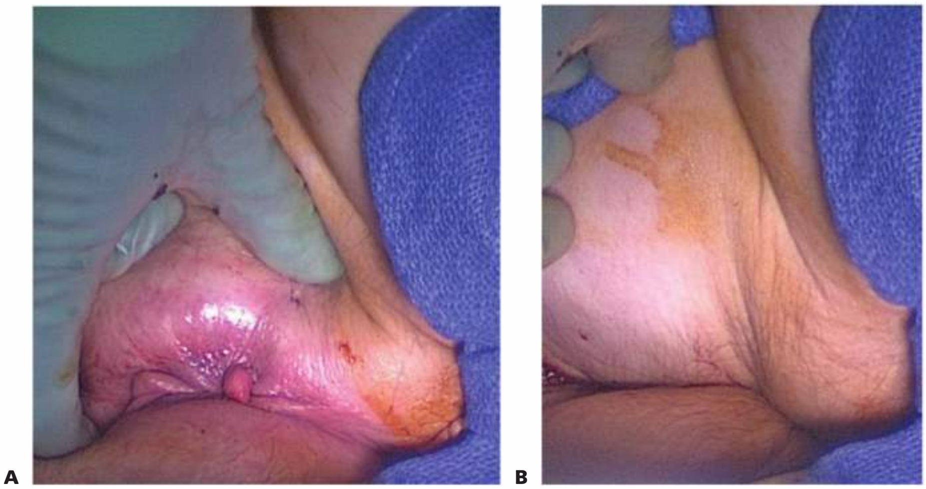


FIG 13 ● After the levators have been circumferentially transected, the surgeon (with his hand through the Gelport) retracts the rectum upwards into the abdominal cavity. This results in the anal canal (Panel **A**) being pulled up into the pelvis and out of view from the perineal side (Panel **B**). The anal canal is now ready for intracorporeal transection distal to the anal sphincter.

to the anal sphincter, using a 45-mm linear tan load stapler introduced through the right lower quadrant (RLQ) port. We reticulate the stapler maximally and we fire the stapler on an anterior to posterior direction.

- The fully disconnected specimen is now extracted through the Pfannenstiel incision with the Alexis wound protector in place. It is paramount that the specimen has an intact mesorectum with no tapering down to the anal canal (**FIG 14**).

FIG 14 ● APR specimen. Note the shiny surface of the intact mesorectum with no tapering.

- Open transperineal approach
  - It is paramount to have completed the anterior pelvic dissection laparoscopically all the way down to the levator ani during step 6.
  - Key anatomic landmark: Identify the coccyx posteriorly.
  - Use headlight for illumination. Dissect circumferentially around the anus with electrocautery across the superficial perineal tissues until you reach the levator ani muscle. Use Gelpi retractors to enhance exposure (**FIG 15A**).
  - Palpate the coccyx posteriorly. Transect the levator ani between the coccyx and the anus with electrocautery and enter the pelvis posteriorly (**FIG 15B**).
  - The assistant pulls the rectum up to facilitate dissection of levator ani muscles.
  - Introduce your left index finger through the posterior opening (careful to avoid avulsing presacral veins) and curve it on top of the left levator ani muscle, pulling it down into view. Transect the left levator ani with electrocautery, staying close to its pelvic wall insertion. Repeat this maneuver on the right side.
  - The assistant now everts the specimen out through the posterior opening on the pelvic floor. The surgeon pulls the specimen out and exposes the anterior attachments of the anal canal to the urethra (in males) or to the vagina (in females), allowing for a safer transection of these anterior attachments and minimizing potential injury to the vagina/urethra. The specimen is now completely removed.
  - After extensive irrigation of the pelvis, close the perineal wound in layers.
  - Place a 19-Fr round Blake in the pelvis through the right lower quadrant port site.

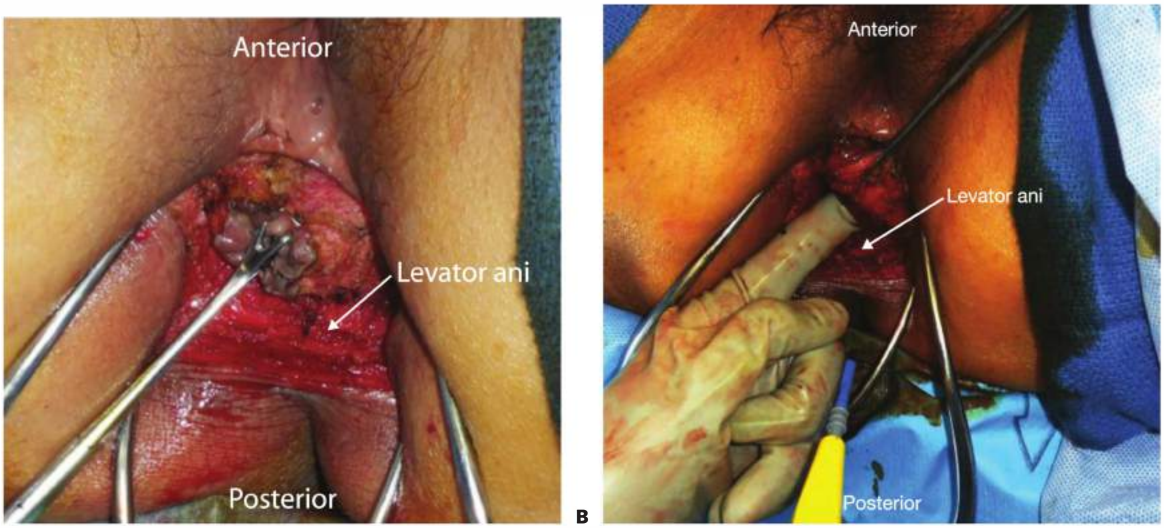


FIG 15 ● Panel **A**: Perineal dissection: Lateral incision around the anal canal. The incision is carried through the skin and subcutaneous tissues until reaching the levator ani muscles. Gelpi retractors are used for exposure. Panel **B**: Perineal dissection: Posterior palpation of coccyx during perineal dissection. The transection of the levators starts posteriorly anterior to the coccyx. The index finger of the surgeon is placed into the pelvis and hooked on to top of the levator muscle, pulling it into the field. This allows for a safe transection of the levator muscle with electrocautery.

Step 8. Creation of Colostomy and Closure of Abdominal Wounds

- Avoid twisting; the descending colon is brought out through the LLQ port site (extended to accommodate two fingers) through the rectus sheet.
- After changing gloves, all ports are removed. Abdominal wounds are closed with absorbable sutures and sealed off with Dermabond.
- Mature the colostomy at skin level with interrupted 3-0 Vicryl sutures. Digitalize the colostomy to ensure that it is patent beneath the fascia.

PEARLS AND PITFALLS

Setup	■ Proper patient, team, port, and instrumentation setup is critical.
Operative technique	■ Point of entry: IMV at the ligament of Treitz. ■ Medial to lateral dissection step sets up all other steps. ■ Vascular dissection to visualize the letter T and high IMA ligation in malignancy; identify left ureter prior to IMA transection. ■ Pelvic dissection progression: first posterior, then lateral, then anterior. ■ We prefer the anterior circumferential transection of the levators to prevent perineal wound complications.
Pitfall: dissecting anterior to the SHA	■ Solution: Identify "groove" between left common iliac artery and SHA and dissect in between the two vessels.
Pitfall: floppy sigmoid difficult to handle	■ Use the back of the hand as a "shelf" to hold the sigmoid up while picking up the SHA with thumb and index finger.

POSTOPERATIVE CARE

- Postoperative care is driven by clinical pathways that includes the following:
  - Pain control: Intravenous acetaminophen for 24 hours (start in the operating room) followed by intravenous ketorolac for 72 hours (if creatinine is normal). The TAP nerve block greatly reduces the need for narcotics.
  - Deep vein thrombosis (DVT) prophylaxis with enoxaparin starting within 24 hours of surgery
  - No additional antibiotics, judicious use of intravenous fluids
  - No nasogastric tube. Remove Foley catheter on post-operative day 1. Remove pelvic drain on postoperative days 2 or 3.
  - Early ambulation, diet ad lib, aggressive pulmonary toilet

- Use soft pillow/jelly doughnut while seating.
- Targeted discharge: postoperative days 3 or 4

OUTCOMES

- HALS leads to improvements in short-term outcomes, including less pain, faster recovery, shorter hospital stay, and lower incidence of cardiac/pulmonary complications when compared to open surgery.
- When compared to conventional laparoscopy, HALS results in higher usage rates of minimally invasive surgery, shorter learning curves, lower conversion rates, shorter operative times, and shorter hospital stays.
- For cancer resection, minimally invasive surgery oncologic outcomes are at least comparable to those of open surgery. Total mesorectal excision with an intact mesorectum is critical to minimize locoregional treatment failures.

COMPLICATIONS

- Wound infections and hernias are markedly reduced with the use of a Pfannenstiel extraction site.
- Perineal wound infection/dehiscence: This complication is virtually eliminated with the use of an anterior circumferential transection technique for the levators. Pelvic abscess are also markedly reduced.
- Urinary/sexual dysfunction: important to preserve hypogastric nerves and parasympathetic ganglia intact
- Ureteral injury: critical to identify the left ureter prior to IMA transection
- DVT: low risk with use of DVT prophylaxis
- Cardiac and pulmonary complications: significantly reduced compared to the open surgery approach

SUGGESTED READINGS

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2. Orcutt ST, Balentine CJ, Marshall CL, et al. Use of a Pfannenstiel incision in minimally invasive colorectal cancer surgery is associated with a lower risk of wound complications. *Tech Coloproctol*. 2012;16(2):127–132.
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Chapter 35

Abdominoperineal Resection: Robotic-Assisted Laparoscopic Surgery Technique

Rodrigo Pedraza Eric M. Haas

DEFINITION

- Robotic-assisted laparoscopic abdominoperineal resection (APR) is a minimally invasive technique in which the rectum and anus are removed with the creation of a permanent end colostomy. The procedure is accomplished with the assistance of the da Vinci® Surgical System (Intuitive Surgical Inc, Sunnyvale, CA) in a minimally invasive fashion.

PATIENT HISTORY AND PHYSICAL FINDINGS

- A thorough history and physical examination should include the following:
  - Presence of rectal pain and/or tenesmus
  - Presence of obstructive symptoms
  - Description of anorectal function, with any fecal incontinence or leakage documented preoperatively
  - Documentation of urinary and erectile function/dysfunction
  - A detailed personal and family history of colorectal cancer, polyps, and/or other malignancies
- Physical examination should include the following:
  - Routine abdominal examination, noting any previous incisions
  - Digital rectal examination with assessment of sphincter function, distal and proximal extent of the lesion measured from the anal verge, exact position of the lesion and extent of the rectal circumference involved, and the presence or absence of fixation to perirectal structures
  - Bilateral inguinal nodal examination
- Robotic-assisted laparoscopic APR is a safe and feasible approach. The most common indication is low rectal cancer in which the sphincter complex cannot be salvaged. Less commonly, APR is performed in those with persistent or recurrent anal cancer following radiation therapy. Other indications include severe inflammatory bowel disease (IBD) involving the rectum and recalcitrant to medical management.
- Low rectal cancer is typically diagnosed during screening colonoscopy or after presenting symptoms such as rectal bleeding, bowel obstruction, or pelvic pain.
- Patients presenting with residual or recurrent anal cancer and those with IBD with recalcitrant perianal disease have typically undergone thorough workup and extensive therapy for the disease prior to be considered candidates for APR.
- Absolute contraindications for robotic-assisted APR are those for any other major abdominal procedure, such as severe cardiovascular or hemodynamic compromise.
- Relative contraindications for robotic-assisted APR include those associated with the patient condition and surgeon experience.
  - Robotic-assisted laparoscopic procedures typically require steep patient positioning and result in prolonged operative times, especially early in the surgeon learning curve; thus, patient inability to tolerate a lengthy procedure may contraindicate the use of robotic-assisted APR.
  - History of prior abdominal surgery is not a contraindication but may additionally prolong the operative time for lysis of adhesions and proper exposure of tissue planes. We advocate performing laparoscopic lysis of adhesions prior robotic docking so as to expedite the procedure.
  - Prior to offering challenging pelvic procedures such as robotic-assisted APR, we suggest the surgeon achieve competency with robotic surgery by performing several less demanding procedures such as rectopexy and/or left/sigmoid colectomy.

IMAGING AND OTHER DIAGNOSTIC STUDIES

- Appropriate imaging, endoscopic, and histopathologic evaluation is mandatory in all cases regardless of diagnosis.
- A full colonoscopy must be performed in all patients with rectal cancer. This allows for assessment of tumor location and pathology. It also serves to rule out and possibly remove any synchronous colonic lesions. Malignant synchronous lesions have been reported in 2% to 8% of cases and benign synchronous polyps in 13% to 62% of cases.
- If a colonoscopy has already been done by another provider, consider performing either a rigid proctoscopy or a flexible sigmoidoscopy for accurate documentation of the size, location, and distance of the tumor from the anal sphincter complex.
- Patients with low rectal cancer requiring APR necessitate a full staging workup. Local tumor assessment and regional node involvement are optimally assessed with endoscopic ultrasound or rectal protocol magnetic resonance imaging (MRI). Distant metastases are evaluated with computed tomographic (CT) scan of the chest abdomen and pelvis.
- Following proper staging, the need of neoadjuvant chemoradiation is determined. Patients with T3–T4 and/or N+ distal rectal cancer are offered neoadjuvant chemoradiation. Surgery is typically considered after 6 to 8 weeks following the last pelvic radiation session to allow for a full therapeutic radiation effect and to avoid operating in early inflammatory radiation tissue changes or late fibrosis; however, delayed intervention has been recently suggested.
- For persistent or recurrent anal cancer, APR is the rescue therapy of choice. These patients typically present after thorough imaging staging and following conventional courses

FIG 1 ● Patient positioning. The patient is placed in a modified lithotomy position with moderate Trendelenburg and with both arms tucked. All pressure points are padded to prevent neurovascular injuries. The patient is secured with a wrap technique using a 3-in tape at the level of the chest in such a fashion to prevent movement but avoiding restriction of chest wall expansion.

of chemoradiation with documented residual or recurrence disease.

- Most patients with recalcitrant perianal disease in the background of IBD present for the consideration of an APR after extensive imaging and endoscopic evaluation. It is imperative to endoscopically assess the disease to determine whether the APR should be accompanied with additional large or small bowel resection. Furthermore, the presence of additional fistulous tracts such as rectovaginal or rectovesicular must be investigated during the preoperative planning.
- A carcinoembryonic antigen (CEA) level is obtained preoperatively in cancer patients.

SURGICAL MANAGEMENT

Preoperative Planning

- Bowel preparation is typically achieved with preoperative enema. Full bowel preparation is performed selectively.
- In the operating room and under anesthesia, rigid proctosigmoidoscopy should be performed to affirm the surgical plan.
- The perineum is adequately prepped for the perineal portion of the procedure.
- Prophylactic antibiotics are administered according to the Surgical Care Improvement Project (SCIP) measures.

Positioning

- The patient is placed in a modified lithotomy position with moderate Trendelenburg and with both arms tucked. All pressure points are padded in order to prevent neurovascular injuries. The patient is secured with a wrapped technique using a 3-in tape at the level of the chest in such a fashion so as to prevent movement but avoiding restriction of chest wall expansion (**FIG 1**). It is imperative to secure the patient firmly, as steep Trendelenburg position will be used later in the procedure before robotic docking.
- Optimal modified lithotomy position is crucial to ensure adequate perineal access while allowing appropriate robotic side docking (see the following text) to avoid external robotic arm conflict (**FIG 2**).

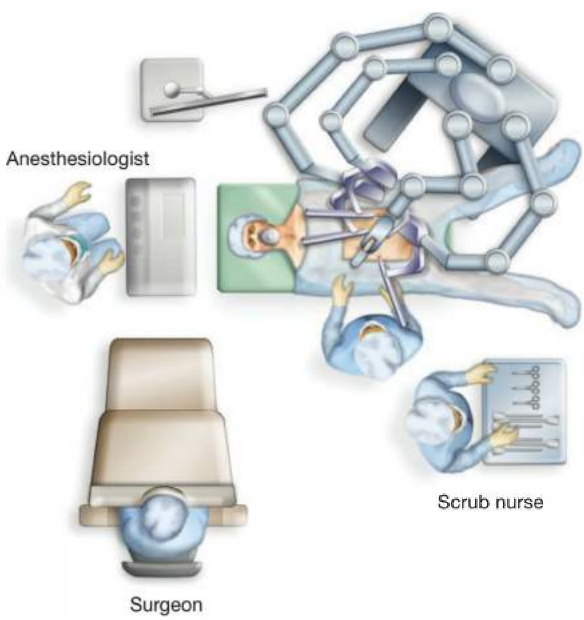


FIG 2 ● Team and robot setup. The robot is docked on the left side of the patient lower extremities in an acute angle. This configuration allows access to the perineum without undocking the robotic cart.

INCISION, PORT PLACEMENT, AND INSTRUMENTS

- A total of five ports are used for robotic-assisted APR: two 12-mm ports for the robotic camera and assistant (the latter is for use with laparoscopic instruments) and three 8-mm ports for robotic instrumentation.
- The robotic camera port is placed in the periumbilical region and the assistant port in the right upper quadrant. The 8-mm instrument ports are placed in the right and left lower quadrants and in the left upper quadrant (**FIG 3**).
- The ports are placed approximately 8 cm apart to prevent conflict between the robotic arms and the camera.

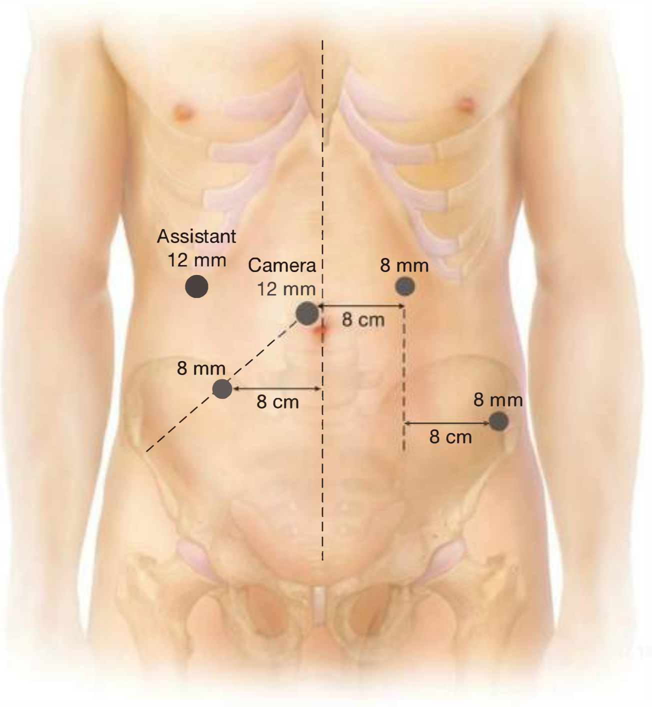


FIG 3 ● Port placement. The camera arm is placed in the 12-mm port in the periumbilical region. The robotic arms 1, 2, and 3 are placed in the right lower, left upper, and left lower quadrants, respectively. A 12-mm port is placed in the right upper quadrant for the assistant to use with laparoscopic instruments. All ports are placed approximately 8 cm apart to avoid conflict between the robotic arms and the camera.

EXPLORATION AND ROBOTIC DOCKING

- The abdominal cavity is assessed and, in oncologic cases, the presence of distant metastases is evaluated.
- Lysis of adhesions is performed laparoscopically, if needed.
- The patient is positioned in a steep Trendelenburg position with the left side elevated 15 degrees. The small bowel and omentum are retracted out of the pelvis.
- The robot is docked on the left side of the patient's lower extremities in an acute angle (**FIG 2**). The camera arm is placed in the 12-mm port in the periumbilical region, whereas the robotic arms 1, 2, and 3 are placed in the right lower, left upper, and left lower quadrants, respectively (**FIG 3**).

ESTABLISHMENT OF THE PRESACRAL PLANE

- A medial to lateral approach is used with an incision of the peritoneum at the level of the sacral promontory. The avascular presacral plane is entered, which is confirmed by the identification of the areolar tissue (**FIG 4**). This plane is developed identifying the superior rectal artery and the left ureter (**FIG 5**). The vascular pedicle is isolated, identifying the inferior mesenteric artery, superior rectal artery, and the left colic artery (**FIG 5**).

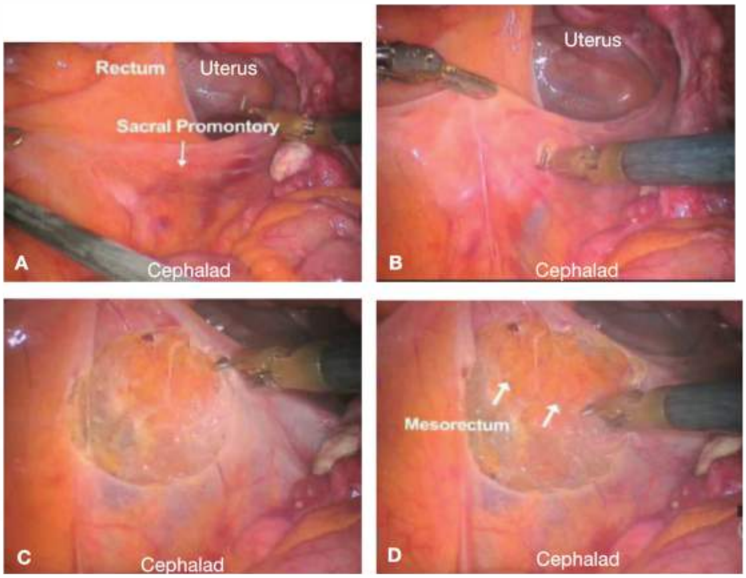


FIG 4 ● Entering the presacral plane. A medial-to-lateral approach is used with an incision of the peritoneum at the level of the sacral promontory *(arrow)* **(A)**. The avascular presacral plane is entered **(B)**, which is confirmed by the identification of the areolar tissue **(C,D)**.

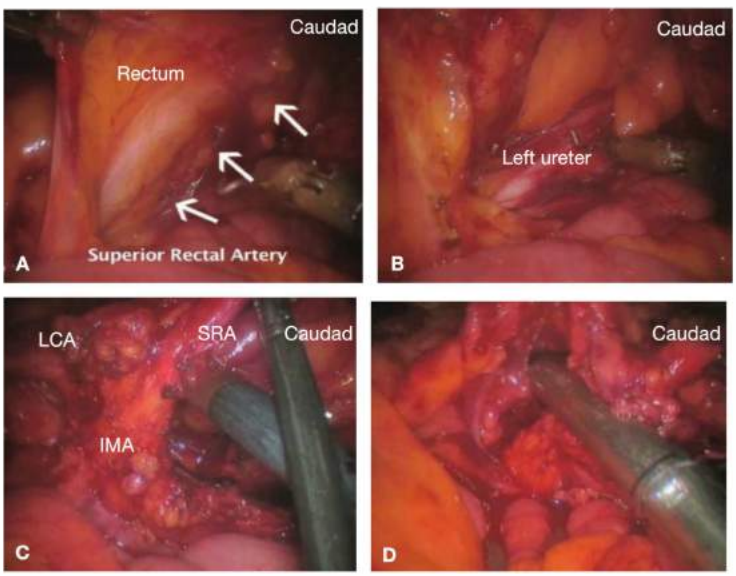


FIG 5 ● Medial to lateral dissection. The anatomic landmarks, superior rectal artery (SRA) **(A)** and left ureter **(B)**, are identified prior to vascular pedicle isolation. The inferior mesenteric artery (IMA), left colic artery (LCA), and SRA are dissected and isolated **(C)**. The IMA is divided **(D)**.

VASCULAR DIVISION

- At this point, the inferior mesenteric artery is ligated at its origin from the aorta using a laparoscopic stapler, electrosurgical device, or clips (FIG 5).

MESORECTAL DISSECTION

- Attention is drawn to the pelvis for the mesorectal excision. The pelvic dissection proceeds posteriorly first, then laterally, and then anteriorly.
- First, the avascular presacral plane is entered for the posterior dissection. Arm 3 is used for retraction, whereas arms 1 and 2 develop a plane of dissection within the avascular presacral space between the presacral fascia, posteriorly, and the mesorectal fascia, anteriorly. Arm 2 of the robot (left hand of the surgeon) should avoid grasping the mesorectum, for the strong robotic arm may tear the mesorectum, which would cause bleeding.
- The fascia propria of the rectum is identified and preserved with sharp dissection using the robotic scissors or monopolar device. Dissection continues in the posterior mesorectal plane through the retrorectal (Waldeyer's) fascia to the level of the anorectal junction (**FIG 6**).
- The lateral mesorectal dissection follows (**FIG 7**). The hypogastric nerve can be seen posterolateral to the plane of the dissection. It is important to preserve these nerves intact to avoid autonomic dysfunction postoperatively (**FIG 7**). Attention is first drawn to the right lateral pelvic attachments, which are divided starting at the level of the anterior peritoneal reflection and extending distally until reaching the levator ani muscle (**FIG 8**). The left lateral rectal ligament is then transected in a similar fashion (**FIG 9**).
- Lastly, the anterior mesorectal dissection is performed (**FIG 10**).
- For the anterior pelvic dissection, exposure is achieved by the assistant retracting the rectum posteriorly and in a cephalad direction, as arm 3 anteriorly retracts the vagina (in females) or the prostate/seminal vesicles (in males).
- In males, the Douglas pouch (rectovesical pouch) is entered by incising the peritoneal reflection between the anterior wall of the rectum and the prostate/seminal vesicles, taking care to avoid injury to the seminal vesicle and prostate (**FIG 11**).
- In the female patient, the anterior cul-de-sac is usually deeper and the rectovaginal plane is readily established once entered.
- Following the anterior dissection, the lateral stalks of the rectum are further divided as necessary, achieving hemostasis with an electrosurgical device. Care is taken at this level to avoid excessive lateral dissection, which may result in injury to the pelvic nerve plexuses (this would lead to autonomic dysfunction postoperatively). It should be noted that, typically, brisk bleeding may occur if the wrong plane is entered (posteriorly, by injuring the

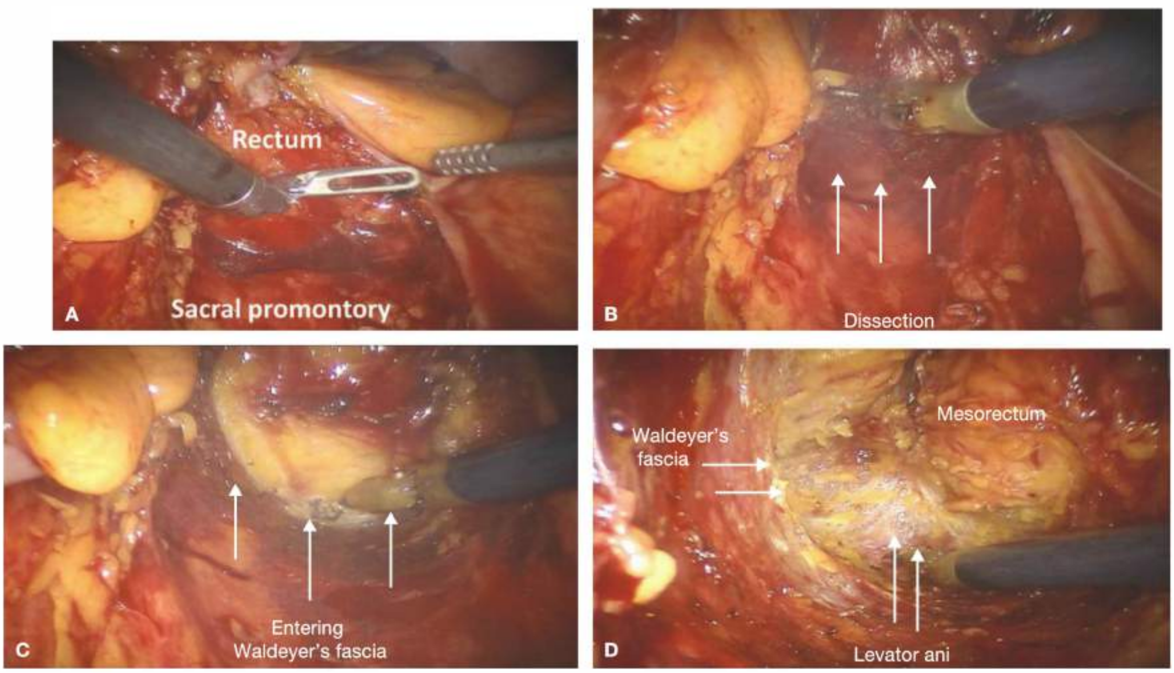


FIG 6 ● Presacral plane dissection. **A.** Development of the avascular presacral plane. The robotic arm 3 (not shown) serves as retractor proximally, whereas robotic arm 2 countertracts the mesorectum anteriorly for dissection with robotic arm 1 (not shown). **B.** The dissection is carried out distally with the robotic arm 1 using monopolar energy or scissors. **C.** The plane is further developed and Waldeyer's fascia is entered. **D.** The plane is completed distally to the level of the levator ani muscles.

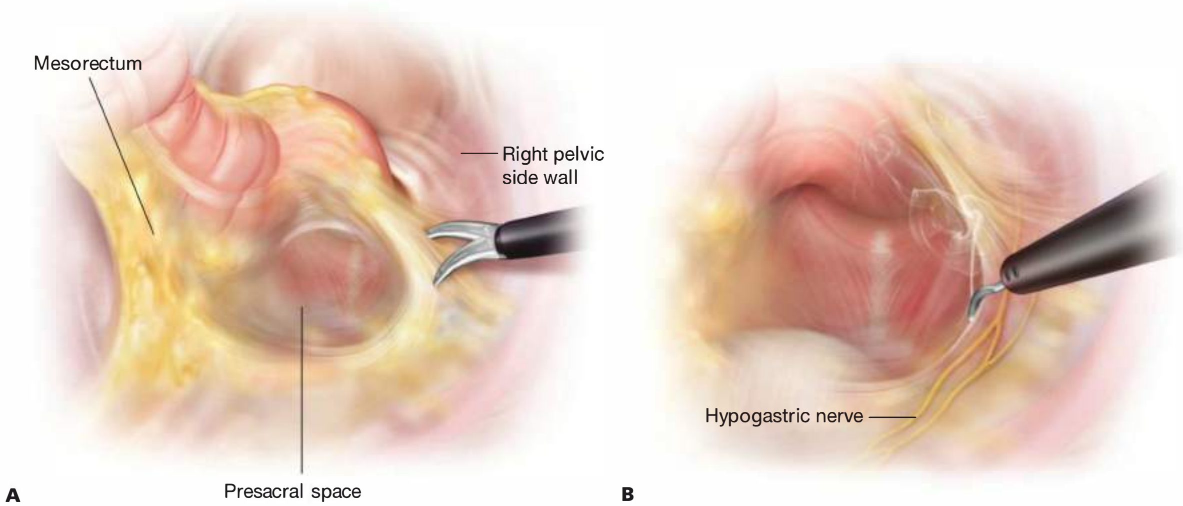


FIG 7 ● Lateral dissection of the mesorectum off the right pelvic sidewall. **A**. Transection of the right lateral rectal ligament. **B.** The hypogastric nerve can be seen posterolateral to the plane of the dissection. It is important to preserve these nerves intact to avoid autonomic dysfunction postoperatively.

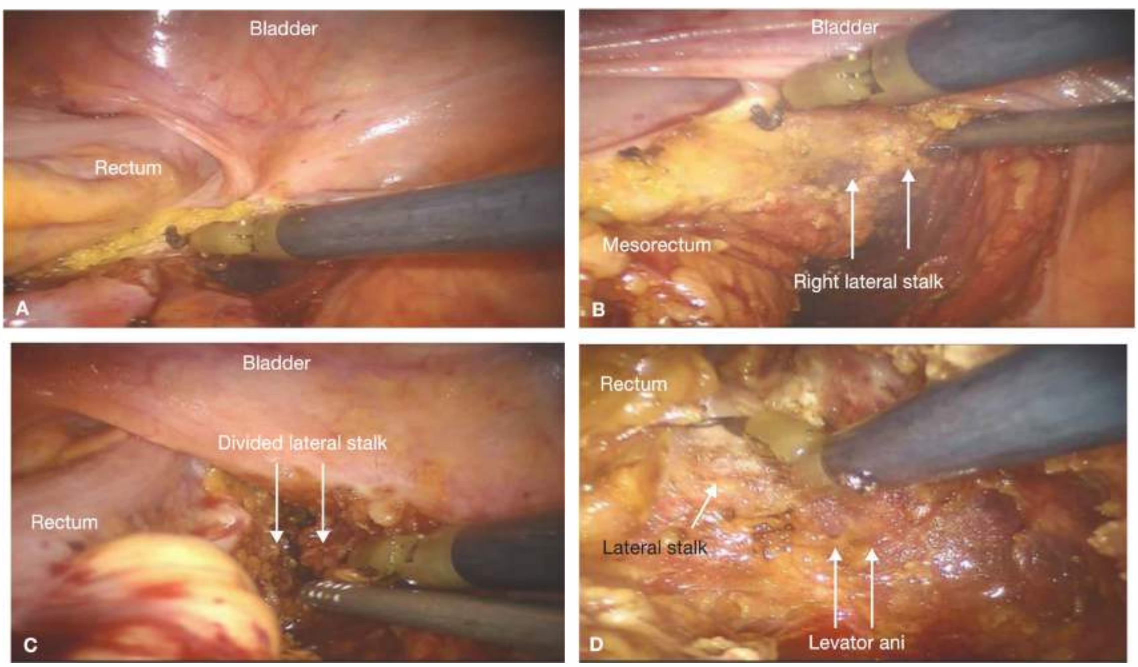


FIG 8 ● Right lateral mesorectal dissection. The right lateral mesorectal dissection is initiated at the level of the cul-de-sac **(A)** and carried out distally taking down the right lateral stalk **(B,C)** and continued distally until reaching the levator ani muscle **(D)**.

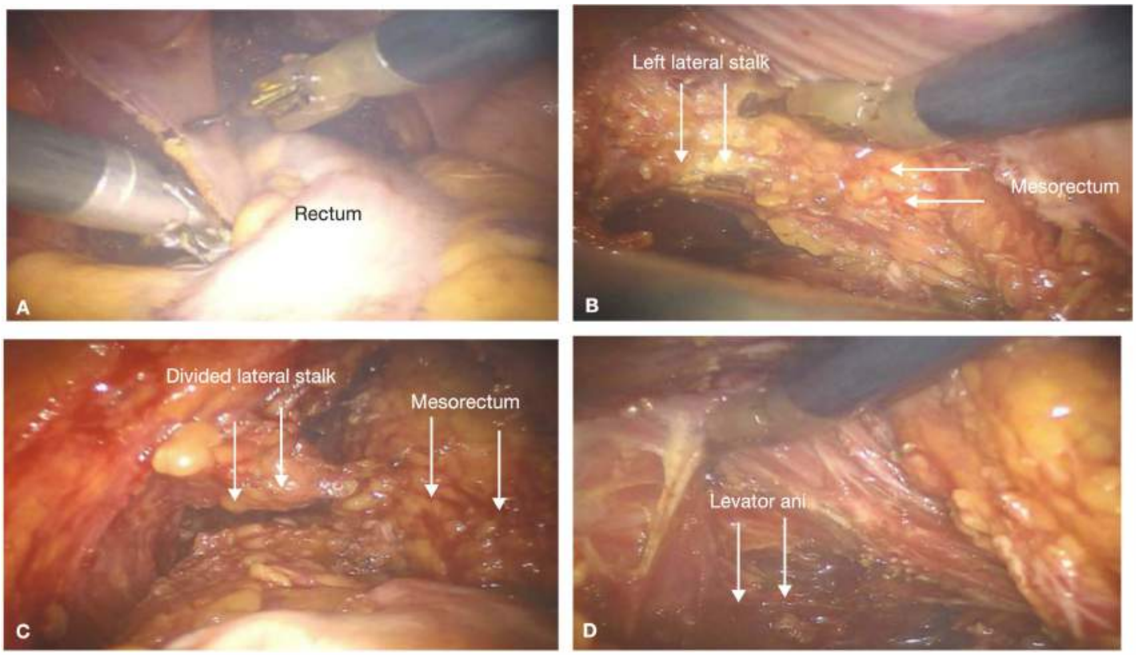


FIG 9 ● Left lateral mesorectal dissection. The left lateral dissection is initiated **(A)** and carried out distally taking down the left lateral stalk **(B,C)** and continued up to the levator ani **(D)** in a similar fashion.

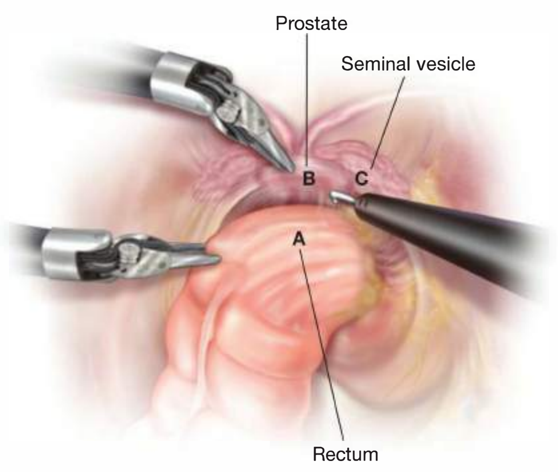


FIG 10 ● Anterior pelvic dissection. Exposure is achieved by the assistant retracting the rectum *(A)* posteriorly and in a cephalad direction as arm 3 anteriorly retracts the prostate/seminal vesicles *(B,C)*, respectively. The anterior plane of dissection is carried along Denonvilliers' fascia, between the rectum posteriorly *(A)* and the prostate *(B)* and seminal vesicles *(C)* anteriorly.

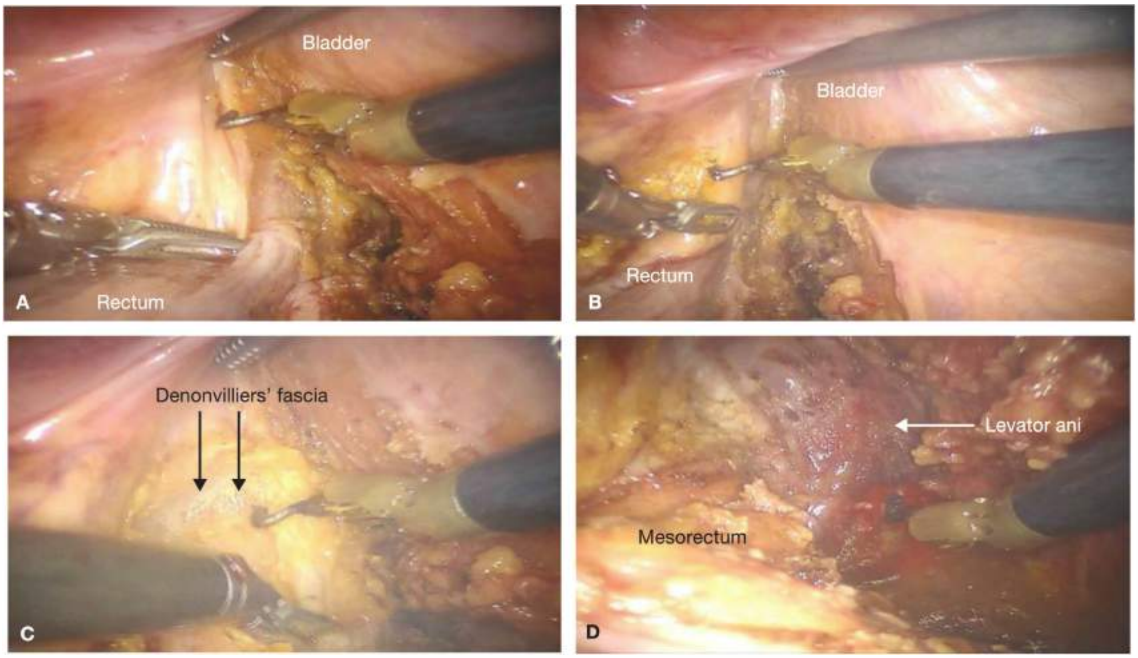
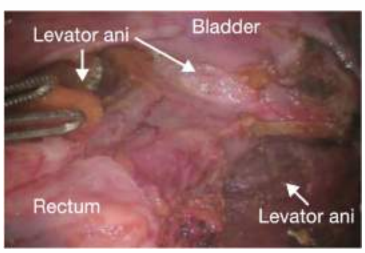


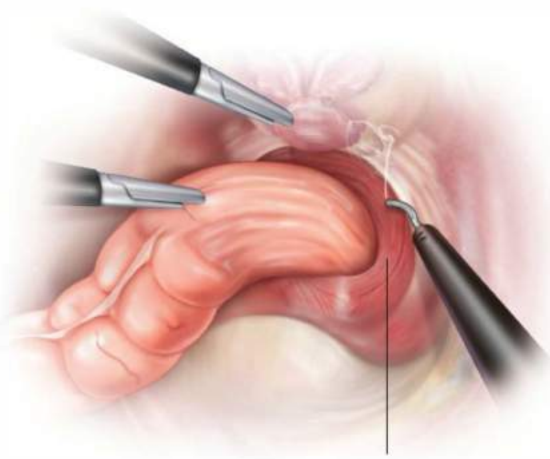
FIG 11 ● Anterior mesorectal dissection. The peritoneum is incised at the peritoneal reflection **(A,B)** and the dissection is carried out distally entering Denonvilliers' fascia **(C)** and continued inferiorly until complete anterior rectal mobilization is achieved and the levator ani muscle is encountered anteriorly **(D)**.

presacral venous plexus, and laterally, by injuring the hypogastric veins or its tributaries).

- Once the planes have been divided, circumferential exposure of the levator complex is achieved. Thus, the robotic portion the APR is carried out into the subcutaneous perineal tissue.
- In malignant cases, a cylindrical excision is then performed through the levator complex to ensure complete resection with proper radial margins. With the assistant retracting the rectum posteriorly and in a cephalad direction with a laparoscopic grasper and with the robotic arm 3 retracting the prostate/seminal vessels anteriorly, the levator ani muscle is exposed circumferentially around the distal rectum (**FIG 12A**). The levator ani is then circumferentially transected using monopolar electrocautery (**FIG 12B**).



A



B

FIG 12 ● Circumferential anterior transection of the levator ani. **A.** With the assistant retracting the rectum posteriorly and in a cephalad direction with a laparoscopic grasper and with the robotic arm 3 retracting the prostate/seminal vessels anteriorly, the levator ani muscle is exposed circumferentially around the distal rectum. **B.** The levator ani is then circumferentially transected using monopolar electrocautery.

PERINEAL PROCEDURE

- For malignant cases, a wide excision of the perineum circumferentially surrounding the anus is performed (**FIG 13A**).
- At this level, the incision is deepened to subcutaneous tissue and the planes achieved during the robotic portion of the procedure are reached (**FIG 13B**).
- The rectum and anus are extracted through the perineal wound.
- Appropriately performed cylindrical excision will result in a rectal specimen with an intact mesorectum and without an hourglass configuration in the final specimen (**FIG 14**).
- In cases involving benign disease, one should preserve levator ani to assist perineal closure and prevent perineal hernias. Such a resection would result in an hourglass configuration.
- Myofascial rotational flaps should be considered for closing the large defect and/or in a radiated pelvic floor.
- For benign cases, a narrow excision should be performed in order to be able to close the levator ani and preserve as much pelvic floor function as possible. In these circumstances, consideration to an intersphincteric excision, in which the external sphincter complex and the levator ani are left intact, is given. These muscle and fascial layers can then be used for primary closure and myofascial flaps can be avoided.

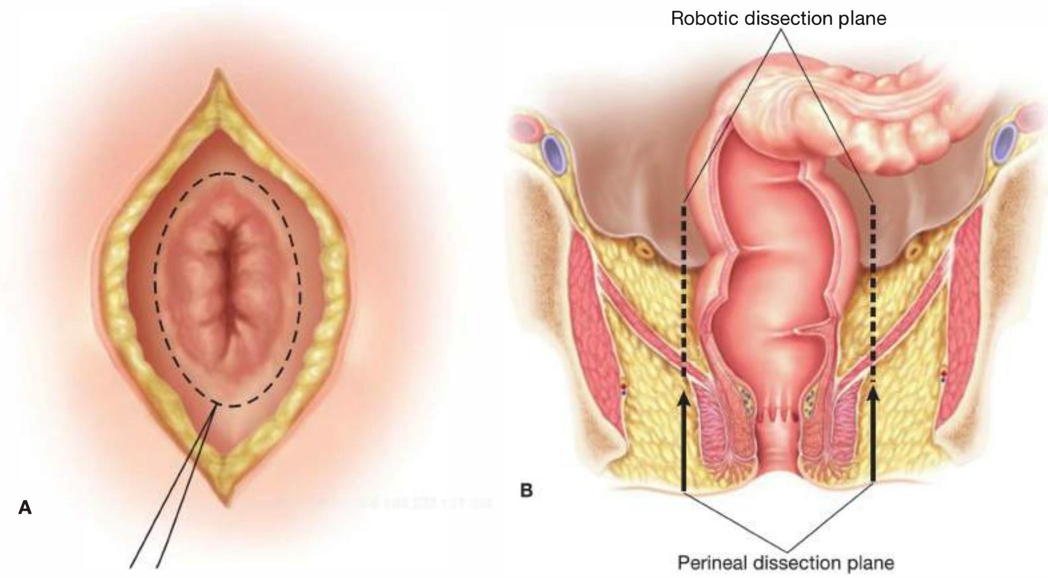


FIG 13 ● The perineal portion of the procedure is performed in a conventional fashion, with an elliptical perianal incision **(A)**. The perineal plane reaches the robotic dissection plane in the subcutaneous level **(B)**.

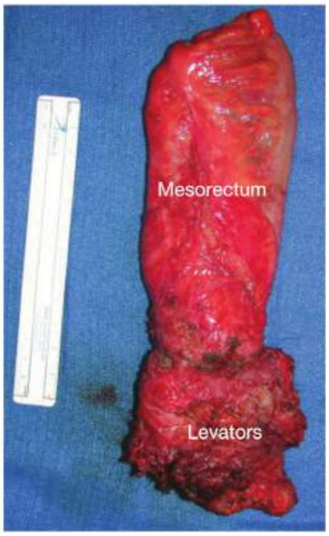


FIG 14 ● APR specimen. Note the shiny surface of the intact mesorectum with no distal tapering, avoiding an hourglass appearance on the specimen.

COLOSTOMY AND CLOSURE

- A circumferential incision in a predetermined size located on the left lower abdominal quadrant is performed through the rectus sheet for the creation of the colostomy.
- The subcutaneous tissue, fascia, and peritoneum are incised with a circumference of at least two fingerbreadths.
- The bowel proximal to the division is brought superficially to the abdominal wall and an end colostomy is performed in a conventional fashion. The colostomy is matured after wound closure.
- Before closure, the perineal incision is irrigated with normal saline and povidone-iodine.
- The perineal wound closure is initiated deep with imbrication of the levator ani (when preserved) with absorbable suture, typically 2-0 polyglactin 910 (Vicryl®). The superficial perineal subcutaneous tissues are reapproximated with 3-0 Vicryl sutures. The skin is closed with interrupted 2-0 nylon sutures.
- Port sites are closed with subcuticular 4-0 polydioxanone (PDS) sutures.

PEARLS AND PITFALLS

Indications	■ Low rectal cancer, anal cancer, recalcitrant IBD with anorectal involvement
Preoperative evaluation	■ Colonoscopy, abdominal CT scan, pelvic MRI, and/or endorectal ultrasound ■ Positron emission tomography (PET) scan selectively
Port placement	■ Two 12-mm ports for camera and assistant in the right upper quadrant and periumbilical region, respectively ■ Three 5-mm ports in the right lower, left upper, and left lower quadrants
Technique—laparoscopic exploration	■ Abdominal exploration and lysis of adhesions are accomplished with conventional multiport laparoscopy.
Robotic docking	■ The robot is docked in the left side of the patient's legs at an acute angle.
Technique—robotic pelvic procedure	■ The posterior mesorectal dissection, along the presacral plane, is done first, followed by the lateral dissection, and then by the anterior dissection. ■ The levator ani muscles are incised circumferentially through an anterior approach; the dissection is continued to the subcutaneous perineal tissue. ■ The pelvic portion is started with a circumferential perianal incision and deepened to reach the robotically established planes. ■ The perineum is closed either primarily or using a myofascial flap. ■ An end sigmoid colostomy is performed in a conventional fashion.
Postoperative management	■ Optimal postoperative outcomes are accomplished with a fast-track perioperative protocol and an ostomy care program.

POSTOPERATIVE CARE

- Patients following minimally invasive colorectal surgery are typically placed in an enhanced recovery pathway.
- Return of oral intake is typically achieved with clear liquids 8 to 12 hours after the procedure and the diet is advanced as tolerated.
- In contrast to purely abdominal procedures, for pelvic surgery the bladder catheter is not removed until postoperative day 2.
- Ambulation is indicated to accelerate recovery.
- Postoperative analgesia is accomplished with a combined modality involving intravenous acetaminophen, opioids, and nonsteroidal antiinflammatory drugs. Alvimopan is used to eliminate the effects of opioids in the gastrointestinal (GI) tract. Additionally, patient-controlled analgesia is limited to 1 to 2 postoperative days.
- Ostomy care is best achieved with a standardized protocol that includes preoperative and postoperative patient education and training. The program involves a multidisciplinary approach with patient and family, surgeon, and ostomy nurse.

OUTCOMES

- Most patients following robotic-assisted colectomy managed with a fast-track perioperative protocol have a length of hospital stay of 4 days.
- Longer hospital stay may be required to address complications.
- Perineal wound complications are common; thus, close postoperative follow-up following APR is required.
- Patients with malignancy should be placed on postoperative surveillance protocols.

COMPLICATIONS

- Vascular injury with intraperitoneal bleeding
- Ureteral injury
- Sexual and/or urinary dysfunction secondary to autonomic nerve injury
- Prolonged postoperative ileus
- Abdominal wound complications (e.g., hematoma, seroma, infection, and dehiscence)
- Persistent perineal sinus
- Intraabdominal abscess

- Perineal sepsis
- Parastomal and perineal hernia formation

SUGGESTED READINGS

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3. Evans J, Tait D, Swift I, et al. Timing of surgery following preoperative therapy in rectal cancer: the need for a prospective randomized trial? *Dis Colon Rectum*. 2011;54:1251–1259.
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Chapter **36**

Restorative Proctocolectomy: Open Technique (Ileal Pouch-Anal Anastomosis)

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DEFINITION

- Restorative proctocolectomy with ileal pouch-anal anastomosis (RP/IPAA) is defined as removal of entire colon and rectum and construction of an anastomosis of ileal pouch to the anal canal using stapled or hand-sewn technique.

DIFFERENTIAL DIAGNOSIS

- When the patients with ulcerative colitis become refractory to medical therapy or steroid dependant, RP/IPAA has been the surgical choice.
- RP/IPAA can be performed with good functional results and quality of life, and low pouch failure for indeterminate colitis.
- Patients with Crohn's disease have greater risk of pouch failure following RP/IPAA compared to those with ulcerative colitis.
- In patients with familial adenomatous polyposis, the risk of colorectal cancer is eliminated by performing RP/IPAA.

PATIENT HISTORY AND PHYSICAL FINDINGS

- A thorough history and physical examination should be obtained.
- In inflammatory bowel disease, it is important to note previous and/or concurrent use of steroids, immunomodulators, and nonsteroidal antiinflammatory medications. Patients refractory to these medications are typically candidates for this procedure.
- Previous surgeries, particularly in Crohn's patients, need to be taken into consideration.
- Anal and urinary sphincter function needs to be evaluated. Patients with poor anal sphincter function may not be good candidates for RP/IPAA and may need a proctocolectomy with end ileostomy instead.
- A full nutritional assessment should be instituted.
- Significant cardiac and/or pulmonary comorbidities may prevent the patient to have this procedure.
- Family history of colorectal polyps, cancer, and/or inflammatory bowel disease should be elicited.

IMAGING AND OTHER DIAGNOSTIC STUDIES

- Preoperative colonoscopy is necessary.
- Diagnosis of ulcerative colitis and exclusion Crohn's disease by colonoscopic biopsy and by an experienced pathologist and/or with the assistance of other laboratory workup, such as Prometheus test, is necessary in order to establish the need for restorative proctocolectomy with ileoanal anastomosis.
- Colonoscopic evidence of terminal ileitis by biopsy may assist in the diagnosis of Crohn's disease.
- Diagnosis of ulcerative colitis with proctitis and involvement of the anal canal by colonoscopy or rigid proctoscopy and biopsy may be necessary in order to establish the need for anal mucosectomy and hand-sewn ileal pouch anastomosis.
- Contrast-enhanced computed axial tomography (CAT) scan may help evaluate cancer patients for locoregional extent of disease and metastases. CAT scan is also helpful in inflammatory bowel disease to evaluate for acute inflammatory processes (phlegmon, abscess, fistula, or obstruction).
- Endorectal ultrasound or rectal protocol magnetic resonance imaging (MRI) may assist with the staging of rectal carcinoma and identification of the anal sphincter muscle involvement. The latter would be a contraindication of a restorative proctocolectomy. It may also delineate the anatomy of the anal sphincter in case of previous obstetric trauma or episiotomies.
- Obtaining a Wexner fecal incontinence score preoperatively may assist with the diagnosis of fecal incontinence. Manometry studies may also be helpful in these patients. Preoperative fecal incontinence may lead to poor functional outcome following an ileoanal pouch anastomosis.
- Preoperative barium enema or small bowel follow-through contrast study may assist with the diagnosis of Crohn's disease.

SURGICAL MANAGEMENT

Preoperative Planning

- The site for a diverting loop ileostomy is marked before surgery.
- A complete bowel preparation is recommended.
- Prophylaxis against deep venous thrombosis and prophylactic perioperative antibiotics should be administered.
- The rectum is washed out with normal saline in the operating room.

Positioning

- The procedure is performed with the patient in a Lloyd-Davies position (**FIG 1**).
- This position is defined as Trendelenburg position with legs apart.
- The thighs are level with the abdomen as this allows efficient placement of a self-retaining retractor without creating excessive pressure between the retractor and the patient's thighs.
- All pressure points are padded to avoid potential neurovascular injuries.
- The perineum is positioned flush with the edge of the operating room table for easy access during the perineal phase of the operation.
- The pelvis is supported with a folded sheet to lift the entire perineum and facilitate exposure during the perineal dissection.
- The arms are placed in a neutral position and supported with suitable armrests or tucked to the side.

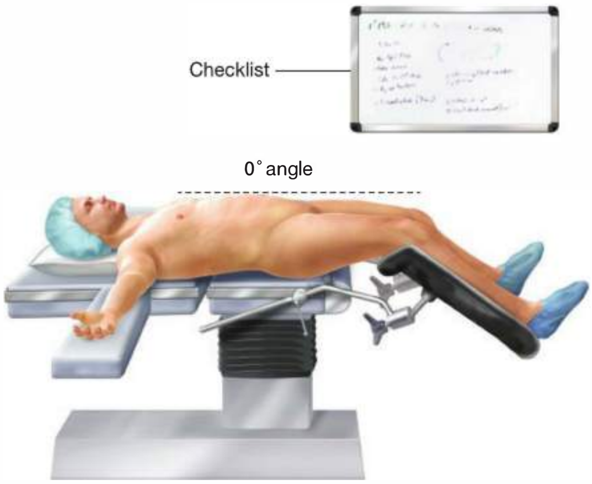

FIG 1 ● Patient positioning. The patient is placed on a Lloyd-Davies position, with the legs on stirrups. The thighs are positioned level with the abdomen, as this allows placement of a self-retaining retractor without creating excessive pressure between the retractor and the patient's thighs. The arms are tucked. All pressure points are padded to prevent neurovascular injuries.

PLACEMENT OF INCISION

- A midline vertical incision is made.
- A suitable laparotomy retractor is inserted.
- After general inspection to see if there are any contraindications to performing RP/IPAA, the small bowel is packed with moist large swab packs into the upper abdominal cavity.

MOBILIZATION OF THE RIGHT COLON: PRESERVATION OF THE ILEOCOLIC VASCULAR PEDICLE

- The surgeon stands to the patient's left side. The patient is placed on a Trendelenburg position with the right side up to facilitate exposure.
- A full Cattell-Braasch maneuver is performed to mobilize the right colon of its retroperitoneal attachments.
- The cecum and ascending colon are freed from the peritoneal reflection by incising along the white line of Toldt (**FIG 2**). The terminal ileum is also freed from the retroperitoneum and mobilized by incising the peritoneum along the root of the mesentery.
- As the colon and terminal ileum are reflected anteriorly and medially, the right gonadal vessels and right ureter should be identified in the retroperitoneum and not mobilized anteriorly so as to avoid injury.

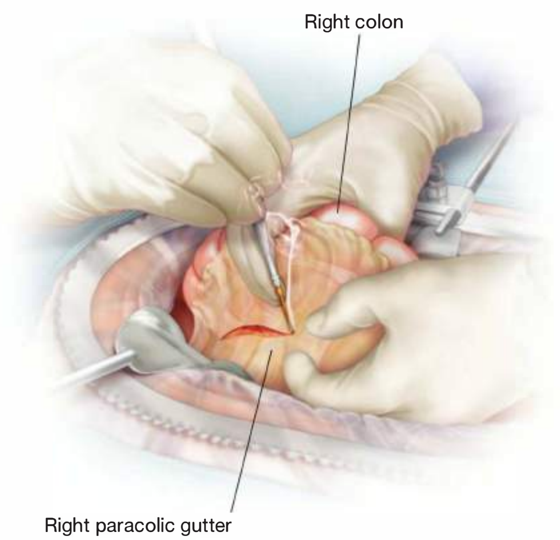

FIG 2 ● Ascending colon mobilization. The surgeon retracts the ascending colon medially. Dissection proceeds along the right paracolic gutter.

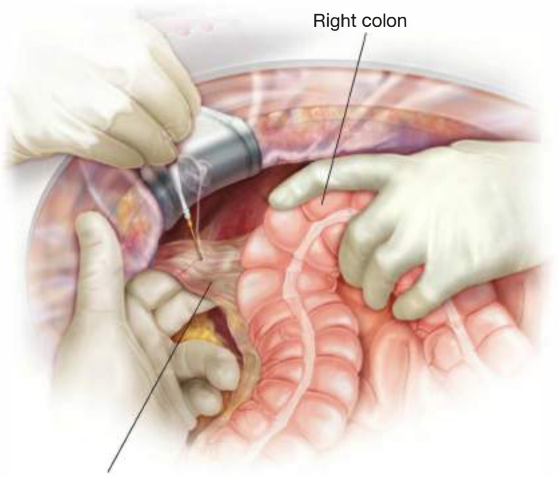

FIG 3 ● Hepatic flexure mobilization. Gentle traction on the hepatic flexure of the colon exposes the hepatocolic ligament, which is then transected with electrocautery.

- The lateral dissection is carried sharply up and around the hepatic flexure in the avascular, embryologic plane between the mesocolon and the duodenum. The second and third portions of the duodenum are identified near the hepatic flexure and injury to this structure must be avoided.
- The hepatocolic ligament is transected (**FIG 3**).
- Using an energy device, we hemostatically divide the ascending colon mesentery between the mesenteric vascular arcade and the colon wall (**FIG 4**) while protecting at all times the ileocolic vascular pedicle up to the mesenteric level of the ileocecal valve. This will allow excellent prograde blood supply to the pouch later on. Avoiding an ileocolic mesenteric bleeding or hematoma is crucial for preservation of the vascular supply to the ileal J-pouch.

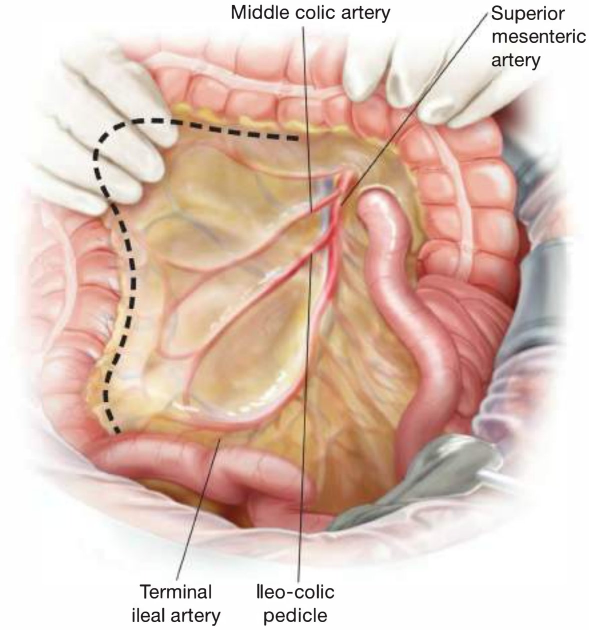

FIG 4 ● Right colon vascular transection. Using an energy device, we hemostatically divide the ascending colon mesentery between the mesenteric vascular arcade and the colon wall *(dotted line)* while protecting at all times the ileocolic vascular pedicle up to the mesenteric level of the ileocecal valve. This will allow excellent prograde blood supply to the pouch later on.

- The mesenteric division extends from the midtransverse colon down to the mesenteric border of the terminal ileum at the selected site of proximal intestinal division—just proximal to the ileocecal valve.

TRANSVERSE COLON MOBILIZATION

- The gastrocolic ligament is exposed as the assistant retracts the greater omentum superiorly while the surgeon retracts the transverse colon anteroinferiorly.
- Diathermy is used to separate the greater omentum from the anterior leaf of the transverse mesocolon.
- Mobilization of the spleen needs to be approached from both sides to facilitate ease of mobilization of the splenic flexure (**FIG 5**). The patient is placed on a reverse Trendelenburg position with the left side up to allow the spleen to come down into the surgical field.

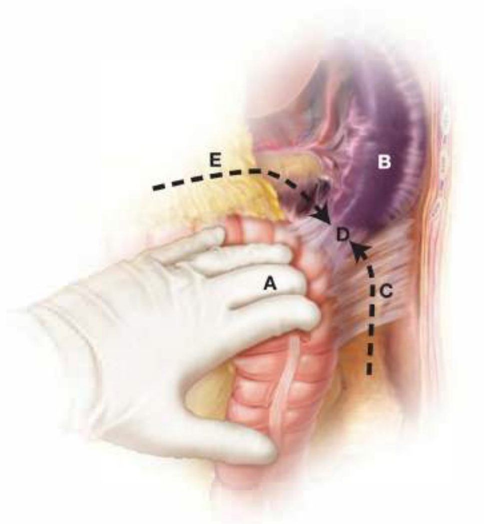

FIG 5 ● Splenic flexure mobilization. The surgeon retracts the splenic flexure of the colon *(A)* downward and medially, exposing the attachments of the splenic flexure to the spleen *(B)*. The phrenocolic *(C)* and splenocolic *(D)* ligaments are transected in an inferior to superior and lateral to medial direction. The gastrocolic ligament *(E)* is then transected in a medial to lateral direction, until both planes of dissection meet and the splenic flexure is fully mobilized.

- Once the gastrocolic ligament has been completely transected, transection of the lateral peritoneal attachments (phrenocolic ligament) allows for lateral mobilization of the splenic flexure.
- At this point and from the right side of the table, the surgeon hooks the splenocolic ligament anteriorly with his or her right index finger, exposing the ligament adequately for the assistant to transect it using electrocautery. The splenocolic ligament is divided as close to the colon as feasible, avoiding undue traction on the spleen.

DESCENDING COLON MOBILIZATION

- The surgeon stays on the right side of the table. The patient is placed on Trendelenburg position with the left side up.
- The descending colon is mobilized by medial traction and dissection along the left paracolic gutter using diathermy.
- The colon is mobilized from the retroperitoneum using a lateral to medial approach.
- Care is taken to identify, and avoid damage to, the left gonadal vessels and left ureter (**FIG 6**). In the lower abdomen, the left ureter is located medial to the gonadal vessels, close to the midline.

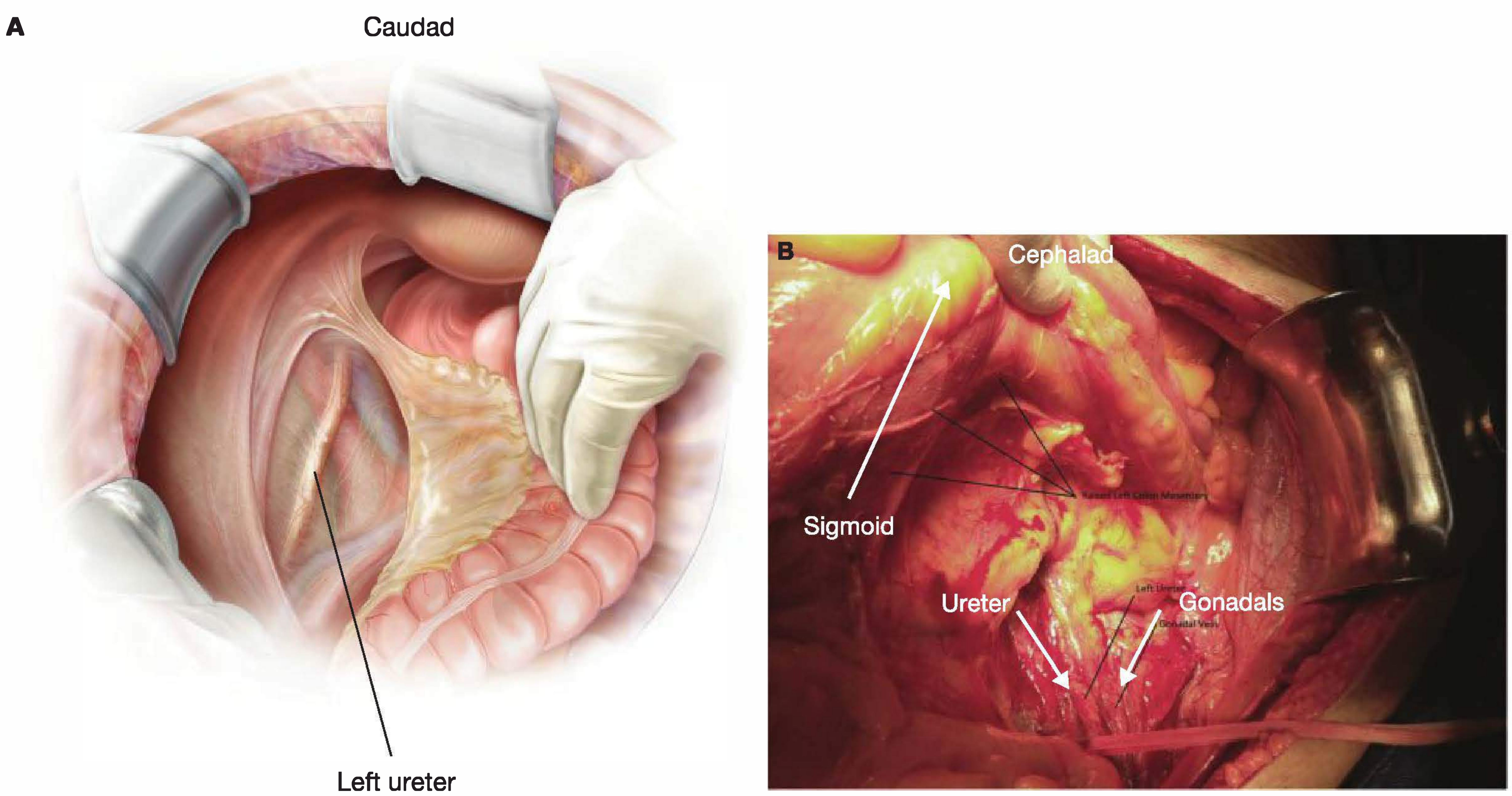

FIG 6 ● Exposure of the left ureter. The illustration **(A)** shows the view of the operative field from cephalad to caudad direction. The operative picture **(B)** shows a caudad to cephalad view of the field. In the lower abdomen, as the descending and sigmoid mesocolon are separated from the retroperitoneum by the lateral to medial dissection, the left ureter is located medial to the gonadal vessels, close to the midline.

INFERIOR MESENTERIC ARTERY TRANSECTION

- With the assistant holding the proximal and distal sigmoid colon up, the root of the mesosigmoid colon is clearly visualized by the surgeon from the right side of the table. At the root of the mesentery, the arch of the superior hemorrhoidal vessels (SHV) can be seen and palpated.
- Placing the index finger behind the SHV arch allows the surgeon to incise with electrocautery the right surface of the peritoneum just under the dorsal surface of the SHV.
- This plane of dissection along the dorsal aspect of the SHV is carried distally over the promontory (leading into the presacral space) and proximally, up to the origin of the inferior mesenteric artery (IMA). The IMA is dissected circumferentially at its origin from the aorta.
- The IMA is then ligated between Sarot clamps, incised, and doubly ligated with braided 2-0 suture (**FIG 7**).

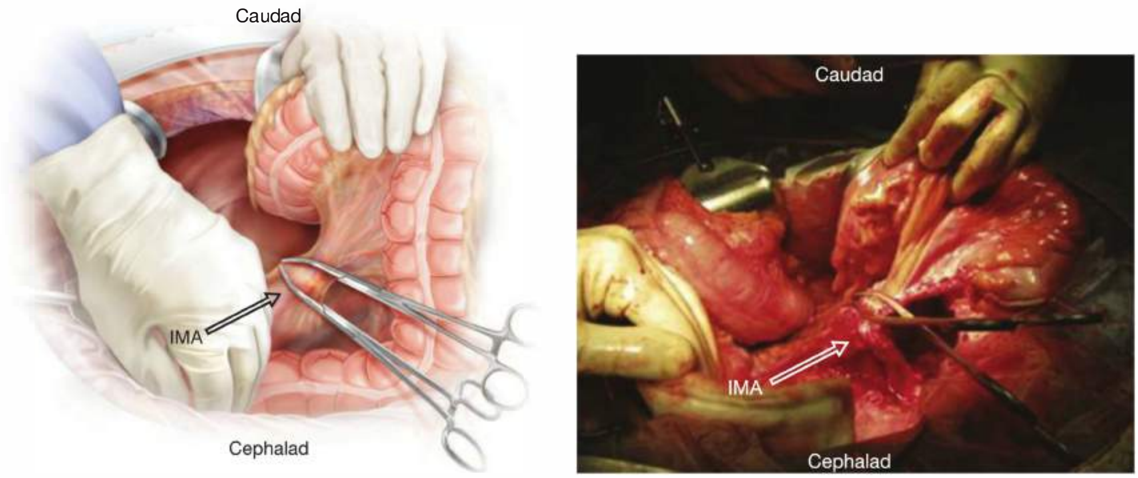

FIG 7 ● IMA division. The IMA is transected between clamps and will subsequently be ligated with heavy silk sutures.

PROCTECTOMY

- The posterior pelvic dissection is performed first. Using a lighted St. Mark's retractor for exposure, the presacral fascia is entered between the investing layer of fascia propria of the mesorectum and presacral fascia (**FIG 8**).
- The hypogastric nerves are identified at the pelvic rim and they are preserved (**FIG 9**).
- The pelvic dissection is continued in the midline between Waldeyer's fascia and the investing layer of the rectum to the level of the levator muscle. It is crucial not to violate the presacral fascia posteriorly where nervi erigentes and the lateral and presacral veins might be damaged.
- After the posterior dissection, a bilateral incision is made on the pelvic peritoneum and joined on the anterior rectal wall 1 cm above the peritoneal reflection. Dissection is then performed closer to the rectum to reduce the risk of nerve injury. The lateral ligaments are divided (**FIG 10**).

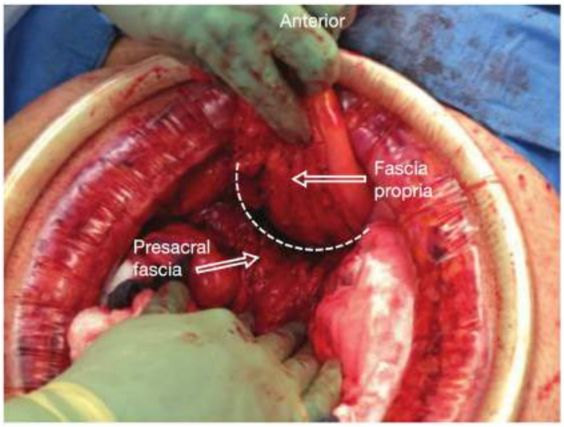

FIG 8 ● Posterior pelvic dissection. The posterior plane of dissection *(dotted line)* proceeds in a semicircular fashion along the presacral space, located between the fascia propria of the rectum, anteriorly, and the presacral fascia, posteriorly. This allows continued exposure of the posterior plane of dissection down to the pelvic floor and prevents vascular and nerve injuries along the lateral pelvic walls.

FIG 9 ● Preservation of the hypogastric nerves. Using a lighted St. Mark's retractor, the rectum is retracted anteriorly, exposing the presacral space posteriorly. The hypogastric nerves are exposed and should be swept posteriorly and away from the mesorectum. This begins the superior and posterior portion of the total mesorectal excision.

- The anterior dissection is done to the lower border of the prostate gland or lower one-third of the vagina (**FIG 10**). The Denonvilliers' fascia is preserved in patients without a carcinoma. The rectum is completely mobilized.
- A transanal digital evaluation with the tip of a finger is performed (**FIG 11**) to mark the level of distal rectal transection. The rectal transection is performed by a linear stapler for double-stapled IPAA or purse-string sutures for a single-stapled IPAA.

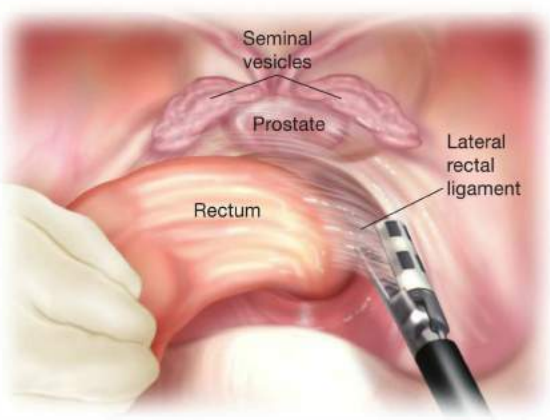

FIG 10 ● Transection of the lateral rectal ligaments and anterior pelvic dissection. Posterolateral retraction of the rectum allows for good exposure of the lateral rectal ligament (the right one is shown here), which can then be transected with an energy device. The anterior dissection will then proceed between Denonvilliers' fascia, posteriorly, and the prostate and seminal vesicles (*B* and *C*, respectively), anteriorly.

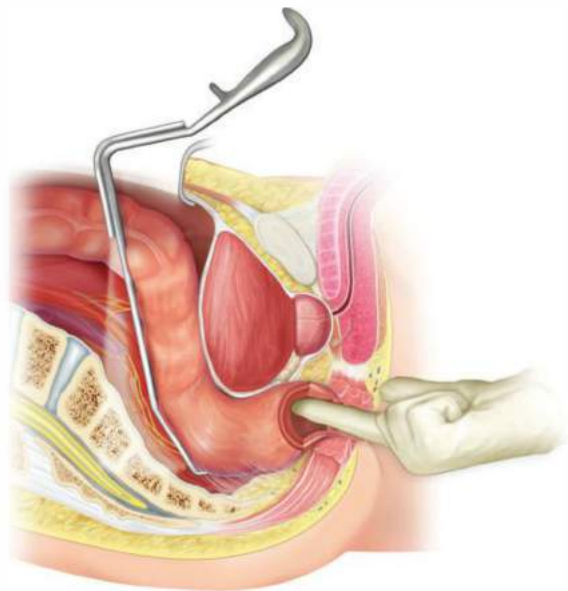

FIG 11 ● A transanal digital evaluation with the tip of a finger is performed to mark the level of distal rectal transection.

CREATION OF THE POUCH

- The pouch designs include J-, S-, or W-pouch (**FIG 12**). The J-pouch is the preferred technique because it is simpler to create. However, if there is an excessive tension in IPAA, an S-pouch can be created, because it usually reaches up to 4 cm further than the J-pouch.
- The J-pouch is created from the terminal 30 to 40 cm of small bowel, folded into two 15-cm or two 20-cm segments (**FIG 13**). A longitudinal 1, 5 cm apical enterotomy is made. A side-to-side anastomosis of the two limbs of the ileum is done with 100-mm linear staplers, which is passed through apical enterotomy. After making sure that no small bowel mesentery is interposed between the anvil and the cartridge, the instrument is fired. A second stapler fire is required in the same way (**FIG 13A**).
- The end of the divided terminal ileum is closed by a linear stapler (**FIG 13B**) and usually reinforced by oversewing with 3-0 polyglycolic acid sutures.
- The pouch is filled with saline to confirm integrity of the anastomosis (**FIG 13C**). The staple lines are checked for hemostasis.
- The apical enterotomy is closed using a 0 polypropylene purse-string suture.
- An S-pouch is created using three limbs of 12 to 15 cm of terminal small bowel with a 2-cm exit conduit. The limbs are approximated by continuous seromuscular 3-0 polyglycolic acid sutures. An S-shaped enterotomy is made. Continuous or running all-coat sutures are applied to the two posterior anastomotic lines from within the pouch. Closure of the anterior wall is done with continuous seromuscular sutures. Lastly, interrupted 3-0 polyglycolic acid reinforcement sutures are applied.

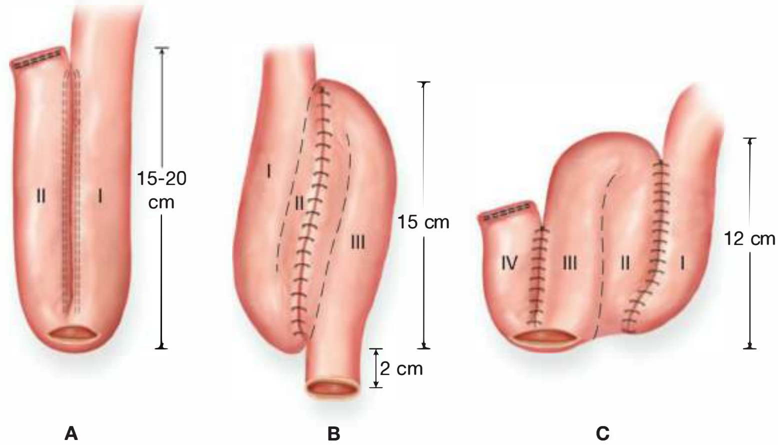

FIG 12 ● Ileal pouch configurations. The potential pouch designs include a J-, S-, or W-pouch.

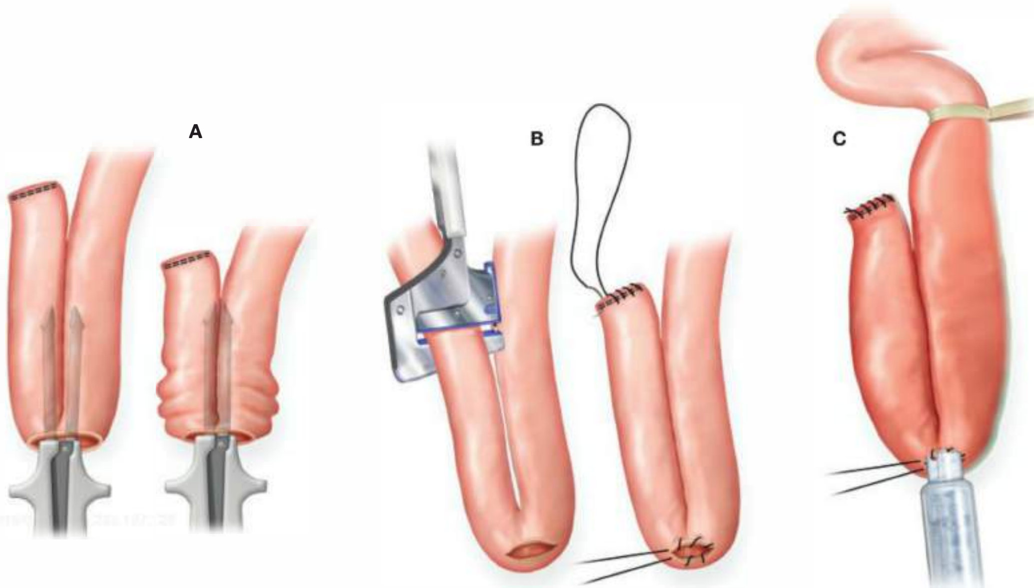

FIG 13 ● Creation of a J-pouch. The J-pouch is created from the terminal 30 to 40 cm of small bowel, folded into two 15-cm or two 20-cm segments by creating a side-to-side anastomosis with two sequential 100-mm linear stapler loads introduced through an apical pouch incision **(A)**. The end of the divided terminal ileum is closed by a linear stapler and reinforced by oversewing with 3-0 polyglycolic acid sutures **(B)**. The pouch is the filled with saline to confirm integrity of the anastomosis **(C)**.

THE POUCH DOES NOT REACH!

- The small bowel should be fully mobilized along the root of the mesentery up to the third portion of the duodenum so that the pouch reaches to the levator floor without tension.
- There may be difficulty with reach of the ileal pouch to the anal canal in obese patients or in patients who have had a previous small bowel resection.
- The reach can be estimated by grasping the ileal pouch at the apex and bringing it down to the pelvic floor.
- If the pouch does not reach, ligation and excision of the ileocolic artery and vein at their origin off the superior mesenteric artery (SMA) provides excellent pouch reach and allows for an anastomosis with no tension (**FIG 14A**).
- If further mobilization is necessary, the peritoneal tissue to the right of the superior mesenteric vessels is excised with the use of translumination. Additionally, transverse 1- to 2-cm peritoneal incisions over the superior mesenteric vessels border anteriorly and posteriorly can be done if needed (**FIG 14B**).
- In a narrow pelvis, a bimanual maneuver can overcome the difficulty in reaching a bulky ileal pouch to the anal canal. A long Babcock clamp is passed transanally to grasp the apex of the pouch and the surgeon's hand is passed behind the pouch to coax and ease the pouch and its exit conduit to the level of the levator floor (**FIG 15**).

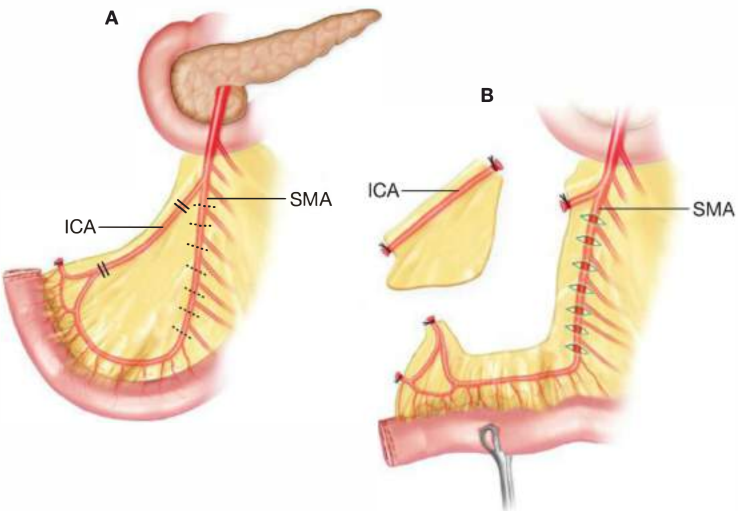

FIG 14 ● **(A)** Pouch elongation. If the pouch does not reach, ligation and excision of the ileocolic artery and vein at their origin off the SMA provides excellent pouch reach and allows for an anastomosis with no tension **(B)**. If further pouch mobilization is necessary, the peritoneal tissue to the right of the superior mesenteric vessels is excised with the use of translumination. Additionally, transverse 1- to 2-cm peritoneal stepladder incisions over the superior mesenteric vessels border anteriorly and posteriorly can be done if needed.

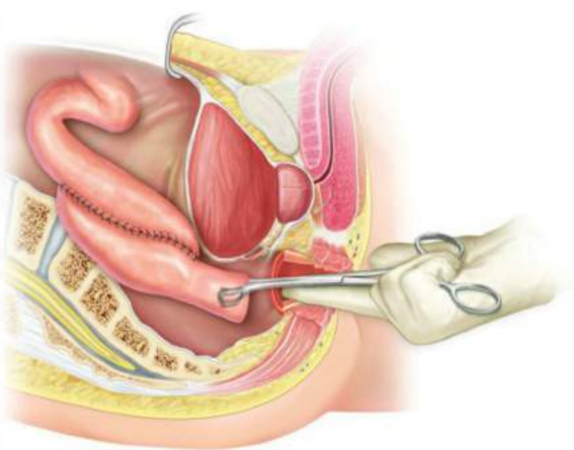

FIG 15 ● Bimanual pouch delivery maneuver. A long Babcock clamp is passed transanally to grasp the apex of the pouch and the surgeon's hand is passed behind the pouch to coax and ease the pouch to the level of the levator floor.

CREATION OF ILEAL POUCH-ANAL ANASTOMOSIS

Stapled Anastomosis

- IPAA can be created by either stapling or hand-sewn techniques. A stapled IPAA is constructed using either a double- or single-stapling techniques.
- In the double-stapling technique (**FIG 16**), the distal anorectal stump is closed with a linear stapler. After the stapler is fired, the specimen is divided above the linear staple line. The linear staple line on the anorectum should rest at a level just below the superior border of the levator floor. Hence, the level of the planned IPAA should be determined and marked beforehand.
- A circular stapler with the anvil detached is inserted into the anus and the pointed shaft/trocar is advanced just posterior to the linear staple line on the anorectum. This can be facilitated by putting the index finger into the anorectal area from the abdominal side and guiding the trocar just posterior to the linear staple line on the anorectum. The shaft of the circular staple line is then mated with the anvil shaft emerging from the ileal pouch. To prevent the twisting of mesentery, the small bowel is correctly oriented. The ends are approximated and anastomosis is completed. Both doughnuts are inspected for integrity. Care must be taken to avoid including the posterior vaginal wall and the anal sphincters within the anastomosis.
- Transanal insufflation with normal saline is performed to confirm that the anastomosis is intact.
- For a single-stapling anastomosis, a distal purse string is applied to the anorectal stump by hand with a 0 polypropylene suture. The surgical circular stapler is inserted transanally, the shaft is advanced completely, and the purse string is tightened. IPAA is then completed.

Hand-Sewn Anastomosis

- A hand-sewn IPAA is performed following mucosectomy of the anorectum (**FIG 17A**). The mucosa is stripped from the underlying sphincters starting at the dentate line to the level of the anorectal transsection. The anal verge is everted using sutures placed in four quadrants. An injection of 10- to 15-mL adrenalin solution (1:100,000) is used to raise the anorectal mucosa. A tube excision of anorectal mucosa is performed using cautery. Meticulous techniques are important to minimize risk of leaving islands of large bowel mucosa that are not amenable to surveillance.
- Excessive stretching of the anal canal may damage the anal sphincters; therefore, it should be avoided.
- 2-0 polyglycolic acid sutures are placed radially at the dentate line, incorporating a small portion of internal anal sphincter. Stitches should not be taken too deeply anteriorly in female patients in order to prevent development of anastomotic-vaginal fistula.
- After the apex of the J-pouch or end of the exit conduit of the S-pouch is delivered to the anal verge using a Babcock clamp (**FIG 17B**), the previously placed sutures at the dentate line are serially placed through the full thickness of the ileum (**FIG 17C,D**).
- The retractor is then removed and the sutures tied.

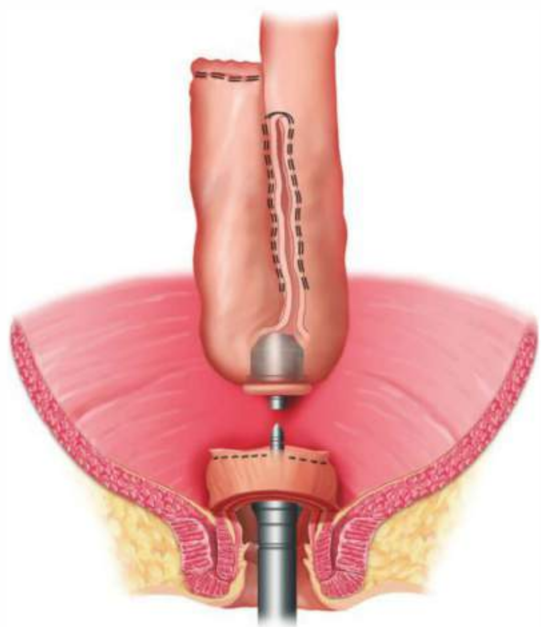

FIG 16 ● J-pouch ileoanal anastomosis: double-stapled technique. An end-to-end stapled anastomosis is performed between the pouch and the anal canal.

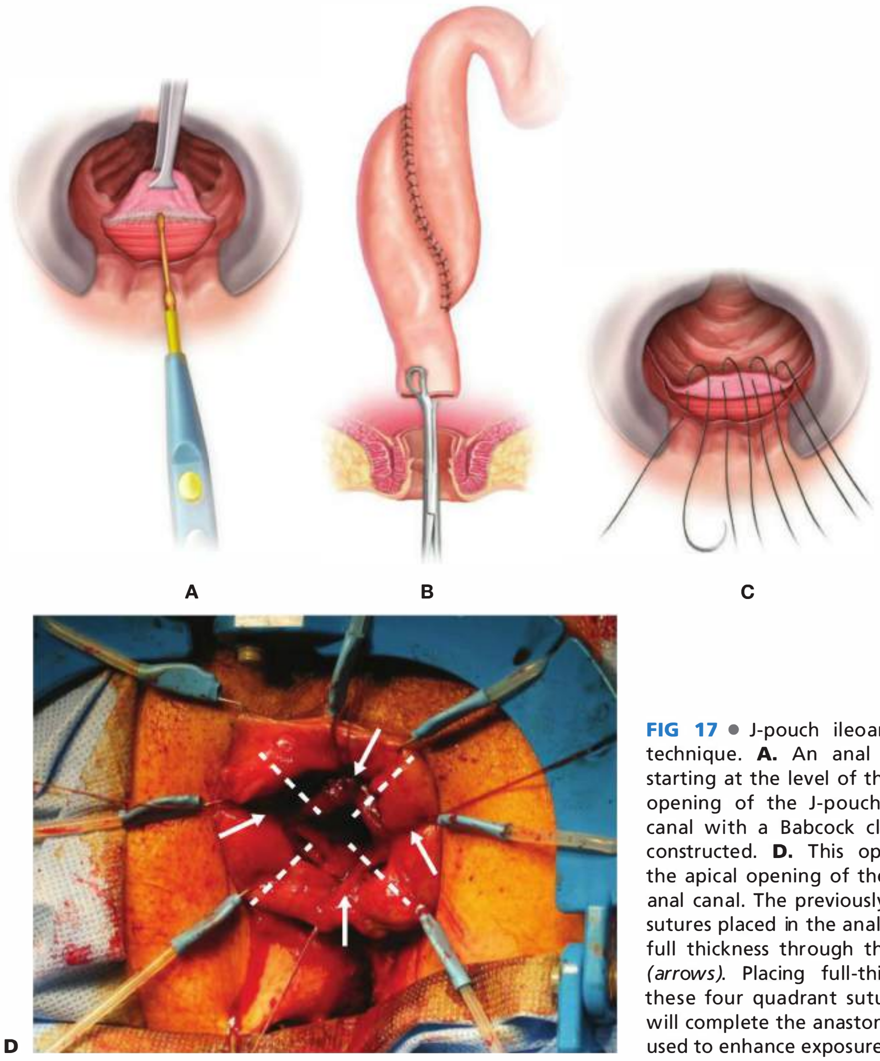

FIG 17 ● J-pouch ileoanal anastomosis: hand-sewn technique. **A.** An anal mucosectomy is performed starting at the level of the dentate line. **B.** The apical opening of the J-pouch is delivered into the anal canal with a Babcock clamp. **C.** The anastomosis is constructed. **D.** This operative picture shows how the apical opening of the J-pouch is anchored to the anal canal. The previously placed four-quadrant distal sutures placed in the anal canal have now been placed full thickness through the open end of the J-pouch *(arrows)*. Placing full-thickness sutures in between these four quadrant sutures (along the *dotted lines*) will complete the anastomosis. A Lone Star retractor is used to enhance exposure.

CREATION OF DIVERTING STOMA AND CLOSURE

- A temporary diverting loop ileostomy is created in the right lower quadrant, 20 to 25 cm proximal to the pouch. In obese patients, if the ileal loop does not reach to the abdominal wall without tension, a divided end ileostomy may be preferred.
- A closed suction drain is placed into presacral space.
- The incision is closed with running no. 1 polydioxanone (PDS) sutures. The skin incision is closed with staples.

PEARLS AND PITFALLS

Patient positioning	■ Place the patient in a Lloyd-Davies position.
Incision	■ Midline incision
In severe fulminant colitis or toxic megacolon	■ RP/IPAA should be performed in multistage: first, subtotal colectomy and end ileostomy, then completion proctectomy, IPAA, and loop ileostomy in 6 months.
Creation of pouch	■ J-pouch should be the preferred technique because of its simplicity. ■ S-pouch can be used if there is excessive tension.

The pouch does not reach	■ Mobilize the small bowel to the third portion of the duodenum. ■ Transect and excise the ileocolic vessels at their origin from the SMA. ■ Stepladder incisions on the mesentery overlying the SMA
IPAA	■ The small bowel should be mobilized sufficiently so that it will reach to the levator floor without tension. ■ Stapled IPAA should be the preferred technique because it is associated with better outcomes.
Diverting stoma	■ Reduces postoperative sepsis ■ In obese patients, if the ileal loop does not reach to the abdominal wall without tension, a divided end ileostomy may be preferred.

POSTOPERATIVE CARE

- Mean time to resuming a liquid diet is 3.8 days after surgery.
- The pelvic drain is left for 3 to 4 days or until the drainage is less than 50 mL a day.
- The mean length of hospital stay after RP/IPAA is 7.8 days.
- The diverting loop ileostomy is reversed in 6 weeks to 3 months, depending on the patient's performance and nutritional status, and only after a contrast study shows that the pouch and the anastomosis are intact.

OUTCOMES

- RP/IPAA is a good option for patients with ulcerative colitis, indeterminate colitis, familial adenomatous polyposis, and selected patients with Crohn's disease.
- J is the preferred design of the ileal pouch.
- Stapled IPAA seems to be associated with significantly less complications and better functional outcomes and quality of life compared to a hand-sewn IPAA.
- Diverting ileostomy during RP/IPAA improves outcomes, especially sepsis.
- However, ileostomy may still be omitted in selected low-risk patients.
- Rate of pouch failure after RP/IPAA can be as low as 5% when it is performed at specialized centers.
- Patients who undergo RP/IPAA report good functional outcomes and quality of life after a long-term follow-up.

COMPLICATIONS

- Early complications: pelvic sepsis, anastomotic leak, hemorrhage, wound infection, small bowel obstruction, pouch fistula, stricture
- Late complications: small bowel obstruction, pelvic sepsis, pouch fistula, anastomotic leak, stricture, pouchitis, chronic pouchitis, pouch failure

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Chapter 37

Restorative Proctocolectomy: Single-Incision Laparoscopic Technique (Including Pouch Ileoanal Anastomosis)

Theodoros Voloyiannis

DEFINITION

- Single-incision laparoscopic restorative proctocolectomy, including pouch ileoanal anastomosis with temporary diverting loop ileostomy, is another application of the single-incision laparoscopic technique where a single multichannel laparoscopic port is used via a 2.5- to 3.5-cm total incision length.
- The procedure can be performed for benign or neoplastic diseases that require elective restorative proctocolectomy with a hand-sewn or stapled coloanal anastomosis including ileoanal pouch anastomosis such as ulcerative pancolitis, polyposis syndromes such as familial adenomatous polyposis or synchronous noninvasive rectal carcinoma and colonic carcinomas and polyps after appropriate oncologic staging workup.
- A variation of this procedure may be applied for mid- or low rectal cancer with adequate oncologic distal rectal wall margin, preferably of at least 2 cm, for creation of an anastomosis. In these cases, a low anterior resection with stapled coloproctostomy or hand-sewn coloanal anastomosis and temporary loop ileostomy may be performed.
- A completion proctectomy, an ileoanal pouch anastomosis with temporary loop ileostomy after a total abdominal colectomy for ulcerative colitis, is another application of this technique.
- A new approach, the transabdominal-transanal single-port technique or transanal single-port total mesorectal excision (ta-TME) for completion of the total mesorectal excision with placement of a transanal single port, is discussed in this chapter.
- The goal is to keep the procedure simple, safe, and cost effective, with comparable outcomes to hand-assisted or multiport laparoscopic technique.
- Although single-incision laparoscopic surgery differs technically from conventional laparoscopic surgery, it follows the same steps and oncologic principles. However, it requires advanced laparoscopic skills.

PATIENT HISTORY AND PHYSICAL FINDINGS

- A detailed history and physical examination is essential preoperatively to determine if the patient is suitable for a laparoscopic approach. Rectal neoplasia after preoperative neoadjuvant chemoradiation or T4 rectal tumor extension to the sacrum, bladder trigone, prostate, posterior vaginal wall, or side pelvic wall with ureteral or major vessel involvement should be addressed preoperatively with appropriate staging workup. In these cases, laparotomy may be the best option, or if the procedure can be accomplished laparoscopically, a hybrid approach with a single-port laparoscopic technique at the suprapubic area with subsequent conversion to a Pfannenstiel incision may be considered.
- Potential intraoperative consultation to other subspecialties, such as gynecology for addressing an incidental neoplastic adnexal pathology, urology for ureteral or bladder tumor involvement or other surgical service, may be necessary. It is the primary surgeon's responsibility to communicate with the consulting service regarding the feasibility of a single-incision laparoscopic approach in order to avoid a lengthy single-incision procedure that may lead to conversion to hand-assisted laparoscopy or to a laparotomy.
- A restorative proctocolectomy allows for extraction of the specimen via the single port or transanally, in case of a planned coloanal or ileoanal pouch hand-sewn anastomosis. A full-thickness rectal division is performed at the level of the dentate line. In case of underlying colonic or rectal neoplasia, the size of the tumor determines if it can be extracted without tension via the single-port wound protector. In general, tumors up to 7 cm can be extracted via a 5-cm maximum length single incision. The procedure can still be performed with elongation of the incision for extraction of larger tumors. In that case, the benefit of the single port is eliminated, with the exception of the avoidance of use of multiple laparoscopic ports. If the single port is placed via the new ileostomy site, then partial approximation of the fascia may be required prior to maturation of the ileostomy.
- A large palpable tumor preoperatively with fixation to the abdominal wall or other organs may be a contraindication to single-incision laparoscopy, although excision en bloc with soft tissue abdominal wall is still possible via a single incision in some cases.
- It is important to define the underlying pathology—benign versus malignant disease and the location of the lesion—preoperatively. Neoplasia may require formal lymphadenectomy with preferable high ligation of the involved vascular supply. This may not be necessary in benign conditions such as ulcerative colitis or polyposis syndromes without dysplasia or neoplasia.
- In case of a planned ileoanal pouch anastomosis, particular attention is paid to the preservation of the ileocolic vascular pedicle in order to maintain the vascular supply of the pouch. The ileal pouch can be fashioned extracorporeally, following extraction of the colon and rectum via the single incision wound protector.
- Previous abdominal surgeries with extensive abdominal or pelvic adhesions may increase the operative time.

IMAGING AND OTHER DIAGNOSTIC STUDIES

- Preoperative colonoscopy is necessary to justify the planned restorative proctocolectomy.
- Diagnosis of ulcerative colitis and exclusion of Crohn's disease by colonoscopic biopsy and by an experienced pathologist

and/or with the assistance of other laboratory workup, such as Prometheus test, are necessary in order to establish the need for restorative proctocolectomy with ileoanal anastomosis.
- Colonoscopic evidence of terminal ileitis by biopsy may assist in the diagnosis of Crohn's disease and avoidance of an ileoanal pouch formation.
- Diagnosis of ulcerative colitis with proctitis and involvement of the anal canal by colonoscopy or rigid proctoscopy and biopsy is necessary in order to establish the need for anal mucosectomy and hand-sewn ileal pouch anastomosis.
- Contrast-enhanced computed axial tomography (CAT) scan of the abdomen/pelvis assists the surgeon to decide on the feasibility of a single-incision laparoscopic approach. It also helps in identifying the exact location of large colonic or rectal neoplastic lesions, the potential involvement of adjacent organs or structures, and the potential presence of mesenteric adenopathy and/or metastases as well as inflammatory processes (phlegmon, abscess, fistula, or obstruction).
- Endorectal ultrasound or rectal protocol magnetic resonance imaging (MRI) may assist with the staging of rectal carcinoma and identification of the anal sphincter muscle involvement. The latter would be a contraindication of a restorative proctocolectomy and may also delineate the anatomy of the anal sphincter in case of previous obstetric trauma or episiotomies.
- Fecal incontinence—Wexner score preoperatively may assist with the diagnosis of fecal incontinence. Preoperative fecal incontinence may lead to poor functional outcome following an ileoanal pouch anastomosis.
- Preoperative barium enema or small bowel follow-through contrast study may assist with the diagnosis of Crohn's disease.
- A carcinoembryonic antigen (CEA) level is obtained in malignancies as a tumor marker.

SURGICAL MANAGEMENT

- Full bowel preparation is administered the day prior to surgery to reduce the weight and volume of the colon. This facilitates the laparoscopic handling of the colon and the extraction of the specimen via a small 3.5-cm single incision.
- Obtain preoperative medical or pulmonary cardiac clearance as necessary.
- Correct anemia, electrolyte imbalances, and malnutrition preoperatively as needed.
- Wean off preoperative steroids to preferably less than 20 mg prednisone per day, if possible.
- Give consideration to weight loss prior to surgery, especially in cases of chronic preoperative steroid usage. A short and thick ileal mesentery may preclude an ileoanal pouch anastomosis.
- Intravenous (IV) antibiotics are administered prior to skin incision.

Instrumentation

- A laparoscopic operating room (OR) table with steep tilting is used. Test maximum tilting prior to draping to assess patients' secure positioning on the table (**FIG 1**).
- Two laparoscopic high-definition screens, one on each side of the OR table, are used.
- We use a bariatric length, 10-mm 30-degree camera. If needed, we use a right-angle adaptor for fiberoptic attachment to the camera to avoid conflict of the fiberoptic cord with other laparoscopic instruments. Using camera heaters and a smoke evacuator channel can avoid the need for repeated camera cleansing, leading to a decrease in operative length.
- We use two bariatric length laparoscopic bowel graspers, laparoscopic scissors, and bariatric length laparoscopic 5- to 10-mm suction irrigation.
- We prefer to use a bariatric length laparoscopic energy device such as the 43-cm LigaSure 5-mm device. Energy devices that produce excessive moisture or fog may impair visibility.
- Laparoscopic Endoloop polydioxanone (PDS) for the ileocolic vascular pedicle
- Staplers
  - Linear GIA 100-mm, triple blue staple lines for the ileal pouch formation
  - A 28- to 29-mm circular stapler for a stapled ileoanal pouch anastomosis
  - A 60-mm Endo GIA for distal division of the rectum as indicated
- A second set of instruments is necessary for an extracorporeal anastomosis.

FIG 1 • Patient setup. The patient is secured to the table, with the arms tucked, a strap across the chest, and the legs on Yellofin stirrups. All pressure points are padded to avoid nerve and vascular injuries. The table tilt is tested prior to starting the case to ensure that the patient does not slide.

Patient Positioning

- The patient is placed on modified lithotomy position on Allen stirrups with arms tucked (**FIG 1**). The patient is secured to the table, with foam pad placed under the patient's torso and with Velcro or broad tape placed across the chest. Rolled surgical towel is placed under the sacrum to elevate the pelvis and assist with the coloanal or ileoanal anastomosis.
- A Foley catheter is inserted and taped over the right thigh in order to avoid urethral trauma with the OR table tilting.
- A bear hugger or other thermal device is applied to the chest and legs.
- A protecting foam pad is placed over the head to protect from injury with laparoscopic instrument positioning.
- We recommend using laparoscopic draping with side plastic bags or pockets to allow for bariatric instrument placement. All laparoscopic cords and energy device cords are brought out via the patient's upper chest.

DIAGNOSTIC LAPAROSCOPY—SINGLE MULTICHANNEL PORT TECHNIQUE

- A 2.5-cm circular incision is performed at the right lower quadrant (RLQ) premarked temporary ileostomy site. Alternatively, a 3.5-cm periumbilical vertical midline incision is performed. A wound protector is inserted, followed by attachment of the single-incision laparoscopic surgery (SILS) port (**FIG 2A,B**).
- Assemble all channels of the SILS port on the back table to avoid losing parts outside the sterile field. Insert the laparoscopic multichannel single port with a wound protector. Insufflate pneumoperitoneum carbon dioxide (CO_2) to 15 mmHg of pressure.
- Perform a diagnostic laparoscopy. The surgical assistant/camera holder and the surgeon stand by the patient's right side when addressing the left colon, sigmoid, or rectum and by the patient's left side when addressing the right colon. For the transverse colon mobilization, either side may be suitable or the surgeon may be positioned between the patient's legs. Tilt the OR table to a steep Trendelenburg position and airplane it to the left or right for maximum exposure.
- Minimize excursion/cluster effect around hands and camera between the surgical assistant and operating surgeon with adherence to the principle that the surgeon should position his or her assisting (nondominant hand) instrument's distal tip (used for grasping, retracting, or suctioning) as close as possible to his or her operating (dominant hand) instrument's (i.e., energy device) tip. This distance should be about 3 to 4 cm between the two instruments' tips. For example, hold the ileocolic vascular pedicle just above the site of the division site rather than holing the cecum itself, which is far more distant from the pedicle. This technique allows achieving a wide angle between the two instruments outside the abdomen as they exit and cross via the single port, thus minimizing instrument conflict effect between the surgeon's hands.
- The assistant/camera holder will avoid conflict with the surgeon's instruments outside the abdomen by holding the camera as far as possible from the surgeon's hands and by using the camera's 30-degree angulation for side view as well as the zoom-in option (**FIG 2B**).
- Minimize the need for frequent laparoscopic instrument exchange, such as exchanging of graspers with monopolar laparoscopic scissors. Instead, consider using multiuse energy devices that provide dissection and sealing-cutting capabilities, thus allowing constant progress in the operating field and significant time saving.
- The surgeon and the assistant can either switch sides during the various steps of the procedure or just rotate the single port clockwise or counterclockwise while the instruments stay in the abdomen under direct visualization with the camera, thus achieving different camera angles, better exposure, and better visualization.
- The OR table can also be tilted accordingly during the various steps of the procedure to increase the exposure and prevent instrument conflict.

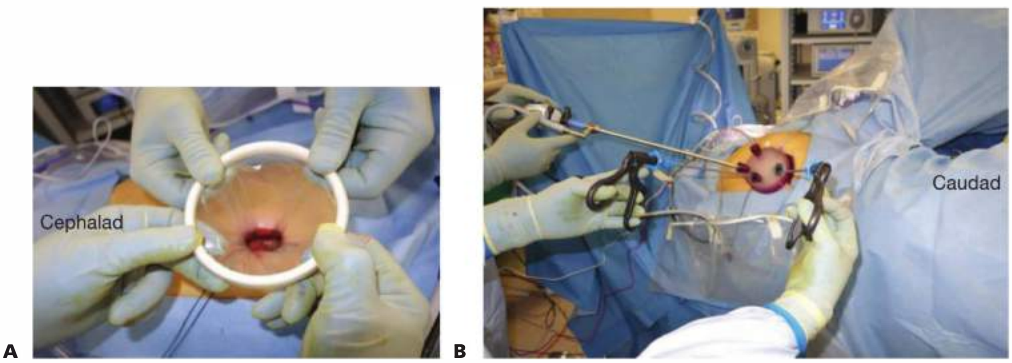

FIG 2 ● SILS port placement and configuration. **A.** A wound protector is inserted in the RLQ at the diverting loop ileostomy site. **B.** A multiport channel with four working ports, insufflation port, and a smoke evacuator port is used. The port is assembled on a side table prior to insertion in the patient. The assistant/camera holder will avoid conflict with the surgeon's instruments outside the abdomen by holding the camera as far as possible from the surgeon's hands.

MOBILIZATION OF THE RIGHT COLON: PRESERVATION OF THE ILEOCOLIC VASCULAR PEDICLE

- The patient is positioned in a steep Trendelenburg position with the OR table tilted maximally toward the patient's left side. The surgeon is standing on patient's lower left side using a grasper in the nondominant hand and the energy device on the dominant hand. The camera holder stands cephalad to the surgeon.
- If the omentum is adherent medially to the hepatic flexure or the ascending colon itself, we start the procedure with the dissection of the omentum off the colon. We may perform omentectomy by including the omentum with the transverse colectomy.

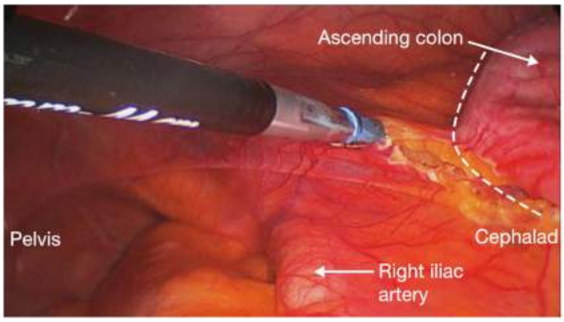

FIG 3 ● Mobilization of the ileum and ascending colon. The mobilization starts by transecting the ileocecal retroperitoneal attachments *(dotted line)*. The dissection will then proceed on a caudad to cephalad direction, eventually exposing the origin of the superior mesenteric artery and the third portion of the duodenum.

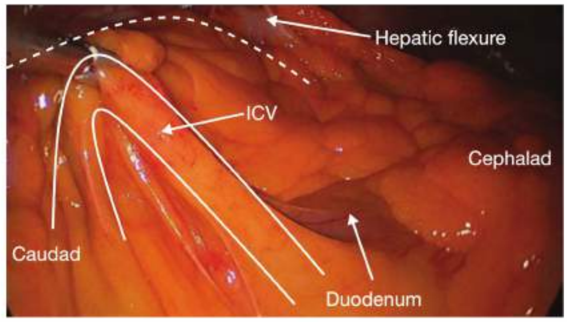

FIG 4 ● Preservation of the ileocolic vessels (ICV). During the dissection of the right colon, it is critical to divide the mesentery close to the colonic wall *(dotted line)*, preserving the ICV (here seen crossing over the third portion of the duodenum) intact. This will ensure excellent blood supply to the pouch.

- Dissect the terminal ileal retroperitoneal attachments and mobilize it toward the midline (**FIG 3**), exposing the origin of the superior mesenteric artery and the third and fourth portions of the duodenum. Morbidly obese patients require a generous terminal ileal medial mobilization to allow for a tension-free ileoanal pouch anastomosis.
- Proceeding from a caudad to cephalad direction, dissect the ascending colon mesentery off its retroperitoneal attachments without entering Gerota's fascia and preserving the right gonadal vessels and the right ureter intact. Dissect the ascending colon mesentery off the second and third portions of the duodenum in an atraumatic fashion.
- Using an energy device, we hemostatically divide the ascending colon mesenteric vascular arcade while protecting the ileocolic vascular pedicle up to the mesenteric level of the ileocecal valve (**FIG 4**). This is critical to ensure a good blood supply to the pouch. Avoiding an ileocolic mesenteric bleeding or hematoma is crucial for preservation of the vascular supply to the ileal J-pouch.
- Divide with the energy device the ascending colon mesentery flush to the ileocolic vascular pedicle (staying close to the colonic wall), up to the mesenteric border of the terminal ileum at the selected site of proximal intestinal division, just proximal to the ileocecal valve.
- Proceed with laparoscopic division of the incidental right colonic artery/vein if present.
- Mobilize the ascending colon medially by transecting the white line of Toldt.

MOBILIZATION OF THE TRANSVERSE COLON

- The surgeon stands in between the patient's leg. Place the patient on Trendelenburg and keep the OR table tilted to the left for the proximal transverse colon mobilization or to the right for the distal transverse colon and the splenic flexure mobilization. Alternatively, we may place the patient on reverse Trendelenburg for exposure and the assistant may use a laparoscopic grasper to assist with the retraction—"tenting"—of the transverse colon.
- Enter the lesser sac via the antimesenteric border of the proximal transverse colon and perform a hepatic flexure mobilization by dividing the hepatocolic ligament with the energy device (**FIG 5**).
- Divide the gastrocolic ligament adjacent to the mesenteric border of the transverse colon while preventing inadvertent injury of the gastroepiploic arcade.

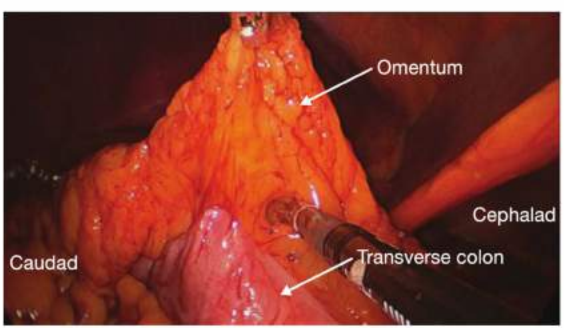

FIG 5 ● Entrance to the lesser sac. Enter the lesser sac via the antimesenteric border of the proximal transverse colon and perform a formal hepatic flexure mobilization using the energy device.

- The omentum may be included with the transverse colon into the specimen.
- Dissect the root of the hepatic flexure and proximal transverse colon mesentery and identify the origin of the middle colic artery and vein. Using an energy device, divide the middle colic vascular pedicle at the root of the mesocolon while holding the stump with a grasper to avoid retraction or residual bleeding (FIG 6).
- Place hemostatic clips or Endoloop PDS at the divided stump to secure the hemostasis. There is no need to use an Endo GIA stapler, unless severe atherosclerosis or vessels larger than 7 mm in size are present, which preclude usage of an energy device.
- Complete the dissection of the root of the distal transverse mesocolon off the retroperitoneum, pancreas, and fourth portion of the duodenum with the energy device.

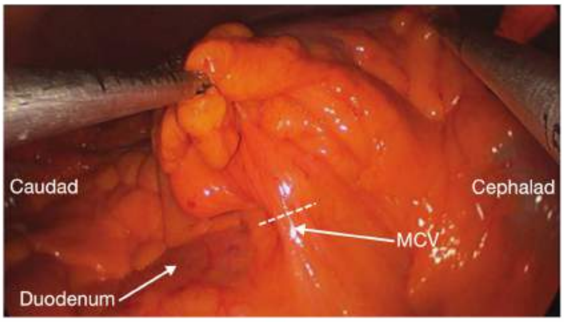

FIG 6 ● Identification and division of the middle colic vascular pedicle. With the transverse colon tented up with two graspers, the middle colic vessels (MCV) can be identified at the intersection of the root of the mesotransverse colon and the third portion of the duodenum. After dissection, the middle colic vessels will be transected *(dotted line)* with an energy device.

SPLENIC FLEXURE MOBILIZATION, LEFT COLECTOMY, AND SIGMOID COLECTOMY

- The surgeon stands on the patient's right side and caudally to the assistant, with the OR table tilted to the right.
- Start the dissection of the root of the sigmoid mesocolon off the retroperitoneal attachments by dissecting dorsal to the superior hemorrhoidal vessels (FIG 7A). Identify and preserve the left ureter (FIG 7B), gonadal vessels, and hypogastric nerves intact.
- Skeletonize the origin of the inferior mesenteric artery (IMA). Perform a high IMA transection (FIG 8A,B) as described earlier for the middle colic vascular pedicle.
- Perform a medial to lateral mobilization of the descending colon mesentery off the retroperitoneal attachments by sweeping the retroperitoneal tissues down (dorsally) with an energy device (FIG 9). This dissection is carried laterally to the lateral abdominal wall, superiorly separating the tail of the pancreas from the splenic flexure of the colon, and inferiorly to the pelvic inlet. This dissection greatly facilitates the lateral mobilization of the descending colon and the splenic flexure mobilization.

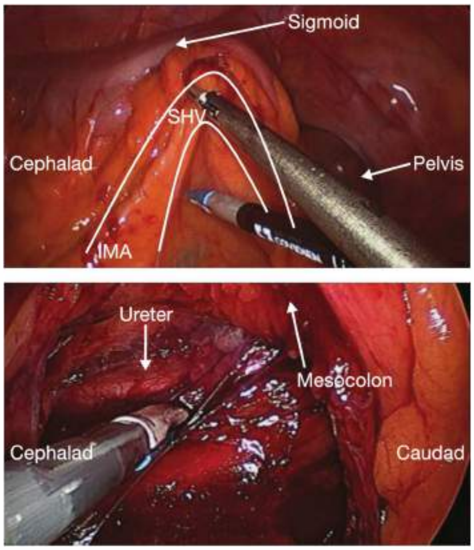

FIG 7 ● Dissection of the IMA and the superior hemorrhoidal vessels (SHV). **A.** The dissection starts at the root of the sigmoid mesentery, dorsal to the SHV. **B.** The retroperitoneal structures, including the left ureter, are swept down (dorsally) with the energy device, separating them for the mesocolon.

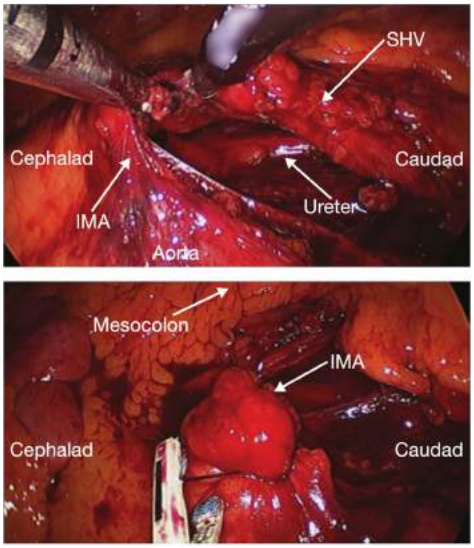

FIG 8 ● IMA transection. **A.** With the left ureter safe in the retroperitoneum, a high IMA transection is performed off the aorta with the energy device. **B.** The IMA stump is secured with an Endoloop.

- Divide the inferior mesenteric vein and the left colic artery by the ligament of Treitz with the energy device.
- Perform a lateral mobilization of the descending and sigmoid colon by transecting the white line of Toldt. The medial to lateral dissection plane is readily entered.
- Mobilize the splenic flexure of the colon by dividing the gastrocolic, splenocolic, and phrenocolic ligaments using an energy device. Care is taken to avoid injury to the pancreatic tail and to the spleen (**FIG 10**).

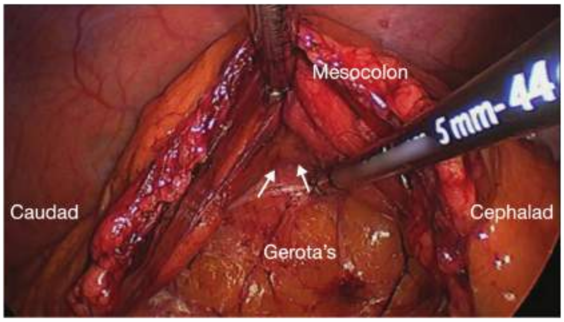

FIG 9 ● Medial to lateral mobilization of the descending colon. The descending mesocolon is separated from Gerota's fascia and other retroperitoneal structures. The dissection proceeds laterally until reaching the lateral abdominal wall. The dissection proceeds at the transition between the two distinctive fat planes *(arrows)*.

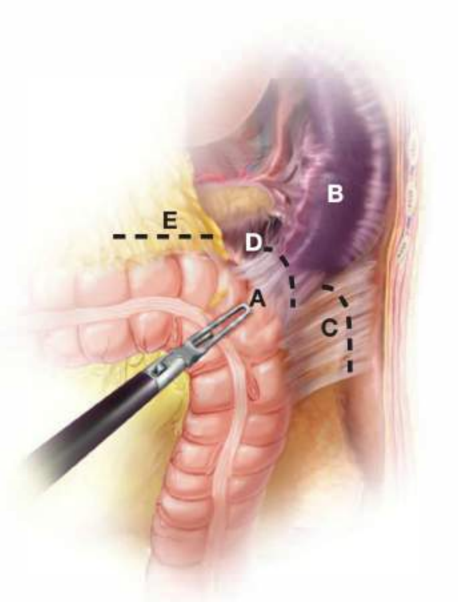

FIG 10 ● Mobilization of the splenic flexure. The splenic flexure *(A)* is separated off the spleen *(B)* by transecting the phrenocolic *(C)*, the splenocolic *(D)*, and the gastrocolic *(E)* ligaments using an energy device.

PROCTECTOMY AND TOTAL MESORECTAL EXCISION

- The surgeon stands on the patient's right side and cephalad to the assistant; the OR table is tilted to the right. The RLQ single port site allows for excellent exposure during the total mesorectal excision.
- Start with the posterior mobilization of the rectum by dissecting the presacral avascular plane. The dissection proceeds caudally in this plane to the level of the levator muscles while preserving the hypogastric nerves (**FIG 11**). Avoid penetrating the presacral fascia in order to avoid potentially serious bleeding from the presacral venous plexus.
- The lateral mobilization of the rectum is then performed by dissecting the lateral rectal attachments and dividing the lateral ligaments with the energy device. Care is taken to avoid penetrating the endopelvic fascia at the lateral pelvic walls, which could result in severe bleeding from injury to the hypogastric vein and its branches (**FIG 12**).
- At this point, mobilize the rectum anteriorly. Include into the specimen the anterior (Denonvilliers') fascia for mid- to low anterior rectal carcinoma while completing the dissection caudally to the levator muscles. Care is taken to avoid injury to the nervi erigentes, bladder, trigone, seminal vesicles, prostatic capsule, and urethra in males or the uterus and posterior vagina in females (**FIG 13**).
- The superior hemorrhoidal pedicle is divided with the energy device at the chosen distal rectal division site if a stapled coloproctostomy is planned.

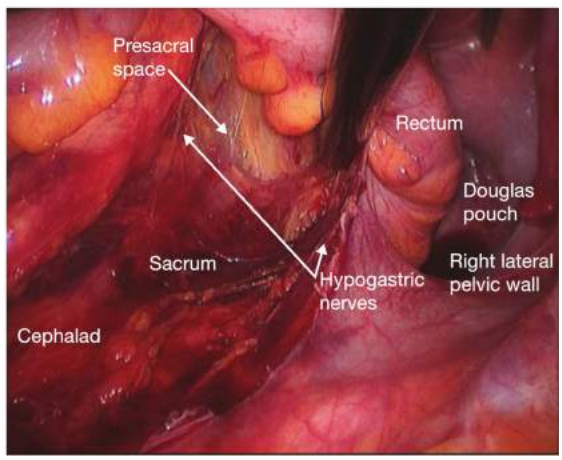

FIG 11 ● Posterior mobilization of the rectum. With the assistant retracting the rectum anteriorly, the presacral space is dissected with the energy device. The dissection proceeds caudally to the level of the levator muscles while preserving the hypogastric nerves. Avoid penetrating the presacral fascia in order to avoid potentially serious bleeding from the presacral venous plexus.

- The perineum may be pushed manually into the pelvis by the assistant surgeon. This maneuver may add another critical 2 cm to the distal rectal resection margin caudally.
- Intraoperative identification of the distal rectal resection site, either with preoperative anterior rectal wall tattoo

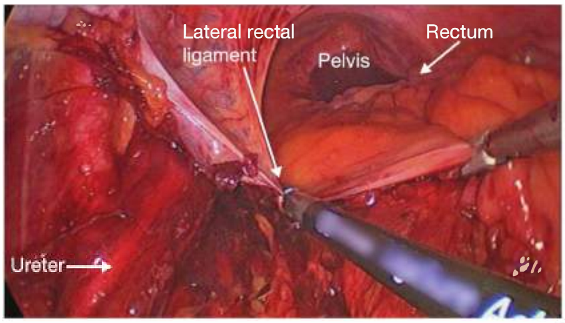

FIG 12 ● Lateral mobilization of the rectum. The lateral rectal ligaments (the left one is shown here) are transected with the energy device. Care is taken to avoid violating the endopelvic fascia along the lateral pelvic walls, which could lead to injury to the ureters and, more distally, the hypogastric vein and its branches. The latter could result in serious bleeding that is difficult to control.

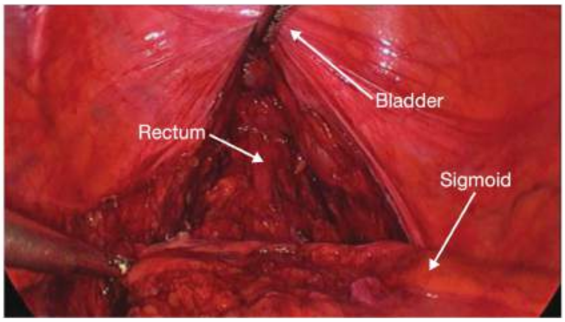

FIG 13 ● Anterior mobilization of the rectum. The dissection proceeds anterior to Denonvilliers' fascia, separating the rectum from the bladder, and more distally, from the seminal vesicles and prostate in men (shown here) or the vagina in females.

placement 2 cm distal to the carcinoma or with intraoperative proctoscopy, is necessary. Preoperative tattooing is particularly helpful in cancer patients that had a complete response to neoadjuvant therapy.

- In case of a distal rectal division at the level of the dentate line with the intention of a stapled coloproctostomy, an Endo GIA laparoscopic stapler is used either via the single port site at the RLQ or by placing a suprapubic 12-mm port and stapling the rectum vertically via that site.
- A vertical stapling of the rectum via a suprapubic port (**FIG 14A,B**), especially in males or patients with narrow pelvis, may prevent from usage of multiple overlapping Endo GIA loads for the rectal division, which lowers anastomotic leak rates. The suprapubic port may be used for placement of the low pelvic Jackson-Pratt drain at the end of the case.
- If a hand-sewn anastomosis is planned, then the dissection is carried to the levator muscle/dentate line with care to obtain an adequate negative radial mesorectal margin.

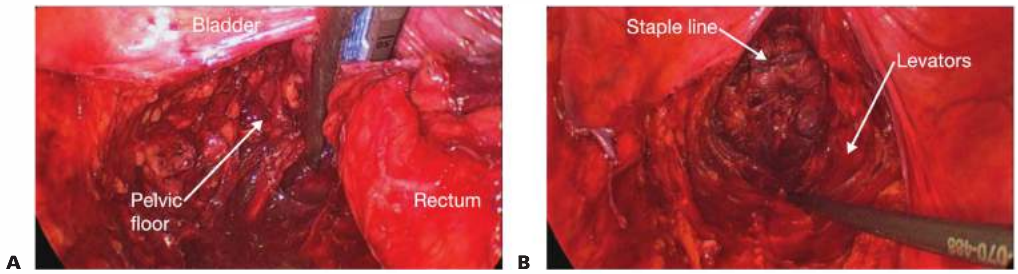

FIG 14 ● Distal rectal transection. **A.** When a stapled coloanal anastomosis is planned, the distal rectum is stapled from an anterior to posterior direction above the dentate line. This technique avoids the need for multiple stapler fires, reducing anastomotic leak rates. **B.** After resection of the rectum, the staple line can be seen in the distal pelvis at the level of the pelvic floor.

TRANSANAL SINGLE-PORT TOTAL MESORECTAL EXCISION: THE NARROW PELVIS

- The surgeon is now seated between the patient's legs, with the patient on Trendelenburg position. A back table with instruments for the perineal portion of the procedure is used.
- The surgeon may use a Mayo tray placed on his or her knees and a headlight.
- In case of a planned hand-sewn coloanal or ileoanal pouch anastomosis, a Lone Star retractor may be placed in the anus for exposure.
- In case of neoplasia, the rectum proximally to the dentate line is obliterated with a mucosal 0-Vicryl or 2-0 PDS purse-string suture (**FIG 15**). A full-thickness division of

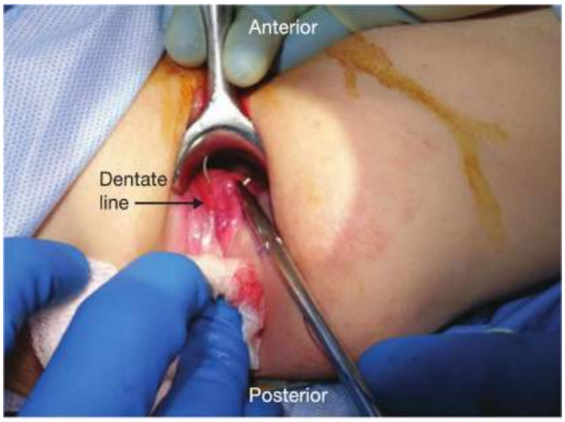

FIG 15 ● Transanal single-port total mesorectal excision. In case of neoplasia, the rectum proximally to the dentate line is obliterated with a mucosal 0-Vicryl or 2-0 PDS purse-string suture.

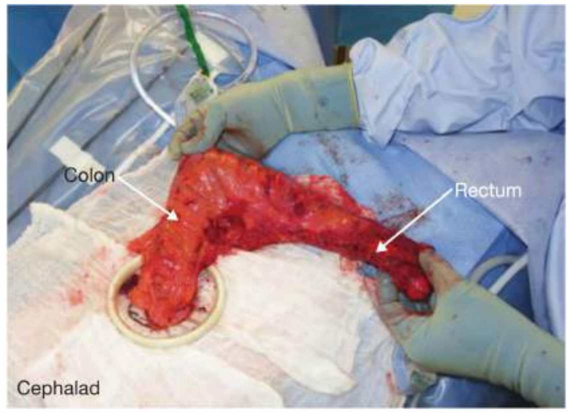

FIG 17 ● Extracorporeal mobilization of the specimen. The colon and rectum may be extracted via the RLQ abdominal single port site with the wound protector in place.

the rectum at the level of the dentate line is performed with electrocautery, with care not to injure the internal sphincter muscle (**FIG 16**).

- If the pelvic total mesorectal excision is adequate caudally, then the rectum is freed up and the colon and rectum may be extracted either via the RLQ abdominal single port site with the wound protector in place (**FIG 17**) or via the anus. The specimen is divided at the level of the terminal ileum/ileocecal valve with a linear stapler.
- If the rectum is still adherent in the inner pelvis secondary to a narrow/deep pelvis precluding further laparoscopic dissection transabdominally, then a Transanal Minimally Invasive Surgery (TAMIS) laparoscopic single port is inserted in the anus after placement of the purse-string rectal lumen obliteration and the division of the rectum at the dentate line is completed (**FIG 18A,B**). This allows for excellent visualization in the distal narrow pelvis.
- Pneumoperitoneum CO_2 to 15 mmHg is insufflated via the transabdominal and pneumopelvis via the transanal single port; you will need two insufflators.
- Using the transanal single port, a 30-degree 5-mm laparoscopic camera, a 5-mm laparoscopic grasper, and the same laparoscopic energy device (**FIG 19**), we proceed with the completion of the total mesorectal division with a circumferential caudal to cephalad direction. The endpoint of the dissection is accomplished by meeting the transabdominal distal dissection site in the inner pelvis (**FIG 20**).

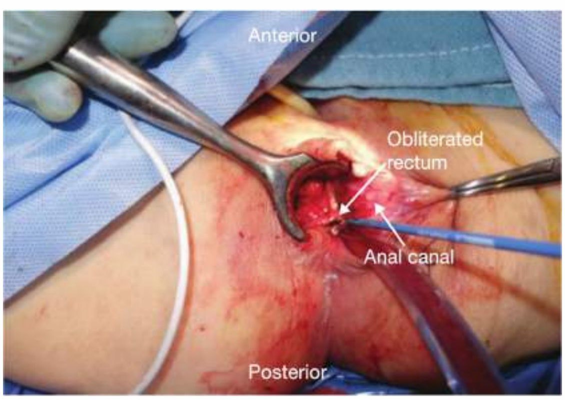

FIG 16 ● Transanal single-port total mesorectal excision. A full-thickness division of the rectum at the level of the dentate line is performed with electrocautery. In this picture, the dissection is proceeding right lateral to the obliterated distal rectum and the distal rectal wall.

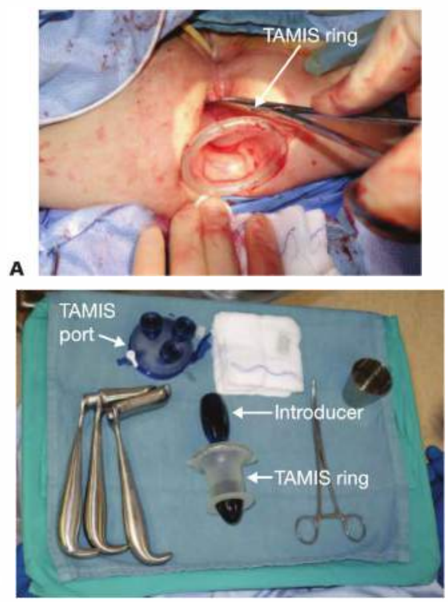

FIG 18 ● Transanal single-port total mesorectal excision: transanal insertion of the TAMIS port. **A.** The TAMIS ring is introduced first, followed by application of the TAMIS port. **B.** The multichannel TAMIS port is assembled on a side table prior to insertion into the anus.

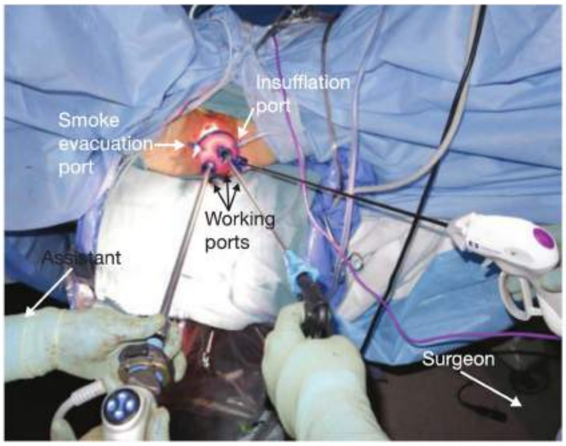

FIG 19 ● Transanal single-port total mesorectal excision. The surgeon operates with an energy device and a grasper while the assistant operates the camera.

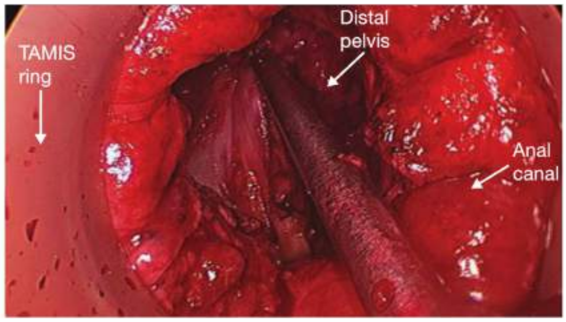

FIG 20 ● Transanal single-port total mesorectal excision. The dissection is carried through the TAMIS port into the distal pelvis until the distal dissection planes from the transabdominal phase of the operation are reached.

- Upon completion of the transanal single port dissection, the specimen is extracted as described earlier. If the specimen is too thick, then elongate the circular incision superiorly using an Army-Navy to "hook" under the fascia protecting the wound protector from perforation. Use a no. 11 scalpel in a sawing move or electrocautery to elongate the incision; extract the specimen, divide it at the terminal ileum, and send it to pathology.
- The transanal single port is removed and an anal canal mucosectomy may be performed as indicated (such as in ulcerative colitis with involvement of the anoderm) by elevating the anoderm with a submucosal injection of Marcaine with epinephrine and performing a sharp excision anal mucosectomy with scalpel or scissors.

ILEOANAL POUCH FORMATION AND J-POUCH ILEOANAL ANASTOMOSIS

- Following division of the terminal ileum at the level of the ileocecal valve with a linear GIA blue load stapler, the ileal pouch is fashioned.
- Place wet lap sponges around the abdominal wound protector and use a second towel for the instruments used for creation of the pouch formation in order to avoid fecal contamination to the laparoscopic surgical drapes.
- Fold the distal 30 cm of terminal ileum in the shape of a J; a pouch length of 15 cm is usually adequate (**FIG 21**). Use a linear GIA stapler 100-mm blue load (double line) or 75-mm blue (triple line) or, if already opened and used, the Endo GIA laparoscopic triple line 60-mm stapler (blue load for Ethicon or tan load for Covidien staplers) to create the pouch.
- Insert the stapler via the antimesenteric border of the terminal ileum at the tip of the J-pouch and fire the loads (usually two loads with the 100-mm linear stapler) in an antimesenteric side-to-side fashion. Inspect the inside of the pouch for bleeding.
- If a stapled anastomosis is planned, place a 28- to 29-mm circular stapler anvil into the tip of the pouch and secure it with a 3-0 Prolene purse string.
- Reintroduce the pouch into the abdomen and place it into the inner pelvis with the pouch mesentery facing posteriorly. Reinsufflate the pneumoperitoneum via the abdominal single port and perform a circular stapled ileal pouch-anal anastomosis (**FIG 22A,B**). Two intact doughnuts should be obtained.
- Test the integrity of the anastomosis by insufflating the pouch under saline immersion. If a major anastomotic leak is noted, 2-0 Vicryl or 2-0 PDS sutures maybe placed transanally using a Hill Ferguson or a Sims Parks retractor. The air leak test may be repeated as discussed earlier to confirm resolution of the leak.
- If a hand-sewn anastomosis is planned, then place a purse string to close the tip of the pouch in order to

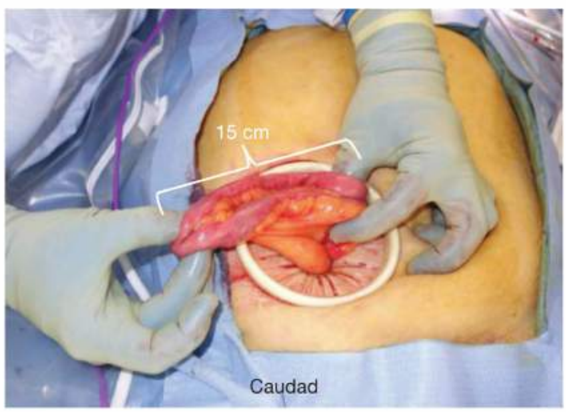

FIG 21 ● Creation of the J-pouch. After delivering the distal 30 cm of terminal ileum through the SILS port site (with the wound protector in place), the ileum is folded in the shape of a "J." The J-pouch will then be created with a 100-mm stapler (usually two loads are needed) inserted via the antimesenteric border of the terminal ileum at the tip of the J-pouch.

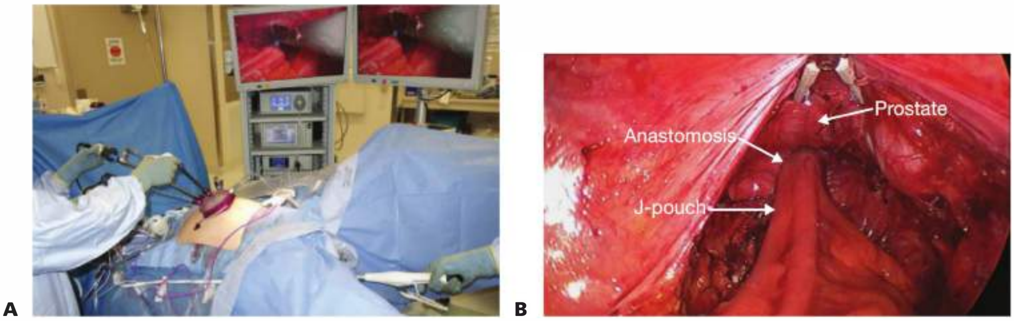

FIG 22 ● Creation of the stapled J-pouch ileoanal anastomosis. **A.** After reintroducing the J-pouch with the anvil in its tip into the abdomen, the pneumoperitoneum is reinsufflated. With an experienced assistant introducing the 28mm end-to-end anastomosis (EEA) stapler transanally and the scrub nurse holding the camera, the surgeon mates the anvil to the stapler's opened torch intracorporeally, as seen in the OR monitors. **B.** After firing the stapler, the anastomosis is now completed. The J-pouch, its mesentery (posteriorly located along the sacrum), and the tension-free anastomosis can be seen here.

prevent soilage in the pelvis. Place the pouch into the inner pelvis with the pouch mesentery facing posteriorly toward the sacrum. The pouch should reach to outside of the anal canal (**FIG 23**). Perform a hand-sewn ileo-anal pouch anastomosis using the Lone Star retractor for exposure (a 2-0 Quill double ended may be used alternatively) using 2-0 Vicryl or 2-0 PDS in interrupted full-thickness fashion, incorporating the internal sphincter muscle and the anoderm at the level of the dentate line (**FIG 24**).

- A Surgicel hemostatic agent may be placed into the anus following completion of the anastomosis.
- A 19-Fr Jackson-Pratt circular drain, placed posteriorly to the pouch with the tip superiorly to the anastomosis, is brought via the suprapubic port site and is placed on bulb suction.

FIG 23 ● Hand-sewn J-pouch ileoanal anastomosis. The pouch should reach to outside the anal canal.

FIG 24 ● Hand-sewn J-pouch ileoanal anastomosis. The completed anastomosis is seen here.

ILEOANAL POUCH ANASTOMOSIS: THE POUCH WILL NOT REACH!

- Perform mesenteric J-pouch serosal dissections.
- Perform mesenteric pouch "windows" by dividing the afferent or efferent mesenteric vessels. Consider the risk for pouch ischemia-necrosis.
- Perform mesenteric ileal serosal dissections laparoscopically up to the origin of the superior mesenteric artery.

DIVERTING LOOP ILEOSTOMY

- Remove the abdominal wound protector and bring a loop of terminal ileum proximal to the afferent limb of the pouch.
- It is advised to place an antiadhesive sheet posterior to the ileostomy fascia edges.
- Mature the loop ileostomy with the proximal limb in a Brooke's fashion and the distal limb as a mucous fistula (**FIG 25**) and place an ileostomy appliance.
- The patient has no wound for approximation!

FIG 25 ● The abdomen after the completed SILS restorative proctocolectomy with J-pouch ileoanal anastomosis and protective temporary diverting loop ileostomy. The temporary ileostomy is constructed at the SILS port site.

PEARLS AND PITFALLS

Preoperative workup	■ Correct identification of the underlying pathology allows for careful selection of the laparoscopic single-incision restorative proctocolectomy technique.
Patient positioning, laparoscopic instruments, surgeon assistant position	■ Securing the patient's position, OR table tilting, single port rotation, and usage of instruments and camera with bariatric length are necessary for a laparoscopic single-incision surgery. Surgeon should change his or her position in relation to the assistant several times during the procedure in order to achieve adequate exposure and visualization.
Laparoscopic instrument tissue handling	■ The tips of the assisting and dominant laparoscopic instruments are positioned as close as possible to each other in the surgical field in order to avoid hand conflict outside the abdomen.
Insertion of the SILS port	■ May use the new temporary loop ileostomy site at the RLQ. Alternatively, an umbilical or suprapubic site may be chosen.
Will the pouch reach?	■ Preoperative evaluation is essential. Intraoperative laparoscopic single port evaluation and surgical approach may be challenging.
Difficult dissection in the distal narrow pelvis	■ Consider the ta-TME technique.
Distal rectal division	■ Divide the rectum on an anterior to posterior direction with a linear reticulating stapler inserted via the suprapubic port. Use this port site to bring a Jackson-Pratt pelvic drain out at the end of the case.

POSTOPERATIVE CARE

- A fast-track postoperative laparoscopic pathway is initiated.
- The orogastric tube is discontinued in the OR upon completion of the procedure.
- IV acetaminophen alvimopan and opioid patient-controlled anesthesia (PCA) is used as per surgeon's preference the day of surgery, with the goal of discontinuing the PCA within 36 hours and adding IV or oral nonsteroidal antiinflammatory drugs (NSAIDs), such as ketorolac, and transition to oral analgesics.
- Ice chips/water diet is introduced the day of surgery with the goal to advance to clear liquids within 24 hours and to regular high-fiber diet within 48 hours postoperatively.
- The Foley catheter is kept until the third postoperative day secondary to the risk for urinary retention from the pelvic surgery/hypogastric nerves manipulation.
- Perioperative antibiotics, pharmacologic venous thromboembolism protocol, incentive spirometry, and early ambulation are initiated the day of surgery.
- Wound care need is minimal. If the umbilicus is used for the single port entry, umbilical skin edges are tucked with Vaseline/Adaptic gauze and cotton, which is removed in 48 to 72 hours. If the ileostomy site is used for single port entry, there is no abdominal wound.
- Surgicel is removed from the anus after 24 hours and the anastomosis is inspected for bleeding.
- The patient usually can be safely discharged home within 72 hours when passage of flatus/succus is documented from the ileostomy and a regular diet is tolerated by at least two consecutive meals and there are no other adverse postoperative findings.
- No weight lifting of more than 20 lb is recommended for 4 to 6 weeks postoperatively in order to avoid incisional hernia.

OUTCOMES

- Single-port laparoscopic restorative proctocolectomy is considered to be an equally safe and cost-effective technique with excellent cosmesis, similar morbidity and operative time, possible less postoperative pain and faster return to full activities, possible shorter hospital stay, and comparable oncologic outcomes when performed for neoplastic diseases to conventional hand-assisted or multiport laparoscopic approach.
- It is achieved with equipment that the hospital already has available and requires no additional training for the operative room personnel.
- It is feasible by surgeons who perform advanced laparoscopy.
- It does require one assistant who has advanced laparoscopic skills for camera handling.
- The laparoscopic single-incision restorative proctocolectomy technique may therefore contribute to decreased total hospital cost.

COMPLICATIONS

- The procedure has similar morbidity and mortality and comparable rates for conversion to laparotomy with conventional laparoscopy.
- The single-incision laparoscopic technique for restorative proctocolectomy has the option for conversion to multiport or hand-assisted laparoscopy.
- Mobilizing/elongating the small intestinal mesentery for an ileoanal anastomosis may be challenging laparoscopically.
- The ileal pouch may not reach the perineum. In these cases, an end ileostomy is needed.
- It may require a longer operative time during the learning curve of the surgeon; this can complicate an already challenging procedure.
- Elongating the ileostomy site single port incision for specimen extraction with fascial reapproximation prior to the ostomy maturation may increase the incidence of parastomal hernia rate.
- It is intrinsically a one-operating surgeon technique with less involvement of the assistant surgeon and a potential impact on resident education during the learning curve period.

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Chapter 38 Restorative Proctocolectomy: Hand-Assisted Laparoscopic Surgery Ileal Pouch-Anal Anastomosis

Robert R. Cima

DEFINITION

- An ileal pouch-anal anastomosis (IPAA) is a restorative procedure used when the entire colon and rectum needs to be removed and the patient wishes to avoid a permanent ileostomy. The two most common indications for IPAA are chronic ulcerative colitis (CUC) and familial adenomatous polyposis (FAP) syndrome. Although the procedure is basically the same, the frequency and indications for surgery are different, and for the purposes of this chapter, the focus will be on the surgical treatment of CUC.[1]
- IPAA involves removal of the entire colon and rectum followed by construction of an ileal reservoir most commonly in a "J shape" that is anastomosed to the anal canal by either a stapled or hand-sewn technique.
- This maintains the normal route of defecation, although the frequency and consistency of the stool is different than normal bowel function.

DIFFERENTIAL DIAGNOSIS

- Primarily, CUC needs to be distinguished from Crohn's colitis. This is particularly important, because a restorative IPAA is not recommended in Crohn's disease patients.
- Other acute colitis syndromes (i.e., toxic bacterial colitis, cytomegalovirus [CMV] colitis, ischemic colitis) can mimic CUC. Thus, a thorough workup to differentiate between CUC and other disease processes needs to be considered prior to surgery.
- A detailed review of the patient's disease course including past endoscopic findings, prior imaging studies, and any history of perianal disease needs to be evaluated. Any history of small bowel inflammation or perianal abscesses, fistulas, or fissures is highly suggestive of underlying Crohn's disease.

FIG 1 ● CT enterography (coronal view, venous phase). Severely inflammed distal colon in a CUC patient with normal appearing small bowel.

- In patients with an established history of CUC presenting with an acute worsening of their symptoms, it is important to rule out an infectious cause such as *Clostridium difficile* or CMV colitis as the *cause* of their disease exacerbation.

PATIENT HISTORY AND PHYSICAL FINDINGS

- CUC is characterized by recurrent episodes of bloody diarrhea associated with urgency and tenesmus.
- Approximately 15% of patients will present initially with fulminant disease, characterized by high-volume bloody diarrhea, severe abdominal distension and pain, fever, and systemic signs of illness. In severe situations, the patient might have peritonitis as the result of colonic perforation or hemodynamic compromise from volume depletion and systemic inflammation.
- More commonly, the CUC patient with medically refractory disease will not have any characteristic physical findings. However, prolonged disease activity can be associated with poor overall nutritional status and significant weight loss.

IMAGING AND OTHER DIAGNOSTIC STUDIES

- Computed tomography (CT) enterography is the most commonly used imaging study in CUC patients (**FIG 1**). The use of intravenous (IV) contrast is essential to highlight intestinal inflammation and helps identify any evidence of small bowel inflammation, which is highly suggestive of Crohn's disease.
- In active CUC, the CT will demonstrate inflammatory changes around the involved colon with thickening of the colonic wall. This inflammation usually starts in the rectum and extends proximally into the colon for a varying distance.
- Endoscopic imaging of the colon is essential (**FIG 2**). It should demonstrate continuous inflammation from the rectum for a variable distance, extending proximally into the colon. Evidence of discontinuous mucosal inflammation is worrisome for an underlying diagnosis of Crohn's disease.

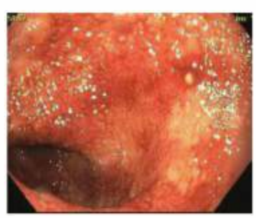

FIG 2 ● Colonoscopy shows diffuse severe inflammation and friable mucosa, with a loss of the vascular appearance of the colon, erythema, hemorrhage, and inflammatory pseudopolyps.

SURGICAL MANAGEMENT

- Frequently, an IPAA for the treatment of CUC is performed in stages, depending on the patient's overall health at the time of surgery or the indications for surgery.
- The primary indications for surgery are toxic or fulminant disease activity, medically refractory disease, and/or evidence of dysplasia/malignancy.
- In an emergency situation, or in an ill patient on multiple immunosuppressive medications, the first operation is a subtotal colectomy with an end ileostomy.
- Once the patient recovers his or her health, a completion proctectomy with IPAA and diverting ileostomy may be performed. At the last operation (the third stage), the ileostomy is reversed.
- In outpatients with mild disease that are coming to surgery, the total proctocolectomy with IPAA and diverting loop ileostomy may be performed at a single operation.
- In some institutions, the diverting loop ileostomy may be routinely omitted, depending on a number of patient- and procedure-specific factors. However, the majority of centers recommend use of a temporary diversion.

PATIENT PREPARATION PRIOR TO SURGERY

- After a detailed discussion regarding the risks, alternatives, benefits, and expected outcomes from the IPAA, the patient should see a certified wound, ostomy, and continence nurse (WOCN) for preoperative education and appropriate site marking for a temporary diverting loop ileostomy. Many patients are provided with a mechanical bowel preparation with oral antibiotics. This is an optional step as there is mixed data as to the necessity of such preparation. An alternative approach would be to perform a tap water enema the morning of surgery to clear the distal colon and rectum. All patients are provided with antimicrobial soap (Hibiclens™) to shower with the night prior to surgery and the morning of surgery.

PATIENT INDUCTION AND POSITIONING

- Prior to the induction of anesthesia, the patient is given 5,000 units of heparin subcutaneously and sequential compression devices are placed on the lower extremities. The patient is positioned supine on the operating table lying on an upper body gel pad to minimize movement during operating room (OR) position changes. Once induction of anesthesia is complete, an orogastric tube is placed. An indwelling urinary catheter is placed using sterile technique.
- Once all necessary IV access is secured, the patient is repositioned in a modified lithotomy position (**FIG 3**). The heels are firmly planted on the stirrups to avoid pressure along the calves and the lateral peroneal nerves. The thighs are placed parallel to the ground to avoid conflict with the surgeon's arms and instruments during the procedure.
- Both arms are wrapped in gel pads and the patient's right arm is placed next to his or her side and secured in position by positioning of an acrylic toboggan. The left arm is placed on an arm board positioned straight outward (**FIG 3**). Alternatively, both arms may be placed at the patient's side, but this will impede access to the arms during the procedure in case the anesthesia team needs to intervene. A chest strap is applied to minimize the risk of the patient shifting on the operating table during frequent position changes during the procedure. A forced warm air warming device is placed on the chest and over the left arm is positioned outward.
- The abdominal wall skin is prepared with a chlorhexidine–alcohol mixture after the perineum has been scrubbed and painted with a Betadine–iodine skin preparation kit. The patient is then draped in a fashion that allows access to the entire abdomen and perineum (**FIG 4A**).
- Video monitors should be placed directly off of the patient's left and right shoulders. If a monitor is available on a boom and it can be positioned over the patient's head which facilitates the dissection in the midportion of the patient's upper abdomen. The scrub nurse should have his or her instruments positioned over the patient's chest and head and he or she should stand on the patient's left side above the outward-positioned left arm (**FIG 4B**). The surgeon will stand between the patient's legs for the hand-assisted laparoscopic mobilization and resection of the abdominal colon. The first assistant/camera operator will initially stand on the patient's right side (**FIG 5**).
- Prior to incision, Surgical Care Improvement Project (SCIP)–compliant antibiotics are administered and documented. A procedural pause is performed, confirming the patient identity, procedure, position, antibiotic administration, allergies, and special equipment needs.

FIG 3 ● Patient positioning. The patient is on a modified lithotomy position with the thighs parallel to the ground to avoid conflict with the surgeon's elbows and instruments. The left arm is placed laterally on an arm board for access by the anesthesia team during the operation. The patient is strapped to the Yellofin stirrups and taped to the table across the chest to avoid sliding during the procedure.

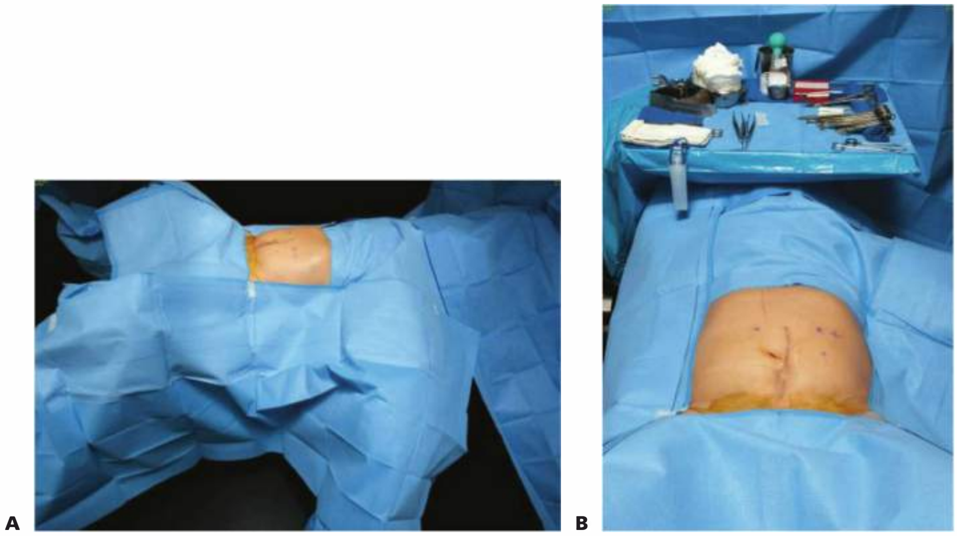

FIG 4 ● **A.** Field setup. The patient is draped in a fashion that allows access to the entire abdomen and perineum. **B.** Field setup. The scrub nurse sets his or her instruments positioned over the patient's chest and head.

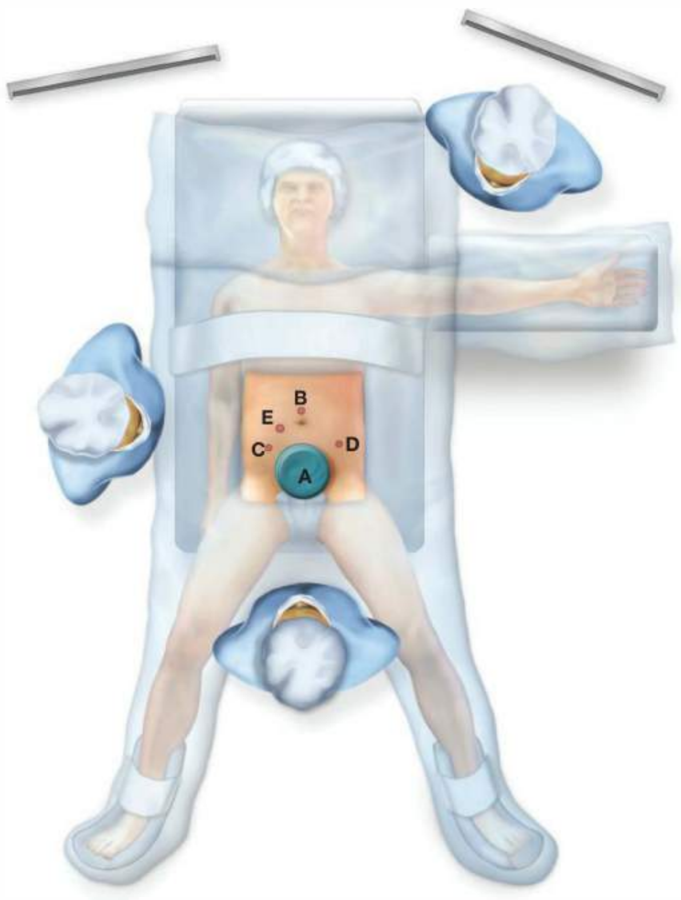

FIG 5 ● Team and monitors setup. The surgeon stands between the patient's legs for the hand-assisted laparoscopic mobilization and resection of the abdominal colon. The first assistant/camera operator stands on the patient's right side. The scrub nurse stands on the patient's left side above the outward-positioned left arm. The monitors are positioned above the right and left shoulders.

INCISION AND TROCAR PLACEMENT

- A midline incision is marked on the patient's abdomen from the pubis to the xiphoid process in case emergent entry into the abdomen is required. In men, our preferred incision for the hand port is a 7-cm lower midline incision starting 1.5 cm above the pubic bone. In women, we prefer a 7-cm Pfannenstiel incision centered on the midline 1.5 cm above the pubis. If a prior midline or Pfannenstiel incision exists, we will use that incision.[2,3]
- The hand-port incision is made and the abdomen is entered under direct vision. With the surgeon's hand in the abdomen through the primary incision, a small 5-mm incision is made in the upper aspect of the umbilicus and a nonbladed 5-mm trocar is guided into the abdomen with the surgeon's hand protecting the abdomen content form inadvertent injury. Next, the hand access device is placed in the lower abdominal incision and pneumoperitoneum is established.
- Under laparoscopic visualization, a 5-mm nonbladed trocar is placed in the left lower abdomen and another in the right lower abdomen. Usually, the best location is 2 to 2.5 cm medial and 1 cm inferior to the superior iliac crest (**FIG 6**).

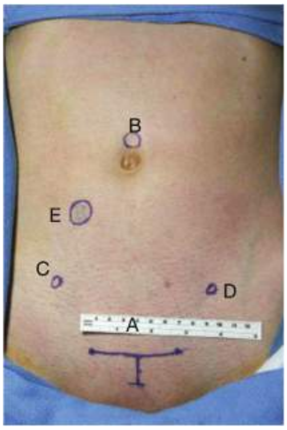

FIG 6 ● Port placement. The hand port will be placed through a 7-cm Pfannenstiel incision *(A)*. Three 5-mm ports are placed for the camera (supraumbilical, *B*) and instruments (right and left lower abdomen, *C,D*). The diverting ileostomy site *(E)* is marked in the right lower quadrant.

MOBILIZATION OF THE LEFT COLON

- The patient is placed in steep Trendelenburg position with left side up. The surgeon stands between the legs and the camera operator is on the patient's right side. A 5-mm camera is placed through the supraumbilical trocar. The surgeon places his or her left arm through the hand-port device and uses the left lower quadrant trocar for his or her dissecting scissors (**FIG 7**). The surgeon uses his or her hand to push the small bowel into the right lower quadrant and to lift the omentum into the upper abdomen. The left colon is then grasped and pulled medially and anteriorly. The camera is used to look over the surgeon's hand into the left abdomen.
- The surgeon starts dissecting from the mid- to lower sigmoid and works upward toward the splenic flexure while maintaining medial retraction of the left colon. The dissecting scissors attached to monopolar cautery are used to incise the peritoneal lining about 1 cm lateral to the edge of the colon (**FIG 8**). A common mistake is to incise too far laterally from the colon in what appears to be a "natural" plane. The surgeon should move in a cephalad direction along the entire left colon in a continuous fashion upward toward the spleen while maintaining medial traction (**FIG 9**).

FIG 7 ● Finalized setup. The surgeon stands between the patient's legs with his or her left hand in the abdomen and his or her right hand controls the dissecting scissors for the mobilization of the left colon. The assistant operates the camera from the right side of the table.

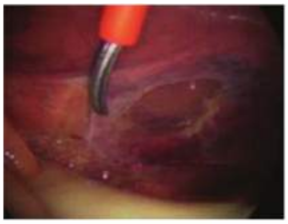

FIG 8 ● Mobilization of the left colon. The lateral peritoneal attachments are incised about 1 cm lateral to the edge of the colon while the surgeon's hand retracts the colon medially.

- The mesentery of the left colon is then dissected off the retroperitoneum (anterior to Gerota's fascia) in a lateral to medial direction. Care is taken to identify the left ureter and gonadal vessels, which should be preserved intact in the retroperitoneum.

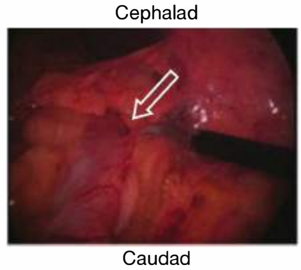

FIG 9 ● Mobilization of the left colon. The lateral dissection is continued in a cephalad direction until reaching the splenic flexure *(arrow)*.

SPLENIC FLEXURE MOBILIZATION AND MESENTERY DIVISION

- Once the left colon mesentery is mobilized medially toward the lateral border of the aorta, the patient is placed in steep reverse Trendelenburg position. The surgeon retracts the upper left colon medially to see the back portion of the splenic flexure as it attaches to Gerota's fascia. Using the dissecting scissors attached to monopolar cautery, the phrenocolic is divided as the surgeon retracts the flexure medially and downward toward the right lower quadrant (**FIG 10**).

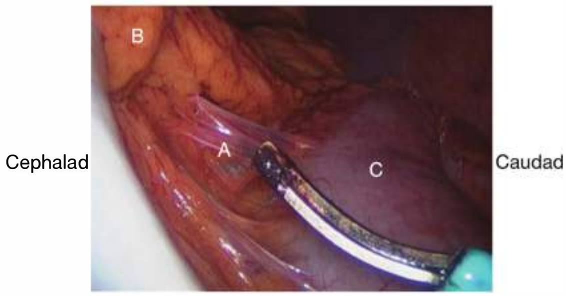

FIG 11 ● Exposure of the gastrocolic ligament. The surgeon exposes the gastrocolic ligament *(A)* by retracting the omentum *(B)* in a cephalad direction with his or her left hand while the assistant retracts the transverse colon *(C)* in a caudad direction.

- To further free up the splenic flexure of the colon, the gastrocolic ligament, exposed by retracting the omentum in a cephalad direction with the left hand (**FIG 11**), is transected at the midline, entering the lesser sac (**FIG 12**). The gastrocolic ligament is then transected from medial to lateral, toward the splenic flexure of the colon, until

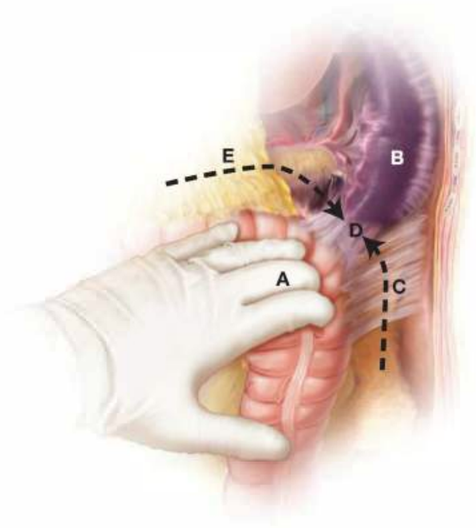

FIG 10 ● Mobilization of the splenic flexure. The surgeon retracts the splenic flexure of the colon *(A)* downward and medially, exposing the attachments of the flexure to the spleen *(B)*. The phrenocolic *(C)* and splenocolic *(D)* ligaments are transected in an inferior to superior and lateral to medial direction. The gastrocolic ligament *(E)* is transected in a medial to lateral direction, until both planes of dissection meet and the splenic flexure is fully mobilized.

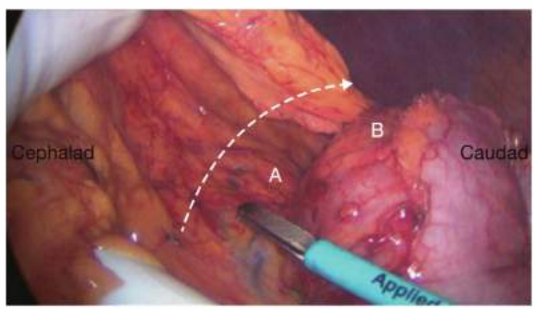

FIG 12 ● Transection of the gastrocolic ligament allows for entrance into the lesser sac, exposing the tail of the pancreas **(A)**. While holding the omentum in a cephalad direction, the gastrocolic ligament is transected in a medial to lateral direction *(arrow)* toward the splenic flexure of the colon **(B)**, until the precious dissection plane is encountered and the splenic flexure of the colon is fully mobilized.

the previous dissection plane around the flexure is encountered (**FIG 12**). At this point, the splenocolic ligament is easily visualized and transected (**FIG 13**).

- Once the splenic flexure is fully mobilized, a 5-mm vessel-sealing device is placed through the left lower quadrant port, replacing the scissors, and the transverse colon mesentery is divided. Once the flexure mesentery is divided, the left colon mesentery and what remains of the gastrocolic ligament are divided (**FIG 14**) while working toward the hepatic flexure. To ensure that the small bowel mesentery is not divided, the surgeon's hand is used to control the colon mesentery while pushing the small bowel mesentery away below the hand.

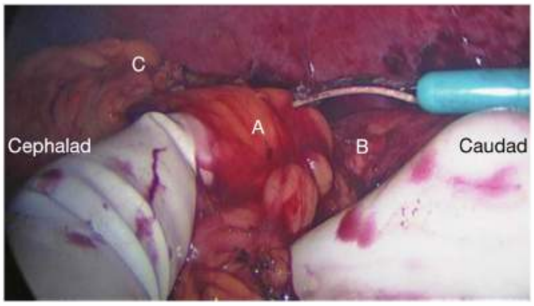

FIG 13 ● Completing the splenic flexure mobilization. After the superior to inferior and the medial to lateral dissection planes meet around the splenic flexure of the colon, the splenocolic ligament *(A)* is easily exposed between the colon *(B)* and the spleen *(C)* and is transected.

FIG 14 ● After the splenic flexure has been mobilized, the transverse colon mesentery is divided, proceeding from the splenic toward the hepatic flexure *(arrow)*, with an energy device.

HEPATIC FLEXURE AND RIGHT COLON MOBILIZATION

- Once the dissection of the transverse colon mesentery has proceeded past the midline of the abdomen, the camera assistant moves to the patient's left side. The patient is kept in reverse Trendelenburg but is placed with the right side up. The surgeon places his or her left hand through the hand access device and uses the dissecting scissors attached to monopolar cautery through the right lower quadrant port. The surgeon's left hand is used to retract the hepatic flexure downward and toward the left lower quadrant (**FIG 15**), exposing the hepatocolic ligament. This ligament is transected with scissors. Once incised, the surgeon's index finger is placed under the lateral peritoneal attachments of the right colon and the dissection is started downward along the lateral edge of the right colon (**FIG 16**). All the while, the surgeon is placing firm and constant traction on the colon toward the left lower quadrant. This action literally peels the right colon and its mesentery off of the retroperitoneum.
- The dissection is carefully continued medially toward the duodenum. The filmy attachments of the colon mesentery are divided off of the anterior wall of the duodenum, the head of the pancreas, and Gerota's fascia (**FIG 17**).
- Once the right colon mesentery is completely mobilized, the 5-mm vessel-sealing device is placed through the right lower quadrant trocar and the hepatic flexure

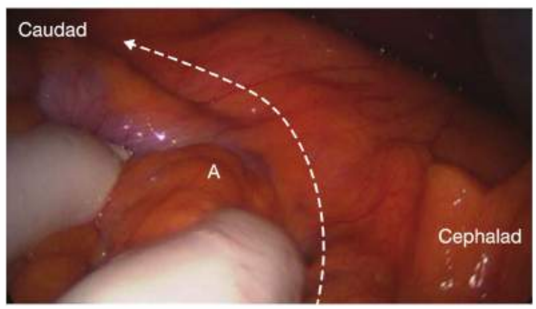

FIG 16 ● While retracting the hepatic flexure of the colon *(A)* with the hand, the hepatocolic ligament and the lateral peritoneal attachments of the right colon are transected in the direction shown *(arrow)*.

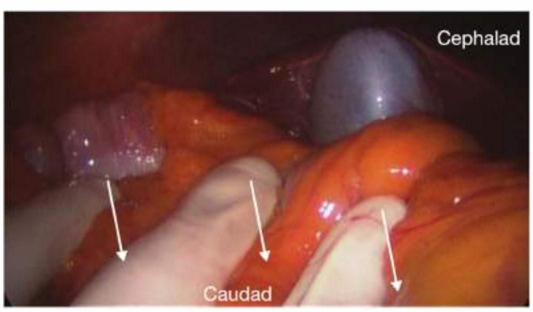

FIG 15 ● The surgeon pulls the hepatic flexure of the colon downward and toward the left lower quadrant of the abdomen *(arrows)*.

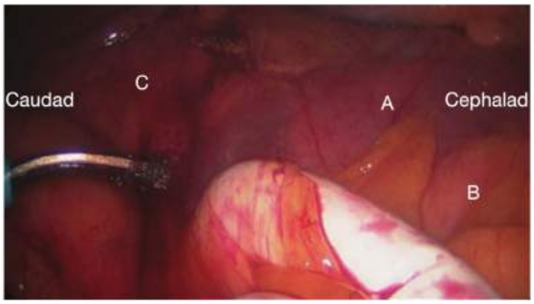

FIG 17 ● Mobilization of the right colon off the retroperitoneum. The right mesocolon is dissected off the duodenum *(A)*, head of the pancreas *(B)*, and Gerota's fascia *(C)*.

mesentery is divided, progressing from right to left. To facilitate this dissection, the surgeon's left hand grabs the transverse mesentery from where the previous mesenteric division was performed. The surgeon places his or her fingers behind the mesentery while the thumb is anterior to the mesentery. The fingertips are near the hepatic flexure mesentery and these are used to facilitate the movement of the vessel-sealing device as it traverses the mesentery from right to left, eventually completing the division of the transverse colon mesentery.

- Once the hepatic flexure and transverse colon mesentery are divided, the entire colon and distal small bowel can be exteriorized through the hand access port site with the wound protector in place (**FIG 18**). The right colon mesentery is divided under direct vision close to the colon wall, thus preventing any injury to the ileocolic vessel and the right-sided marginal arterial arcade. This is critical to ensure good antegrade blood supply to the J-pouch to be constructed later.
- The terminal ileum is divided using a linear stapling device about 1 to 2 cm proximal to the ileal–cecal valve. The distal sigmoid colon is divided with a stapling device. The abdominal colon is sent to pathology to confirm the diagnosis of ulcerative colitis.
- To facilitate pouch placement in the pelvis, the small bowel mesentery needs to be mobilized off of the retroperitoneum. Once the abdominal colon is removed, the small bowel is returned to the abdomen and the pneumoperitoneum is reestablished. The surgeon with his or her left hand in the abdomen places his or her hand under the small bowel mesentery and pushes it up and to the left upper quadrant. Using the dissecting scissor from the right lower quadrant trocar, the mesentery is dissected off of the retroperitoneum and duodenum. If needed, this dissection can be carried out up over the pancreas to the origin of the superior mesenteric vessels.

FIG 18 ● Extracorporeal delivery of the colon and terminal ileum.

OPEN PROCTECTOMY THROUGH THE HAND ACCESS DEVICE

- The patient is leveled from a right to left perspective and then placed in steep Trendelenburg position. The surgeons then moves to the patient's right side, the first assistant is on the left side, and the second assistant goes between the patient's legs. The small bowel is packed off into the upper abdomen. The hand access device is maintained in the incision as a wound protector. The distal sigmoid colon is exteriorized through the hand access device and used as a "handle" to initiate the dissection into the pelvis. The superior rectal vessels are divided and the presacral space is entered posteriorly.
- The dissection is carried out into the posterior deep pelvis facilitated by the use of two long, narrow, specially designed St. Mark's retractors, one lighted and the other not lighted (**FIG 19**). Both retractors are used through the hand access device so that no hands are placed through the device that would obstruct the view into the pelvis.
- The posterior pelvic dissection is carried first, along the presacral space between the presacral fascia, posteriorly, and the investing fascia of the mesorectum, anteriorly (**FIG 20**). The lateral rectal ligaments are transected with an energy device.
- The pelvic dissection is then carried anteriorly in a circumferential fashion around the rectum. The Douglas

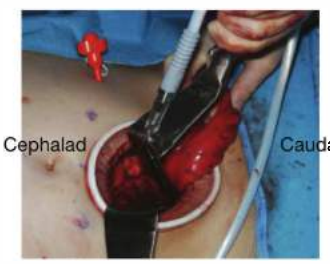

FIG 19 ● Rectal dissection through the hand access device using two narrow, double bent St. Mark's retractor (one lighted).

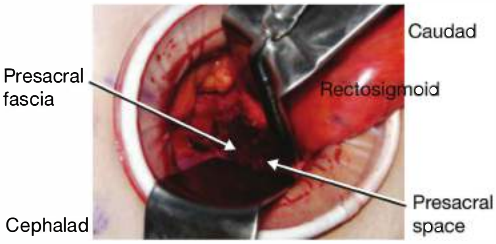

FIG 20 ● The posterior pelvic dissection is carried along the presacral space between the presacral fascia, posteriorly, and the investing fascia of the mesorectum, anteriorly.

pouch is incised open with cautery. The plane of dissection anteriorly is carried in between Denonvilliers fascia (along the anterior wall of the rectum), posteriorly, and the prostate/seminal vesicles (in males, **FIG 21**) or the vagina (in females), anteriorly. The pelvic floor (with the levator muscles) is identified (**FIG 21**).

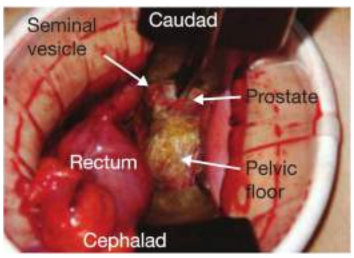

FIG 21 ● The pelvic dissection is then carried anteriorly in a circumferential fashion around the rectum. The pelvic floor (with the levator muscles) is identified. The seminal vesicles and the prostate can be seen anteriorly.

- Once the pelvic floor is reached, a transverse stapling device is placed through the hand access device and around the low rectum at the level of the pelvic floor (**FIG 22**). Before the stapler is fired, a digital rectal examination is performed to ensure that the device will be dividing the rectum at the top of the anal canal. Once the device is fired, the rectum is removed and a check of hemostasis in the pelvis is made.

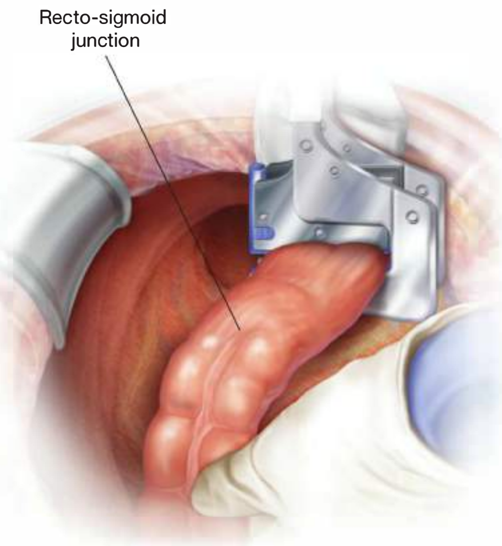

FIG 22 ● Once the pelvic floor is reached, a transverse stapling device is placed through the hand access device and around the low rectum at the level of the pelvic floor.

J-POUCH CONSTRUCTION AND POUCH ANAL ANASTOMOSIS

- Once the rectum is removed, the small bowel is exteriorized through the hand access device. The last 25 to 30 cm of the terminal ileum is folded into a "J" shape and the apex of the fold is opened anteriorly to allow placement of a linear stapler (**FIG 23**). The common wall between the two limbs of the J is divided with the linear stapler. To make an adequate-sized pouch (approximately 15 cm in length), many sequential firings of the linear stapler are usually required. Before the stapler is fired, care must be taken to ensure that the small bowel mesentery of the pouch is not trapped by the stapler in between the limbs of the pouch.
- Through the same opening that the linear stapler was placed, a monofilament suture is placed as a purse string and the anvil of a circular stapling device is secured to the apex of the J-pouch (**FIG 24**). The end of the J staple line and the anterior pouch staple lines are oversewn with 3-0 suture to reinforce the staple lines.

FIG 23 ● Creation of the J-pouch. The small bowel is exteriorized through the hand access device. The last 25 to 30 cm of the terminal ileum is folded into a J shape and the apex of the fold is opened anteriorly to allow placement of a linear stapler. The common wall between the two limbs of the J is divided with the linear stapler.

FIG 24 ● Creation of the J-pouch. Through the same opening that the linear stapler was placed, a monofilament suture is placed as a purse string and the anvil of a circular stapling device is secured to the apex of the J-pouch *(arrow)*. The pouch is approximately 15 cm long.

- An end-to-end stapled anastomosis is performed between the pouch and the anal canal (**FIG 25**). The mesentery of the pouch should be placed posteriorly against the sacrum. In a woman, prior to the firing of the circular stapler, great care must be taken to ensure that the vagina is not trapped into the circular stapling device. A diagnostic rigid proctoscopy is performed through the anus after the pelvis has been filled with saline to check for any evidence of an air leak from the pouch (**FIG 26**).
- Two 19-Fr closed bulb suction drains are placed behind the pouch and brought out the lower abdominal trocar sites. These are secured to the skin with monofilament suture.

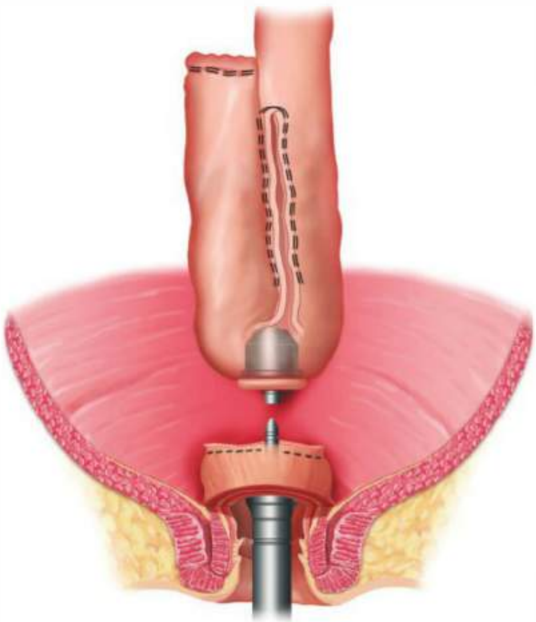

FIG 25 ● An end-to-end stapled anastomosis is performed between the pouch and the anal canal.

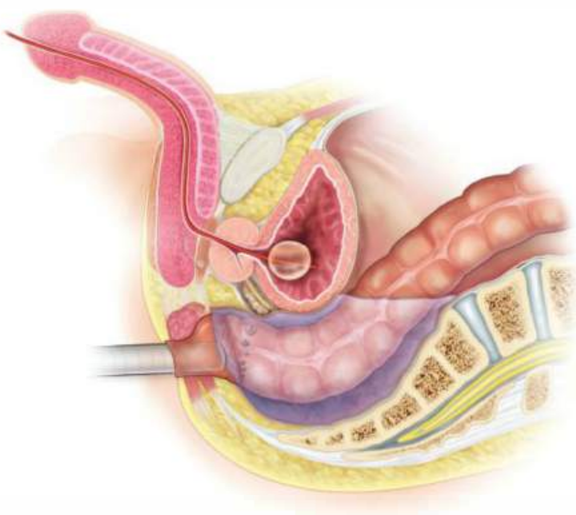

FIG 26 ● A diagnostic rigid proctoscopy is performed through the anus after the pelvis has been filled with saline to check for any evidence of an air leak from the pouch.

TEMPORARY DIVERTING LOOP ILEOSTOMY CONSTRUCTION

- Prior to surgery, the patient should have been counseled by a WOCN and site marked for a temporary ileostomy. At the marked site in the right lower quadrant, a diverting loop ileostomy is constructed. Usually, the loop should be 20 to 30 cm proximal to the J-pouch. To facilitate ileostomy reversal in the future, the bowel can be wrapped in an adhesion barrier material, which should also be placed in the abdomen under the site of the stoma to minimize adhesions.
- The hand access device/wound protector is removed and the incision is closed in the standard fashion. The 5-mm camera trocar site is closed at the skin level with a monofilament suture.
- The loop ileostomy is matured, with the proximal limb matured in a Brooke's fashion. The distal limb is matured as a mucous fistula (**FIG 27**).

FIG 27 ● The end result after a HALS-IPAA.

PEARLS AND PITFALLS

Indication	■ In cases of acute disease or indeterminate colitis, proceeding to a subtotal colectomy as the initial operation is preferred to allow thorough pathologic review of the specimen and withdrawal of the medications to unmask potential Crohn's disease.
Conduct of the abdominal portion	■ It is best to start with the left colon and the splenic mobilization first as this will determine if you can use a hand-assisted laparoscopic surgery (HALS) approach.
Creation of the J-pouch	■ Preservation of the right-sided marginal arterial arcade is critical to ensure good blood supply to the pouch. ■ Separation of the pouch mesentery from the retroperitoneum allows for adequate pouch length to reach the pelvic floor. ■ Place the pouch mesentery along the presacral space posteriorly.
Conduct of the pelvic portion	■ Avoid placing the surgeon's hands into the pelvis as this will completely obstruct the view through the hand access device.

POSTOPERATIVE CARE

- We use an enhanced recovery pathway approach to the postoperative care in our patients. They are started on a regular ileostomy diet upon arrival to the ward.
- IV fluids are kept to a minimum (<40 mL per hour) the night of surgery. All IV fluids are discontinued the morning after surgery.
- The urinary catheter is removed at 8 AM the morning after surgery.
- The two drains are removed the morning of the second day after surgery.

OUTCOMES

- The functional outcomes of IPAA over the last few decades in numerous institutional experiences have been quite comparable. Most patients report six to eight bowel movements in a 24-hour period, with one of those occurring at night.
- Depending on the patient's age and gender, about 20% to 30% will experience minor leakage of stool, particularly at night.
- The majority of patients will experience one or more episodes of pouchitis, with approximately 20% having chronic pouchitis, which requires treatment.
- IPAA patient's quality of life is usually significantly improved relative to his or her presurgery health state.
- Finally, IPAA is a durable operation with over 90% of patients having a well-functioning pouch at 20 years after surgery.

COMPLICATIONS

- The most concerning complication is a pouch leak or pelvic sepsis. Unexplained tachycardia, lower abdominal pain, or low back/pelvic pain are worrisome signs for a pouch leak. Early operative intervention with pelvic irrigation/washout and drain placement is the procedure of choice. Later presentation with fever, pelvic pain, and urinary symptoms warrant abdominal imaging with a CT scan and percutaneous drain placement.[4]
- Prior to ileostomy reversal, usually 2 to 3 months after the pouch surgery, a contrast enema is obtained to evaluate for a possible anastomotic leak or narrowing. If a small anastomotic sinus is observed, closure should be delayed for another 2 to 3 months and a repeat contrast study obtained. Commonly, the sinus will close. However, if it persists, an examination under anesthesia is required in an attempt to open the sinus or to curette the tract to promote healing.

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Chapter **39** # Pelvic Exenteration

Cherry E. Koh Michael J. Solomon

DEFINITION

- Pelvic exenteration, also known as extended radical resection, is a form of radical surgery first described for the treatment of locally advanced cervical cancer, which was adopted for locally advanced colorectal cancer shortly thereafter. Currently, locally advanced primary rectal cancers (LARC) and locally recurrent rectal cancers (LRRC) are amongst the more common indications for pelvic exenteration.
- The fundamental surgical principle of pelvic exenteration is complete en bloc removal of all viscera or structures contiguously involved by tumor with a clear resection margin (R0 resection). Therefore, depending on the location of the tumor, different types of exenteration will be required, which may include en bloc cystoprostatectomy, vaginectomy, radical hysterectomy, or even sacrectomy. The same surgical principles may be applied to other locally advanced pelvic cancers including uterine, bladder, and prostate cancers and sarcomas.
- Different classifications have evolved to describe the different types of recurrence and exenteration, although of note, there is no universally accepted terminology.
- Although lengthy anatomical discussion is beyond the scope of this chapter, a brief discussion is necessary to facilitate understanding of the key concepts and principles of surgery.

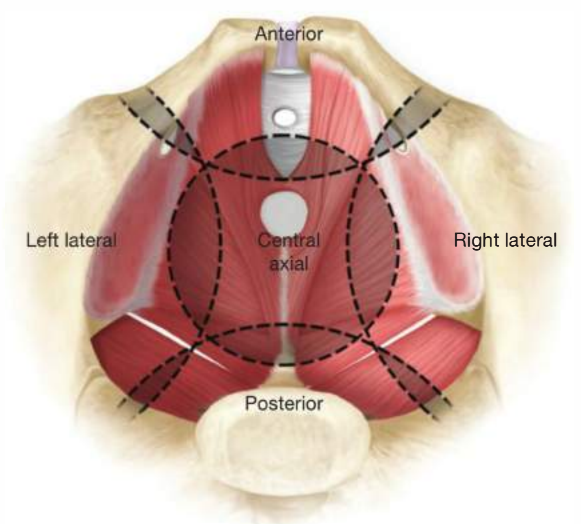


FIG 1 ● The compartments of the pelvis are shown in this diagram. The pelvis can be divided into the anterior, central, posterior, and lateral compartments, which are centered on the urethra, the tip of the coccyx, the third sacral vertebra, and the ischial spines, respectively. A complete pelvic exenteration is one where all viscera are removed and involves surgery in all five compartments of the pelvis with or without bony resection, whereas a partial exenteration is one which involves removal of at least three compartments of the pelvis with or without bony resection.

- Anatomically, the pelvis can be divided into four compartments: the anterior, central, posterior, and lateral compartments (**FIG 1**). Each compartment overlaps at their margins but the axis of each compartment is centered on a different structure. The urethra, the tip of the coccyx, the third sacral vertebra, and the ischial spine form the axis of the anterior, central, posterior, and lateral compartments, respectively.
- For clarity, exenteration is best classified as complete exenteration or partial exenteration. Complete exenteration is defined as complete removal of all compartments of the pelvis with or without en bloc bony resection, whereas a partial exenteration is defined as the removal of at least three compartments of the pelvis, with or without en bloc bony resection. Within partial exenteration, there are many subtypes of exenterations that often involve surgery on parts of different compartments (**FIGS 2A,B**).
- As a general principle, the resection margin for a compartment will involve excision of the soft tissue at its attachment to the bone or en bloc excision of the involved bone (e.g., en bloc sacrectomy, excision of ischial spine or of pubic ramus). Attempting to obtain a soft tissue margin within a compartment will invariably result in a very rate of highly involved margins. **FIGS 2A** and **2B** illustrate the potential dissection planes depending on the location of the tumor.
- In addition to consideration of the compartments of the pelvis, the "height" of the tumor is also important to determine resectability (if there is high sacral involvement), the extent of perineal resection and reconstruction required as well as whether or not intestinal continuity can be restored.

PATIENT HISTORY AND PHYSICAL FINDINGS

- Patients with LARC are usually symptomatic. Patients with LRRC may be symptomatic or asymptomatic (see below), although most patients are symptomatic.
- Symptoms experienced by the patient reflect the location of the cancer. Common symptoms include pain, rectal bleeding, altered bowel habits, and tenesmus. Pain may be the result of direct nerve (sacral nerve roots and sciatic nerve), muscle (levator, piriformis, and obturator internus), or bony (sacral) infiltration or the result of referred pain, usually to the buttock or hamstring.
- As the tumor gets larger, mass effect may ensue with ureteric or bowel obstruction. Advanced cancers of the pelvis may also present with malignant fistulae between the small or large bowel and an adjacent viscera such as the vagina or bladder. Occasionally, patients may present as an offensive fungating tumor or lymphedema of the lower limb because of venous compression.
- Asymptomatic local recurrences may be detected on routine follow-up with elevated carcinoembryonic antigen (CEA), surveillance computed tomography (CT), or colonoscopy. Asymptomatic anastomotic recurrence following low rectal

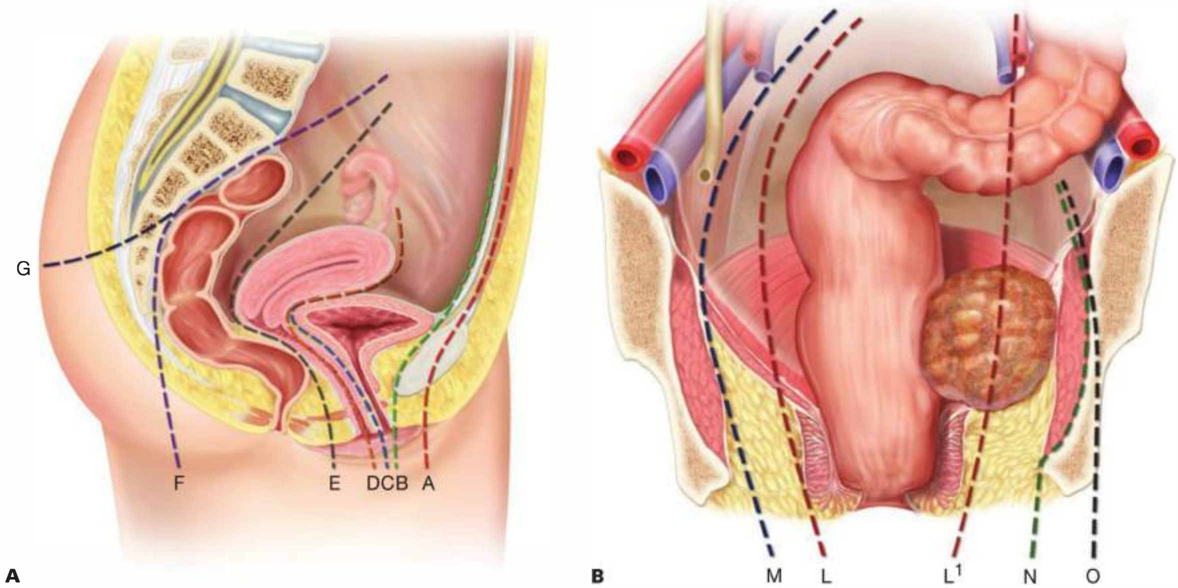


FIG 2 ● **A.** This is the sagittal section of a female pelvis. *Planes A* and *B* are the dissection planes for complete or partial exenterations involving the anterior compartment with and without en bloc pubic excision, respectively. *Planes C* and *D* are dissection planes for partial exenteration involving the central compartment with total or subtotal vaginectomy and posterior vaginectomy, respectively. Note that *planes C* and *D* do not exist in men. *Planes E* and *F* are the anterior and posterior total mesorectal excision planes, respectively, whereas *plane G* is the plane for en bloc sacrectomy. **B.** Coronal section of the pelvis. There are four possible lateral dissection planes. *Plane L* represents the total mesorectal excision plane and is the lateral plane for a partial exenteration not involving the lateral compartment. *Plane M* represents the extravascular plane, which is a plane lateral to the iliac vasculature but medial to obturator internus. *Plane N* involves excision of the entire lateral compartment including obturator internus, whereas *plane O* includes en bloc bony resection such as the ischial spine or ischial tuberosity. The right hand side of Figure 2B shows a tumour that involves the lateral compartment. Dissection in the lateral mesorectal plane depicted by *plane L1* will invariably result in an involved surgical margin. In order to achieve R0 resection margins, dissection should follow *plane N*.

resection may be readily palpable with digital rectal examination or be visible on rigid sigmoidoscopy.

- As pain frequently accompanies LARC or LRRC, clinical assessment may require an examination under anesthesia, which will also permit biopsies and other investigations to be undertaken concurrently such as a completion colonoscopy or cystoscopy where ureteric stents may also be inserted at the same time if necessary.
- In patients with a previous abdominoperineal excision, clinical findings are often limited.
- A general assessment for obvious systemic metastasis such as hepatomegaly or inguinal lymphadenopathy should also be performed to rule out the presence of metastatic disease.

IMAGING AND OTHER DIAGNOSTIC STUDIES

- CT scan of the chest, abdomen and pelvis is a useful first step to rule out systemic metastasis. In general, CT scans do not provide adequate soft tissue delineation in the pelvis to permit accurate staging of LARC for decision making on neoadjuvant therapy. In patients with potential LRRC, CT scans have are limited in its ability to distinguish between post-surgical fibrosis and tumour recurrence.
- Positron emission tomography (PET) scans complement CT scans in detecting the presence of metastatic disease (**FIG 3A,B**). By detecting metabolically active tissue, it has the advantage of being able to distinguish between postoperative fibrosis and metabolically active local recurrence. PET in LARC or LRRC has been shown to alter clinical decision making by 20% to 40% by detecting occult metastatic disease.
- Magnetic resonance imaging (MRI) is currently the gold standard to determine the local extent of tumor, to assess resectability, and to determine the potential need of neoadjuvant (for LARC) therapy (**FIG 4A,B**). The accuracy of MRI in

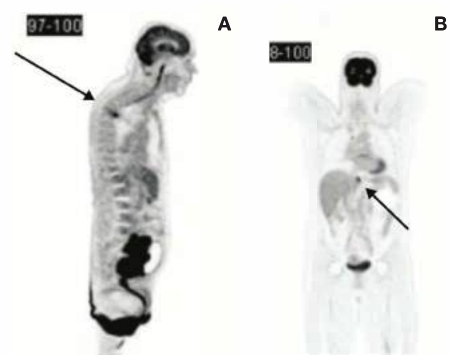
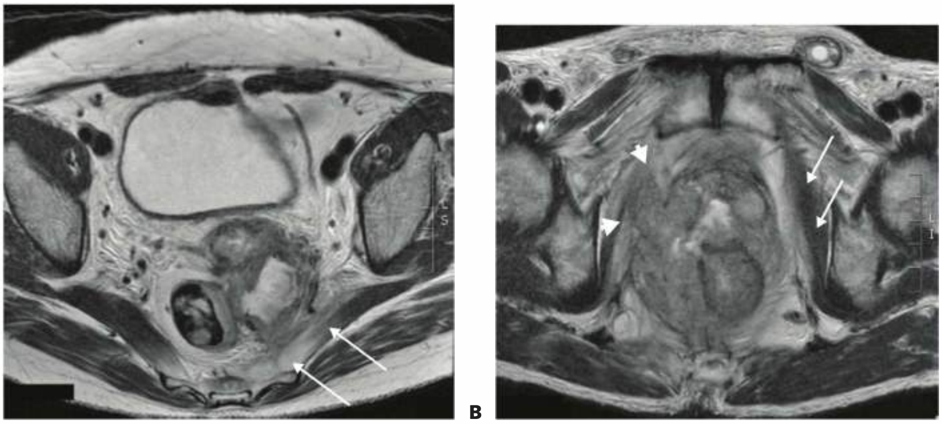


FIG 3 ● **A.** PET scan of a patient with locally advanced rectosigmoid cancer referred for pelvic exenteration. PET scan was consistent with metastatic disease *(arrow)*. **B.** PET scan of a patient with an anastomotic recurrence after a previous sigmoidectomy who presented with an asymptomatic recurrence manifesting with an elevated CEA. The patient was being considered for pelvic exentertation. PET scan showed a small liver metastasis otherwise undetected on CT scan *(arrow)*.



A B

FIG 4 ● **A.** MRI of the pelvis showing locally advanced cervical cancer. The cancer is seen to the left of the rectum and is invading the left piriformis muscle *(arrows)*. This patient has pain in the left S2-S3 nerve root territory consistent with sacral plexus infiltration. **B.** MRI of the pelvis of a patient with a large LRRC abutting the left obturator internus muscles *(arrows)* and directly infiltrating the right obturator internus muscle *(arrowheads)*.

confirming anterior compartment, pelvic sidewall and sacral involvement ranges between 60% and 100%. The major limitation of MRI with LRRC resides in its inability to accurately diagnose pelvic sidewall involvement.

- Tissue diagnosis, although easily obtained in LARC, is a contentious issue in patients with LRRC when the lesion may be inaccessible luminally and a biopsy would necessitate a percutaneous route that could lead to tract seeding. However, without tissue diagnosis, patients in whom the final pathology report shows no recurrence of cancer may have been subjected to an unnecessary major operation with significant morbidity. It is our practice to accept a diagnosis of LRRC when there is a positive PET scan provided that there is corroborative history, MRI findings, and elevated CEA level.
- CEA level is helpful for ongoing disease surveillance in patients with LARC. The sensitivity of CEA for detecting recurrent disease is low but the specificity is 85%.
- A complete colonoscopy is performed to obtain tissue diagnosis and to rule out synchronous colon cancer prior to embarking on a major resection.
- CT or magnetic resonance angiography may be useful to ensure the patency of inferior epigastric arteries if a rectus abdominis myocutaneous flap is being considered for perineal reconstruction in a patient who previously had or currently has stoma(s). They may also help to determine if a vascular surgeon may be needed if there is major arterial involvement of the common iliac or external iliac vessels.
- Cystoscopy can help diagnose bladder involvement and may allow ureteric stenting to relieve ureteric obstruction and prevent impending renal failure.

SURGICAL MANAGEMENT

Preoperative Planning

- All patients should be discussed preoperatively at a multidisciplinary team meeting to determine resectability and operative strategy.
- Patients who are radiotherapy naive should be considered for preoperative long-course chemoradiation prior to pelvic exenteration.
- A detailed informed consent is obtained. Because studies have shown that patients often underestimate the magnitude of the procedure, we encourage family members to participate in the discussions and we schedule at least two separate consultations.
- A preoperative review by the cancer coordinator and psychooncologist is obtained. Further, as most patients will require the creation of at least one, if not two, stoma, it is essential that the patient receive stomal education prior to the procedure.
- Bowel preparation is usually necessary for patients without an existing colostomy.

Positioning

- Depending on the location and the extent of the cancer, the patient may require surgery from the abdominal and the perineal compartment. In patients where a high sacrectomy is required, repositioning in a prone position after completion of the abdominal and perineal components of the operation is also necessary.
- Patients are placed in a modified Lloyd-Davies position directly on a gel mat with both arms tucked by their sides and protecting all pressure areas (**FIG 5**). In patients who require major perineal resections, the buttocks should be elevated with a rolled towel and overhang the end of the operating bed by up to 5 cm to permit access into the natal cleft if needed.
- To avoid muscle compartment syndrome, the legs should not be elevated more than 30 degrees during abdominal phase and only elevated for the perineal phase.
- Patients will require an arterial line, a central line, and a large-bore intravenous cannula. These lines need to be well secured prior to be being tucked away by the patient's sides.
- Patients should also receive prophylactic antibiotics, subcutaneous heparin, mechanical venous thromboprophylaxis in the form of graduated compression stockings and calf compressors.
- An indwelling Foley catheter is inserted. The anterior thigh is prepped and draped if a vascular graft using the great or common saphenous veins needs to be harvested. The vagina should also be included in the preparation.

FIG 5 ● The patient is positioned in modified Lloyd-Davies position with both arms tucked by their sides. The previous midline scar is marked. In this patient, a high sacrectomy and rectus abdominis myocutaneous is planned. The rectus abdominis myocutaneous flap is to be harvested from the patient's right where there has not been a previous stoma and this has also been marked out with the ileal conduit site being lateralized to *A′* by the same distance as that between the midline and the first stoma site *A*.

- A purse-string suture at the anal verge is used to prevent fecal spillage during the procedure.
- Prior midline incisions or scars should be marked so that the same incision can be used. In patients where a rectus abdominis myocutaneous flap is planned, this should also be premarked prior to prepping and draping (**FIG 5**). The colostomy is prepped and covered with a swab, which is then held in place by an impervious adhesive plastic dressing.
- Insertion of bilateral ureteric stents is not routinely done in all cases.

ABDOMINAL PHASE

- We start with a meticulous adhesiolysis to mobilize all small bowel loops from the pelvis. Avoiding enterotomies in pelvic small bowel loops which may have been damaged by previous radiotherapy is important to prevent a postoperative enterocutaneous fistula.
- The abdominal cavity is inspected for peritoneal carcinomatosis or unresectable metastatic liver disease not identified during pre-operative staging. Presence of either usually precludes curative resection and is likely to alter the surgical plan.
- Pelvic small bowel loops invaded by cancer should be resected en bloc using linear staplers. The remaining small bowel loops are packed into the upper abdomen using moist sponges held in a fixed table retractor such as the Omni-Tract®.
- If the colon is still intact, it should be mobilized along its anatomic planes. Reflection of the sigmoid and descending colon on its mesentery medially will expose the left ureter. Identification of the ureter is important to avoid inadvertent ureteral injury.
- For a LARC, a high ligation of the inferior mesenteric artery is performed. The colon is divided at a point of convenience that remains well vascularized. The proximal divided colon can then be packed into the upper abdomen, isolating the pelvis from the abdominal contents.
- The appendix is prophylactically removed in patients who require a conduit as dense adhesions and mesh closure of the abdomen would make a future appendectomy difficult.

Lateral Compartment Dissection

- There are four possible planes of dissection in the lateral compartment (**FIG 2B**). *Plane L* is the conventional total mesorectal excision plane that is familiar to all colorectal surgeons. This plane is used for partial exenterations not involving the lateral compartment or in small anastomotic recurrence that only requires a reoperative anterior resection.
- For dissections in *plane M*, *N*, or *O*, the procedure begins with identification and mobilization of the ureters with a cuff of connective tissue to preserve their blood supply (**FIG 6**). Both ureters are mobilized as distal as possible into the pelvis. If en bloc cystectomy is planned, the ureters are divided without compromising resection margins and to provide adequate ureteric length for urinary reconstruction with an ileal or colonic conduit. Ureters should be anastomosed to the conduit out of the field of prior radiotherapy when possible. Even if en bloc cystectomy is not required, mobilizing the ureters along their entire length allows them to be mobilized off the pelvic sidewall such that the next layer of structures under the ureter (the common, external, and internal iliac arteries) can be accessed (**FIG 7**).
- Other than an early anastomotic recurrence, complete pelvic lymphadenectomy, starting at the level of the aortic bifurcation, is routinely performed for most other LRRC. **FIG 7** also demonstrates the appearances of the iliac vasculature after complete pelvic lymphadenectomy.
- Dissecting in *plane M* will require ligation and excision of the internal iliac vasculature so as to get into and to

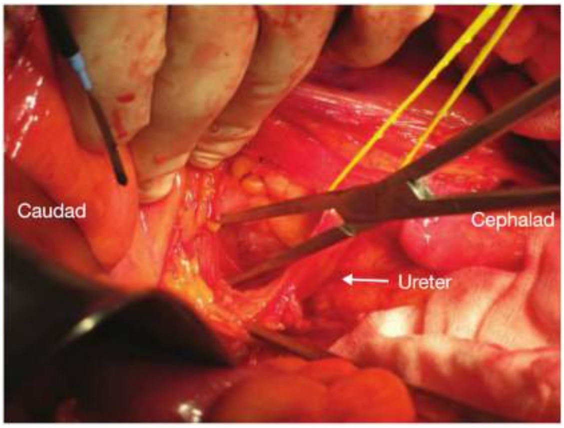


FIG 6 ● Mobilization of the right ureter with a cuff of connective tissue around the ureter so as to preserve its blood supply. We use yellow vessel loops for ureters (blue for veins and red for arteries). Ureterolysis is performed with the operator dissecting using right-angle forceps and the assistant dividing tissue between the forceps using diathermy.

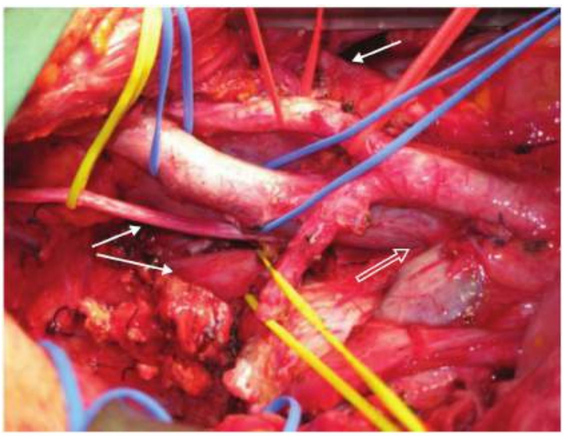


FIG 7 ● Right pelvic sidewall. The ureter has been fully mobilized, divided and is placed in the right iliac fossa away from the pelvic sidewall while further dissection of the right pelvic side wall continues *(top arrow)*. Pelvic lymphadenectomy has been performed from the bifurcation of the aorta and the common iliac artery (CIA). This exposes the common iliac vessels and the confluence between the external and internal iliac vessels *(block arrow)*. The right external iliac artery (EIA) is held in red vessel loops and the right internal iliac artery (IIA) has been ligated and divided. The external iliac and common iliac veins are held in blue vessel loops with the internal iliac vein ligated and divided. The two yellow vessel loops demonstrate two nerves. The smaller nerve is the obturator nerve and the larger nerve is the lumbosacral trunk *(left sided arrows)*. Note the "layered" arrangement of the pelvic sidewall where the iliac arterial system lies superficial to the iliac venous system which in turn lies superficial to the lumbosacral trunk. Note that after ligation and division of the internal iliac artery or vein, the external iliac artery and vein can then be "floated off" the pelvic sidewall.

remain in the extravascular plane. Even if formal excision of the internal iliac vasculature is not required, in situ ligation of the internal iliac artery and vein can be helpful to provide vascular control to limit blood loss as the dissection continues, especially if sacrectomy is planned. In LRRC, previous total mesorectal excision and radiotherapy usually cause tissue fibrosis and obliterate tissue planes making dissection difficult. Even if extra-vascular dissection is not necessary, the plane is typically virginal and may be comparatively easier to dissect.

- To get into plane M, after ureterolysis is performed, the internal iliac artery is dissected. When an adequate segment of internal iliac artery has been mobilized, it can be suture ligated and divided.
- Continued mobilization of the common iliac and external iliac arteries, which do not have any branches within the pelvis, will allow the common and external iliac arteries to be "floated" out of the operative field using two vessel loops held apart to prevent acute kinking of the artery. This exposes the next layer of structures—the common, external, and internal iliac veins. The combination of ligation of the internal iliac venous system and lymphadenectomy will result in progressive exposure of the sacral nerve roots on the piriformis muscle (**FIG 8**).
- Next, the internal iliac vein can then be ligated and excised en bloc together with the specimen, allowing the operator to get progressively more lateral within the lateral compartment. Variable venous anatomy and tributaries coupled with thin-walled veins make dissection of the venous system particularly challenging. Once the internal iliac vein is ligated, the external iliac vein and distal common iliac vein can be similarly mobilized (as with the common and external iliac arteries) to allow these veins to be floated out of the pelvis providing access to the deeper structures—the lumbosacral trunk (**FIG 7**). Lumbosacral trunk is derived from L4 and L5 nerve roots and joins the sacral plexus on the piriformis muscle to

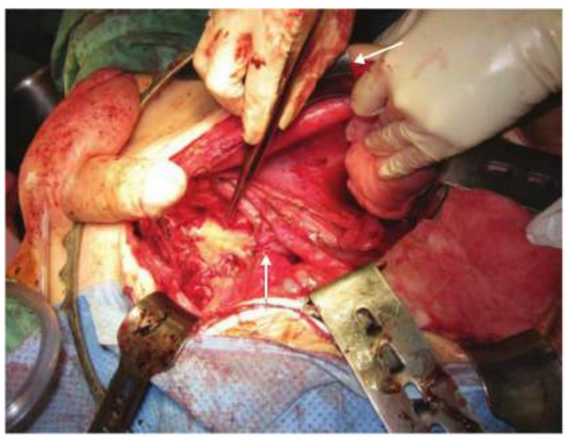


FIG 8 ● By dissecting and ligating the internal iliac vasculature and performing a lymphadenectomy, the lumbosacral trunks and the sacral plexus (S1, S2, and S3 nerve roots) are displayed. The internal iliac artery and internal iliac vein stumps are seen *(arrows)*. The DeBakey forceps points to the S1 and S2 sacral plexus nerve roots. (S3 has been divided.)

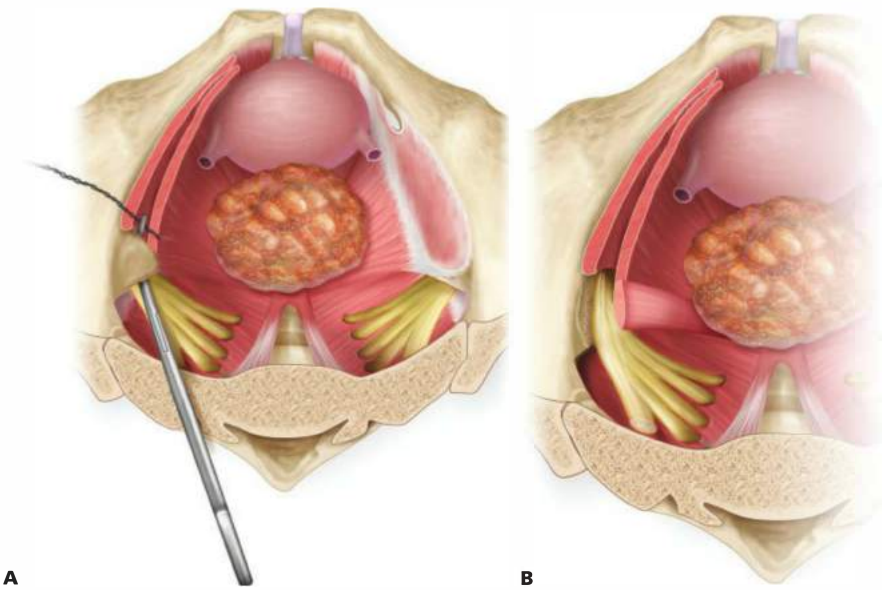


FIG 9 ● **A.** Curved large right-angle forceps passed around ischial spine in preparation to its excision. The end of a Gigli saw is grasped and pulled through. The sciatic nerve under the saw is protected by a malleable retractor while the ischial spine is being divided. **B.** View of the pelvic sidewall after ischial spine has been excised. This exposes the entire intrapelvic course of the sciatic nerve.

form the sciatic nerve, which exits the pelvis by coursing posterior to the ischial spine via the greater sciatic notch.

- Identification of the lumbosacral trunk is an important step as this ensures the nerve is preserved for lower limb function and serves as an anatomic gatekeeper that helps guide the operator to the obturator internus muscle and ischial spine.
- Continued lateral dissection staying within the extravascular plane (*plane M*) will stay medial to the obturator internus muscle within the lateral compartment. While dissecting in *plane M*, numerous small branches and tributaries of the internal iliac vessels will be encountered that will need to be individually ligated to ensure hemostasis is secure. Continued dissection within *plane M* will lead to the origin of the levator ani, which can then be divided to enter the perineal compartment (**FIG 2B**).
- For complete excision of the lateral compartment (*plane N*), the lumbosacral trunk is traced distally to the obturator internus muscle and ischial spine. The entire obturator internus muscle can be excised by detaching it at its origin from the medial aspect of the pelvis (pubic bone) using diathermy. The ischial spine may also be excised en bloc to gain wider exposure. To do this, a large curved right-angle forceps is passed from the posterior to anterior around ischial spine (**FIG 9A**). The free end of a Gigli saw is pulled through. Using a malleable retractor to protect the sciatic nerve, which is immediately deep to the ischial spine, the Gigli saw may be used to saw off the spine at its origin from the remainder of ischium (**FIG 9B**). The combination of dividing the ischial spine and the obturator internus exposed the entire pregluteal, pelvic course of the sciatic nerve (**FIG 8**) and releases the sacrospinous ligament exposing the sacrotuberous ligament.
- For wider excision of the medial wall of the ischium or of the ischial tuberosity (**FIG 2B**, *plane O*), the origin of the obturator internus is mobilized as described earlier. The perineal surgeon commences perineal dissection to gain wide exposure of the perineal aspect of inferior pubic ramus, leading to ischial tuberosity. Soft tissue attachments (origin of adductor magnus and semimembranosus muscles) are mobilized from the inferolateral aspect of ischial tuberosity, which then allows the ischial tuberosity to be excised using either an electric or Gigli saw while protecting the sciatic nerve using a malleable retractor. In some cases, the ischium can be removed through an abdominolithotomy approach.

Anterior Compartment Dissection

- The anterior plane of dissection for complete exenteration or partial exenteration involving the anterior compartment is depicted by *planes A* and *B* in **FIG 2A**.
- To dissect *plane B*, the peritoneum overlying the bladder is incised to enter the retropubic space of Retzius (**FIG 10A**). This incision continues laterally to open the endopelvic fascia. This is largely a bloodless plane, although anterolaterally, the superior vesical pedicle, vas deferens in a male patient, and the inferior vesicle pedicle will be encountered, which will require suture ligation. Laterally, the obturator neurovascular bundle will be seen and obturator lymphadenectomy is also performed with preservation of the obturator nerve.
- Anteriorly, the dorsal venous complex is the next to be encountered which will require suture ligation (**FIG 10B**). Division of the dorsal venous complex will allow the bladder to be reflected more posteriorly.

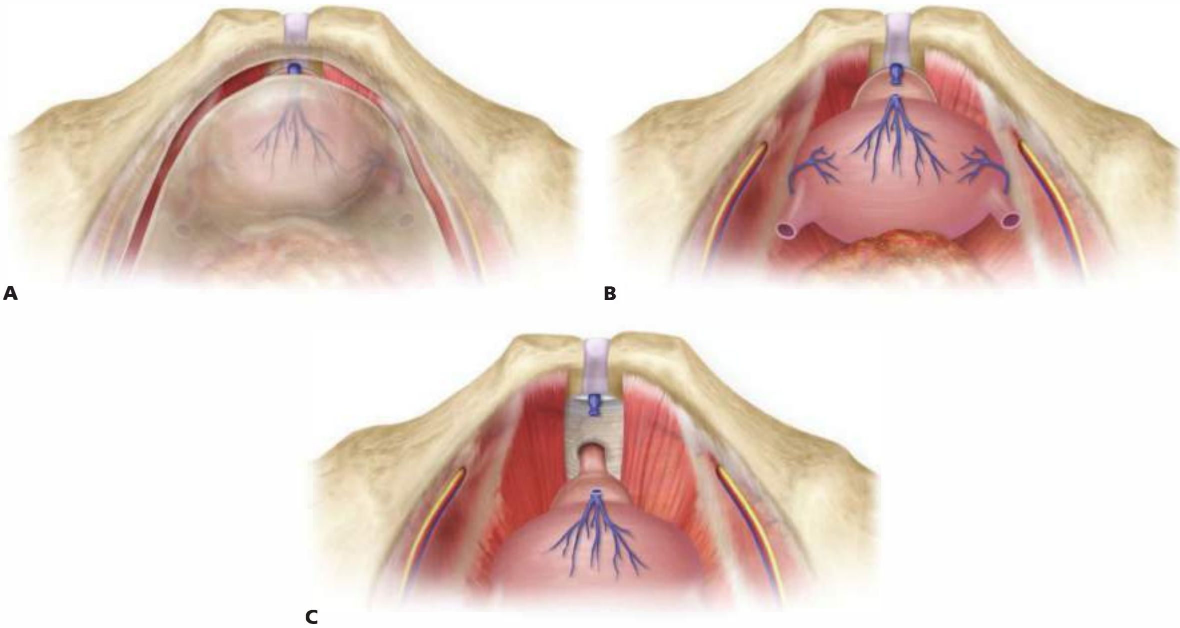


FIG 10 ● **A.** Anterior dissection plane for complete exenteration or partial exenteration involving the anterior compartment. This step involves incising the peritoneum over the bladder anteriorly. This enters the space of Retzius and is largely bloodless. However, the superior and inferior vesical pedicles and vas deferens (in men) will need to be ligated and divided. Laterally, the endopelvic fascia is also released. **B.** The dorsal venous complex has been ligated, which allows the bladder to be mobilized further. In males, this exposes the prostate. **C.** Continued mobilization of the anterior plane exposes the urethra as it exits the prostate. The presence of urethra can be confirmed by palpating the indwelling urinary catheter.

- In a male patient, the prostate will be encountered next (**FIG 10C**). Further mobilization of the prostate from the pelvic floor will lead to the urethra as it exits the prostate and traverses the urogenital diaphragm to become the penile urethra (**FIG 10C**). Presence of the urethra can be confirmed by palpation of the indwelling urinary catheter.
- The urethra is first partially incised to allow the catheter to be completely divided and removed before completely transecting the urethra and suture ligating the distal end of urethra. This completes the abdominal dissection in *plane B*.
- If restoring intestinal continuity is not possible, the perineal surgeon then begins dissection from the perineum to join the abdominal dissection similar to an abdominoperineal excision. In LRRC, if the tumor invades the prostate or membranous urethra (e.g., after previous abdominoperineal excision), then the urethra can be transected more distally from the perineal approach often with a cuff of pubic bone (see the following text).
- Dissection in *plane A* involves the first step in anterior plane mobilization, which is incision of the peritoneum overlying the bladder to enter the retropubic space of Retzius immediately deep to pubic symphysis and superior pubic rami. This incision is extended laterally to incise the endopelvic fascia. Mobilization of the bladder and ligation of the superior and inferior vesical vessels and the vas deferens (in a male patient) as described earlier are also carried out but ligation of the dorsal venous complex is not performed.
- In order to perform en bloc pubic excision, the pubic symphysis and pubic ramus will need to be defined and widely exposed both from the abdominal as well as perineal compartments. Thus, once the abdominal surgeon enters the retropubic space of Retzius, the perineal surgeon commences perineal dissection working toward defining the pubic symphysis, inferior pubic ramus up to the ischial tuberosity widely (**FIG 11**).

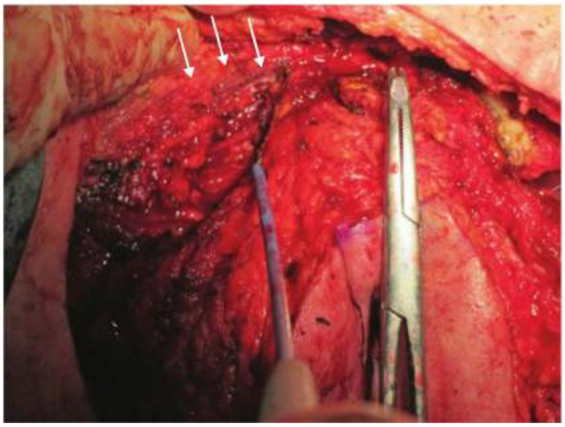


FIG 11 ● Perineal dissection with wide exposure of the pubic symphysis, inferior pubic ramus, and ischial tuberosity in preparation for en bloc pubic bone excision. The inferior pubic ramus bony edge is illustrated by the *arrows*.

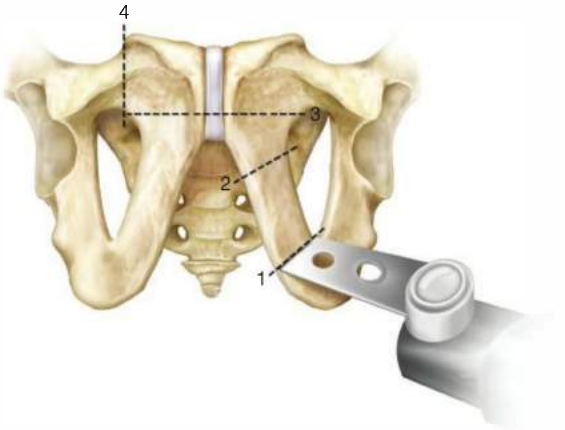


FIG 12 ● Diagram of the bony pelvis with *lines 1* to *4* demonstrating possible excision planes. Dividing pubic bones between *lines 1* and *2* will resect the inferior pubic ramus; between *lines 2* and *3* will cause central partial pubic excision; between *lines 2* and *4* bilaterally will result in central pubic excision.

- The anterior levator plane is not excised but is also defined widely. The origins of the adductor and gracilis muscles as well as the obturator fascia deep to the adductors are divided to expose the anteroinferior surface of the inferior pubic ramus. Depending on the site of tumor involvement, different extent of bony resections can be performed ranging from unilateral or bilateral pubic ramus excision (**FIG 12**, *lines 1* and *2*), partial pubic symphysis excision (**FIG 12**, *lines 2* and *3*), or central pubic excision (**FIG 12**, *line 2* and *4*) using either a Gigli saw or a handheld electric saw (**FIGS 13** and **14**).
- Internal fixation following pubic symphysis excision is generally not required even when it has been completely excised. Mesh reconstruction using polypropylene mesh to the cut ends of all four pubic rami and flap closure is usually all that is required.

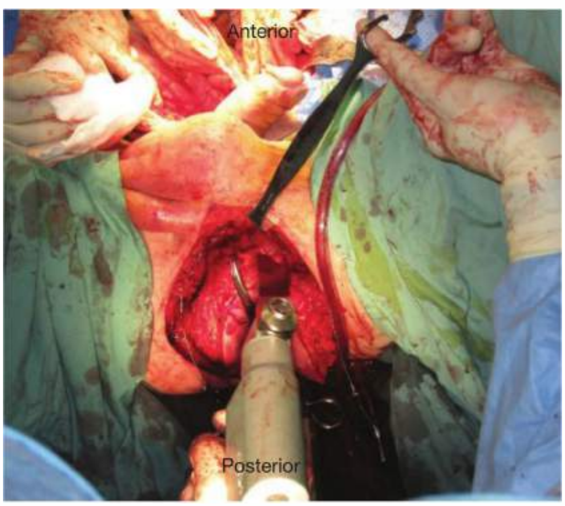


FIG 13 ● A handheld oscillating saw being used to divide the inferior pubic ramus.

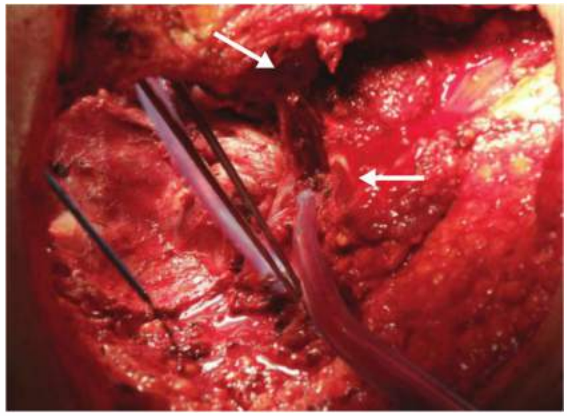


FIG 14 ● This patient has had en bloc excision of the left inferior pubic ramus. The picture demonstrates an oblique caudal to cephalad view into the pelvis. The divided ends of the pubic ramus can be seen in the photo *(block arrows)*.

- *Plane C* is the anterior dissection plane for a partial exenteration not involving the anterior compartment. Dissecting in this plane is dissecting in the vesicovaginal plane for en bloc radical hysterectomy and bilateral salpingo-oophorectomy.
- The procedure begins by grasping each uterine cornu for retraction (**FIG 15**). Gonadal vessels are ligated at the level of pelvic brim and the broad ligament is incised with ligation of the round ligament. The peritoneum between the uterus and bladder is incised (**FIG 15**) to permit placement of a lipped St. Mark's retractor to maintain retraction of the bladder anteriorly.
- Bilateral ureterolysis should be performed in order to mobilize the ureters from the lateral aspects of lower uterus and cervix to prevent inadvertent injury.
- Whether or not an en bloc hysterectomy is required depends on whether or not the uterus is involved more proximally.
- Whether a total vaginectomy or subtotal vaginectomy is required depends on the location of the cancer. When only posterior vaginectomy is required, dissection is carried out in *plane D*. Using a swab-on stick or a vaginal retractor is useful so that the operator is able to confidently incise the posterior wall of vagina without damaging the anterior wall.
- Vaginal reconstruction can be achieved using the skin paddle from a rectus abdominis myocutaneous flap to reconstruct the posterior and lateral walls of vagina.
- Note that *planes C* and *D* do not exist in men.

Posterior Compartment Dissection

- *Plane E* is the anterior dissection plane for a partial exenteration involving the central and posterior compartments or the posterior dissection plane for a partial exenteration involving the central and anterior compartments. This is also a plane familiar to all colorectal surgeons and is the anterior mesorectal plane.

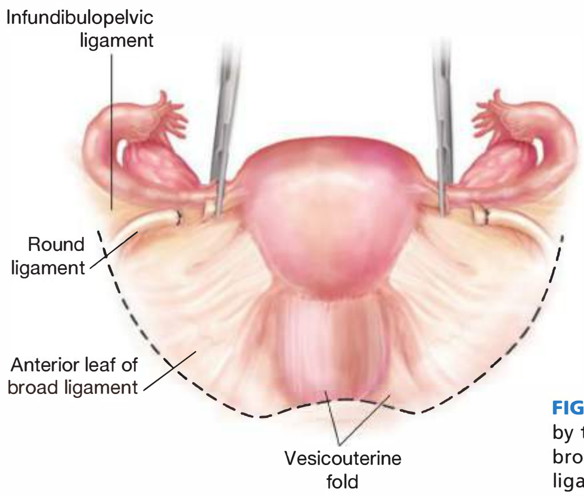


FIG 15 ● Uterine dissection. Two Kocher forceps grasp the uterus by the uterine cornu so as to provide retraction. The base of the broad ligament is incised as shown. The round ligament is also ligated and divided.

- Dissection proceeds in the usual manner using a total mesorectal excision technique with an assistant retracting the uterus and/or the bladder forward using a lipped St. Mark's retractor while the operator provides backward and downward countertraction on the rectum.
- This dissection continues to the pelvic floor. If a low rectal anastomosis is to be fashioned, the rectum is stapled at the level of the pelvic floor, but if an anastomosis is inappropriate, then an abdominoperineal excision can be performed with the abdominal surgeon guiding the perineal surgeon about the point of entry into the pelvis.
- *Plane F* is the surgical plane for a complete exenteration or partial exenteration without sacral involvement. Rectal mobilization begins by incising peritoneum over the left or right mesorectal fold. This plane, which is usually bloodless, is dissected using sharp dissection. Retrograde dissection in this plane joins the mesocolic plane and allows inferior mesenteric artery to be ligated if this is not ligated yet. With an assistant providing traction on the rectum and retracting the rectum forward using a St. Mark's retractor, the surgeon can continue to dissect in this bloodless plane until the coccyx is reached, where Waldeyer's fascia is incised in order to mobilize the rectum down to the pelvic floor.
- When an en bloc sacrectomy is necessary, plane G is the suggested plane of dissection. Depending on the level of sacrectomy (high vs. low), a different surgical approach is needed. Further, sacral resection is usually the last step in the procedure after completion of abdominal (anterior, lateral dissections) and perineal phases.
- A low sacrectomy involving S3, S4 and S5 can usually be performed with the patient in modified Lloyd-Davies position via an abdomino-lithotomy approach whereas a high sacrectomy (excision of S1 or S2) generally requires a prone approach.
- Surgery begins as described earlier with the abdominal phase of dissection. Lateral compartment dissection with vascular ligation and exposure of the lumbosacral trunk so as to preserve lower limb function is performed. The ischial spine may also need to be excised laterally.
- Dissection in the appropriate anterior plane is performed and posterior dissection stops about 2 cm above the site where the tumor is adherent to the sacrum. Overlying S3, S4, and S5 in the midline is the anterior longitudinal ligament, which is often abnormally thickened in patients with LRRC as a result of previous radiotherapy and surgery. Lateral to this at S3 level is piriformis medially and sacral nerve roots laterally. These may also need to be disconnected depending on the level of sacral resection.
- Perineal dissection should also be completed before attempting en bloc distal sacrectomy (see "Perineal Phase"). To perform abdominal sacrectomy, the perineal surgeon will have to extend the posterior dissection to first get to the coccyx. Once the coccyx is defined, the perineal surgeon continues dissection immediately posterior to the coccyx mobilizing the posterior aspect of the coccyx and sacrum from surrounding attachments of gluteus maximus and ligamentous attachments.
- By tunneling to the appropriate level of sacral excision, a malleable retractor or osteotome can then be inserted to protect the natal cleft tissue as the abdominal surgeon performs sacrectomy using a 20-mm osteotome and mallet (**FIG 16**). Once all bony attachments are divided, the specimen can then be delivered from the perineal wound.
- Where a high sacrectomy (excision of S1 and S2) is necessary, abdominal and anterior compartment perineal phases of the operation have to be completed before the patient is turned prone for posterior compartment excision. This includes completion of all aspects of abdominal and perineal procedures such as visceral reconstruction, drain placement, abdominal wound closure and temporary perineal wound closure, harvest of rectus abdominis flap as well as formation of a colostomy.
- To ensure the appropriate sacral segments are excised from a prone approach, an orthopedic pin or staple is secured into the sacrum about 1 to 2 cm above the desired point of transection (11 × 15 mm, Smith & Nephew™ fixation staple). The position of this stapler is checked with an intraoperative x-ray to confirm the point of transection (**FIG 17A**) when commencing the prone approach.

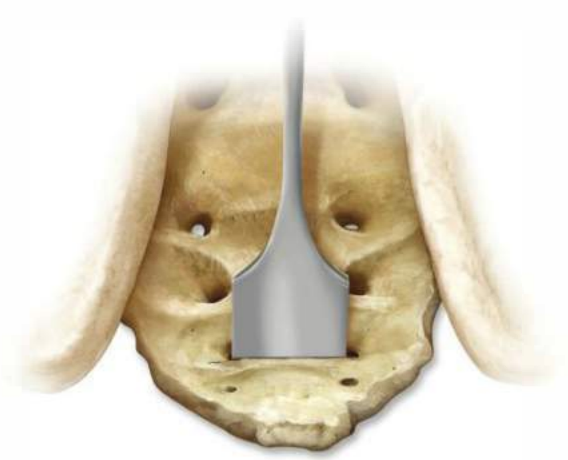


FIG 16 ● Diagram showing how low sacrectomy is performed by using an osteotome and a mallet.

- It is also useful to leave both lumbosacral trunks marked with a yellow vessel loop and to have a suture to orientate a rectus abdominis myocutaneous flap to avoid flap malrotation. Abdominal sponges may also be left just anterior to the sacrum to prevent small bowel from coming into contact with the anterior aspect of sacrum, which may be inadvertently injured as the sacrum is being transected from the prone approach.
- Prone approach to high sacrectomy is usually performed in collaboration with orthopedic surgeons or neurosurgeons and begins with a longitudinal incision in the natal cleft that extends from the posterior aspect of the perineal incision.
- The incision is deepened until the sacrum is reached. Attachments of gluteus maximus are released bilaterally so as to provide access to the sacrum (**FIG 17B**). Deep to gluteus maximus are the sacrococcygeal, sacroiliac, and the sacrotuberous ligaments, which are also released. Dividing these soft tissue attachments frees the lateral borders of the sacrum. Deep to the sacrotuberous ligament is the sacrospinous ligament, which is divided exposing the underlying piriformis muscles. Immediately deep to

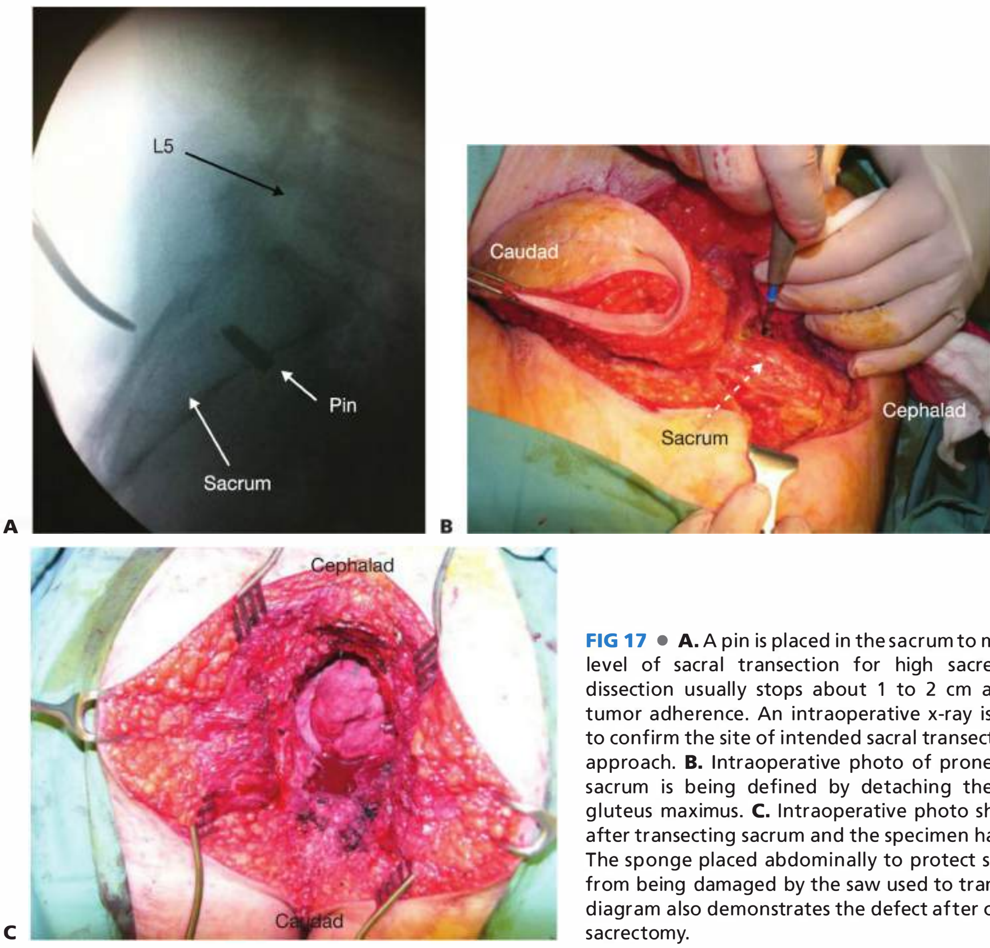


FIG 17 ● **A.** A pin is placed in the sacrum to mark the intended level of sacral transection for high sacrectomy. Posterior dissection usually stops about 1 to 2 cm above the site of tumor adherence. An intraoperative x-ray is then performed to confirm the site of intended sacral transection from a prone approach. **B.** Intraoperative photo of prone sacrectomy. The sacrum is being defined by detaching the attachments of gluteus maximus. **C.** Intraoperative photo showing the result after transecting sacrum and the specimen has been retrieved. The sponge placed abdominally to protect small bowel loops from being damaged by the saw used to transect sacrum. This diagram also demonstrates the defect after completing a high sacrectomy.

piriformis are the sacral nerve roots. It is imperative that the operator remains close to the lateral border of the sacrum to avoid any injury to these nerve roots.

- The level of transection is confirmed by a cross-table x-ray to check the position of the pelvic staple placed above the tumor (**FIG 17A**). This enables the sacrum to be transected with the staple in situ so as to ensure adequate bony margins.
- Once the level is determined, the sacral crest between the median and intermediate sacral crest is resected to expose the dural sac, which is ligated to prevent ongoing leakage of cerebrospinal fluid.
- Sacrectomy is then completed by using a handheld oscillating saw. The specimen is removed, exposing the abdominal pack protecting small bowel loops (**FIG 17C**). Hemostasis is secured; bone wax may be necessary to stop bleeding from exposed cancellous sacrum. The vessel loops around lumbosacral trunks should be intact and need to be removed. The preinserted abdominal drain needs to be repositioned and the preorientated rectus abdominis flap can then be retrieved and secured in place.

Perineal Phase

- The perineal phase is carried out with the patient in wide lithotomy position. This phase is usually only commenced when abdominal dissection is near completion.
- The extent of perineal excision required depends on the location of the cancer. The wider the perineal excision, the more likely the patient is to require closure using a pedicled myocutaneous flap to avoid tension closure, which will only predispose to perineal wound breakdown and prolonged healing due to previous irradiation.
- An elliptical skin incision is made. Using Lone Star retractor, the incision is deepened into ischiorectal fossa fat. Depending on the planned dissection plane from the abdominal compartment, the incision is deepened to approximate the dissection plane from the abdominal compartment. Wide excision of levator muscle is usually performed even if the amount of perineal skin excised does not have to be excessive.
- When en bloc distal sacrectomy is required, the perineal surgeon continues dissecting immediately posterior to the coccyx to the proposed level of sacrectomy, detaching gluteus maximus from the lateral and posterior aspects of coccyx and lower sacrum. A malleable retractor blade or second osteotome is then placed into the space to protect natal cleft soft tissue which the abdominal surgeon divides the sacrum using an osteotome and mallet.
- When a proximal sacrectomy is required, the perineal wound is temporarily closed so that the patient can be turned prone for the posterior dissection.

Urinary Reconstruction

- When an en bloc cystectomy is required, reconstruction using ileal or colonic conduit is usually performed. The decision for an ileal or colonic conduit is surgeon dependent and although ileal conduits are usually preferable in the urologic literature, in patients with LRRC where pelvic small bowel loops may have been previously irradiated, isolating a segment of ileum may be associated with increased risk of postoperative complications including anastomotic leak from the ureteroileal anastomosis and the ileoileal anastomosis.
- A colonic conduit is usually out of the radiation field and a study from our institution found a higher leak rate with ileal conduits as opposed to colonic conduits. Further, to minimize the risk of ileoileal anastomotic leaks, the segment of ileum isolated should be such that the subsequent ileoileal anastomosis is at least 10 to 15 cm away from the ileocecal valve so that it is away from the back pressure exerted by the valve.
- The use of orthotopic neobladder reconstruction is popular within the gynecologic oncology literature but few, if any, are considering the technique in LARC or LRRC.
- When en bloc partial cystectomy is required, double-layered suture repair of the bladder in conjunction with leaving the indwelling urinary catheter in situ for a minimum of 7 days with a check cystography prior to catheter removal is usually sufficient.
- When a segment of ureter is involved unilaterally, depending on the extent of ureteric excision and preexisting renal function in the kidney involved, the options are to consider a ureteric reimplantation with a psoas hitch, reimplanting the resected ureter to the contralateral ureter, or if renal preserving options are not available, a nephrectomy. Anastomosing the resected ureter to the contralateral ureter is avoided where possible as any anastomotic problem or surgical complication can have repercussions on both kidneys instead of one.
- To perform ureteric reimplantation and psoas hitch, the bladder has to be adequately mobilized bilaterally. Once the bladder is mobilized, a transverse cystostomy is performed. By inserting a finger through the cystostomy, an assessment is made to determine the best position for the ureter to be anastomosed to the bladder without excessive tension. A separate small cystostomy is created and the ureter is pulled through and anastomosed to the bladder using fine absorbable sutures over a ureteric stent. Reinforcing sutures are placed between the bladder and the psoas tendon to avoid traction injury on the newly created ureterovesical anastomosis. The cystostomy is then closed longitudinally in two layers, completing the reconstruction.

Intestinal Reconstruction

- When an ileal conduit is fashioned and when a segment of small bowel is resected en bloc with the main specimen, intestinal continuity needs to be restored, either using a hand-sewn or stapled anastomosis.
- Most patients with LRRC will require an end colostomy.
- Patients with LARC or selected patients with early anastomotic recurrences may be suitable for a colorectal anastomosis provided there are no other contraindications for the anastomosis. Even if a colorectal anastomosis is performed, in view of the complex surgery and previous irradiation, these patients should be at least temporarily defunctionalized with a proximal stoma.

Abdominal and Perineal Closure and Reconstruction

- In patients where a wide perineal excision, high sacrectomy, or complete pelvic exenteration has been performed, consideration needs to be given to flap reconstruction. Although our preference is for rectus abdominis myocutaneous flap, other perforator flaps based on the inferior gluteal artery perforator (I-GAP) or anterior thigh flaps may be necessary when the rectus abdominis is not available due to previous stomas.
- Rectus abdominis on the side where there are no prior stomas is preferable. In our practice, a vertical elliptical skin paddle (used for simplicity and ease of abdominal skin closure) with a maximum diameter of 5 cm is harvested (**FIG 5**) with the underlying anterior sheath and rectus abdominis muscle but leaving the posterior sheath intact. We avoid excessively wide skin paddles as this may introduce donor site morbidity with difficult abdominal skin closure and tension on stomas.
- The flap can then be rotated into the pelvis after harvesting. There are two possible ways of rotating the flap. The first is to rotate the flap with the pedicle acting as a pivot and the second is to roll the flap downward like a "Swiss roll."
- After harvesting the flap, it is important to raise skin flaps either on the ipsilateral side alone or bilaterally (if there are no existing stomas) prior to fashioning stomas. Broad-based skin flaps are raised on the external oblique with hemostasis of perforators as they penetrate the anterior abdominal wall to supply the overlying skin.
- Prior to abdominal and perineal wound closure, a thorough lavage of the abdomen, pelvis, and perineal wound is carried out. Hemostasis is checked to ensure there is no active bleeding. Minor oozing is not uncommon but should be controlled with electrocautery, clips, or sutures where possible. Ongoing oozing may require topical hemostatic agents such as Gelfoam®, Surgicel®, or Nu-knit®. At least one large-bore drain is placed in the pelvis, making sure that it drains the most dependent part of the pelvis.
- The myocutaneous flap is usually secured in the perineum using a combination of absorbable dermal and nonabsorbable skin sutures.
- When myocutaneous flaps are not required, the perineal wound is closed in layers. Due to wide excision of levator ani, muscle closure is generally not possible and closure is generally that of subcutaneous fat and skin using a braided suture such as Vicryl.
- There has been an increasing interest in prophylactic mesh repairs of the perineal wound to prevent subsequent perineal hernias. Currently, the safest and cost-effective method remains unclear, with some authors reporting the use of flaps and others the use of biologic mesh. Considering the high prevalence of postoperative pelvic septic complications and low prevalence of perineal hernias in our practice, we have not found prophylactic perineal mesh repair beneficial.
- Abdominal closure when a rectus abdominis flap is not required is relatively straightforward using mass closure with either a no. 1 polydioxanone (PDS) suture or nylon suture. However, when a rectus abdominis flap has been harvested, the abdominal wall will require mesh reconstruction to prevent a future incisional hernia. In these patients, closure of the posterior sheath on the ipsilateral side of harvest to full thickness of the abdominal wall on the contralateral side is performed using no. 1 PDS suture. It is important to remain mindful of the inferior aspect of the midline laparotomy wound where closure should be loose to prevent strangulating the arterial supply or impeding venous drainage of the flap particularly when edema sets in after surgery.
- An onlay mesh repair using polypropylene mesh is then carried out to reinforce the abdominal wall, securing it to the linea semilunaris laterally and the linea alba in the midline wound using 2.0 Prolene suture (**FIG 18**). A drain is also placed to prevent wound seromas.
- Abdominal skin closure is performed using a combination of skin staples and nonabsorbable interrupted vertical mattress sutures.

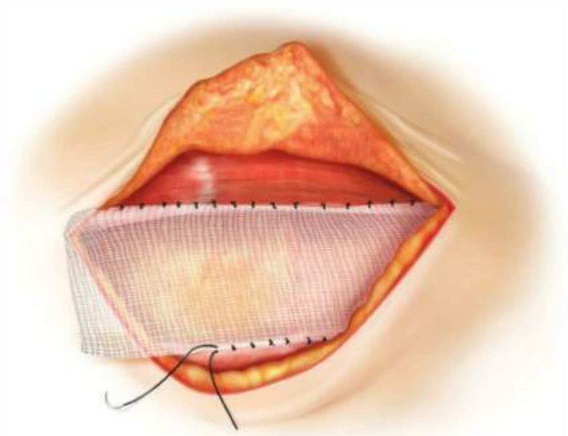


FIG 18 ● Abdominal wall reconstruction using polypropylene mesh.

PEARLS AND PITFALLS

Intraoperative surgical management	■ Meticulous adhesiolysis to avoid inadvertent enterotomies will prevent future complications. A trial of dissection is permissible but if the tissue is very adherent, consideration should be given to en bloc excision of that structure to avoid an involved surgical margin.
Lateral compartment dissection	■ The pelvic sidewall is organized in a "layered" structure. The layers are the ureter, the iliac arteries, the iliac veins, the lumbosacral trunk, and pelvic sidewall muscles.

Meticulous venous dissection	■ Although highly variable, there is an underlying pattern to venous drainage. ■ Usually, there is at least one spinal, gluteal, and visceral tributary entering the main trunk of internal iliac vein at each level. ■ Dissection of each tributary such that there is an adequate cuff before ligation of each tributary is advisable to prevent ties from slipping due to a short cuff. ■ Suture ligation is preferred over clips as it is not unusual for clips to slip or be inadvertently dislodged. ■ When suture ligation fails to control bleeding, adjacent muscle tissue can be used as a pledget and provides additional bulk for providing direct pressure for hemostasis.
Visceral reconstruction	■ In patients with LRRC, heavily irradiated small bowel loops are poor candidates for ureteroileal or ileoileal anastomosis. In these patients, a colonic conduit may be considered as the colon is typically beyond the irradiation field. ■ Mixed colostomies (combined urine and stool stomas) are not routinely advised.
Perineal reconstruction	■ Most recurrences do not require wide perineal excision. However, in patients with wide perineal excision and/or with a sacrectomy, a rectus abdominis myocutaneous flap reconstruction provides well-vascularized tissue in the pelvis to fill the "dead space" and to additional skin paddle to facilitate tension-free skin closure. ■ Alternatively, a pedicled omental flap is also very useful to fill the space within the pelvis to prevent infected fluid collections.
Postoperative management	■ Prolonged ileus is common. Early commencement of total parenteral nutrition should be considered. ■ In view of high complication rates, a high index of clinical suspicion is required for early recognition and treatment to prevent further morbidity.

POSTOPERATIVE CARE

- All exenteration patients are routinely admitted to an intensive care unit for postoperative care. The patient is often left intubated overnight.
- Aggressive fluid and blood product replacement and correction of coagulopathy is often required after a complete exenteration with en bloc sacral resection.
- Prolonged ileus is common; early initiation of total parenteral nutrition is recommended.
- Mechanical venous thromboprophylaxis is vital.
- Patients who have had a flap reconstruction are usually required to rest in bed for the first 5 to 7 days after surgery. It is important that these patients are turned regularly to minimize pressure on their flaps. Flap observations should also be performed regularly to ensure the flap remains well perfused.
- In patients with a urinary conduit, it is imperative to ensure that the patient is well hydrated to maintain a good urine output. Regular drain fluid creatinine check (1 to 2 days) also helps to detect urinary leaks early so that intervention can be readily instituted to avoid further morbidity.
- Septic complications are also particularly common in this group of patients; thus, it is common to continue prophylactic antibiotics for 5 days after surgery. Most causes of sepsis originate from urinary sepsis, infected abdominal or pelvic collections, and hospital-acquired pneumonia. Early mobilization and chest physiotherapy are helpful.
- Infected pelvic collections are common and are usually diagnosed on CT performed for persistent fevers with no obvious source. One of the challenges with interpreting CT scans after such surgery is distinguishing between infected and noninfected fluid collections as postoperative fluid collections are also very common. Postoperative inflammatory changes also take a longer time to dissipate; hence, interpretation of the CT by an experienced radiologist in conjunction with the surgeon is helpful. Keeping an abdominal drain in situ for a longer period of time may allow the drain to be rewired for abdominal drain replacement as opposed to a transgluteal approach for drain insertion, which is usually uncomfortable.
- In patients who have undergone a high sacrectomy, early documentation of neurologic deficit in lower limbs is helpful before swelling of nerves. Neuropathic pain in this group of patients is common and early input from the acute and chronic pain teams with early consideration for gabapentin may be helpful to facilitate pain management.
- Most patients will require ongoing input from dietitians, stomal therapists, and psychooncologists. Further, most patients will require a period of inpatient rehabilitation at a rehabilitation center. Thus, early involvement of all allied health specialists is important. As follow-up plans are often complex, clear written instructions and contact persons should be provided.

OUTCOMES

- The main aim of surgery is to achieve a clear resection margin (R0) as this is the single most important predictor of long-term survival.
- R0 rates within the literature vary between 38% and 85%. In as much as R0 is the most important surgical outcome, R0 is by no means an accurate reflection of a recurrent cancer unit's experience and performance because, as alluded to early in the chapter, different units have different resectability criteria. Without an understanding of the types of exenterations offered, units performing only limited exenterations on patients with good prognostic features may be seen to outperform higher volume and more established units.

Table 1: Complications from Pelvic Exenteration

Septic complications
- Urinary tract infection
- Wound infection
- Pneumonia
- Deep-seated intraabdominal/pelvic collections
- Osteomyelitis

Gastrointestinal complications
- Prolonged ileus
- Small bowel obstruction
- Enterocutaneous fistula
- Anastomotic leak
- Colovaginal fistula

Cardiorespiratory complications
- Atrial fibrillation or other cardiac arrhythmias
- Myocardial infarction
- Pulmonary embolism (deep venous thrombosis)

Wound complications
- Wound dehiscence
- Persistent perineal sinus
- Perineal flap necrosis
- Infected prosthetic mesh
- Hematomas

Urologic
- Urinary retention
- Urologic leak
- Colovesical fistula

Neurologic
- Sciatic nerve palsy

Stomal complications
- Stomal dehiscence
- Ischemia

- Pelvic sidewall recurrence was traditionally considered a formidable challenge because of the difficult dissection, risk of major bleeding, and concerns for involved surgical resection margins, and, therefore, often considered incurable. However, with improved surgical techniques, pelvic sidewall as a site of recurrence is no longer considered a contraindication for surgery and provided clear margins can be obtained, comparable survival with recurrence at other sites can be achieved.
- Quality of life in patients following pelvic exenteration is an area that remains understudied. Although much remains unknown, it is known that quality of life following exenteration is comparable to that of patients after total mesorectal excision for primary rectal cancer.

COMPLICATIONS

- Reported mortality rates range between 0.3% and 8%, although larger series in recent years have tended to report mortality rates of less than 1%.
- Published complication rates range from 21% to 72%, with major complication rates within contemporary literature originating from high-volume centers at about 25%.
- Common complications published are listed in Table 1.

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Chapter 40

Transanal Excision of Rectal Tumors

Ryan M. Thomas *Barry Feig*

DEFINITION

- Transanal excision (TAE) of rectal tumors refers to the complete resection of a benign or malignant neoplasm of the distal rectum such that negative surgical margins are achieved while avoiding the morbidity of transabdominal resection procedures.

PATIENT HISTORY AND PHYSICAL FINDINGS

- Not all patients are candidates for TAE of rectal tumors and many factors may prove to be a contraindication to such treatment. The surgeon must take into account physiologic, anatomic, and pathologic factors in order to deem a patient an appropriate candidate for TAE of a benign or malignant rectal tumor (Table 1).
- A full history must be performed with special focus on any changes in bowel habits including stool caliber, the presence of melena or hematochezia, personal or family history of colorectal cancer, and the use of any antiplatelet or anticoagulant medications in preparation for surgical excision.
- Physiologic factors and patient desires may make TAE a viable option, namely in patients who physiologically cannot tolerate an extensive transabdominal resection or have a short life expectancy because of metastatic disease yet have a bleeding tumor in need of palliation. In addition, some patients may not desire an abdominoperineal resection and resultant permanent colostomy or the possibility of sexual dysfunction. Given appropriate physical and pathologic criteria, these patients may be appropriate candidates for TAE as well.
- A thorough physical examination must be performed with special focus on rectal tone, location of the rectal tumor, distance of the tumor from the anal verge, and mobility/fixation of the tumor to underlying structures. These physical factors are critical to determine the feasibility of resection as the criteria for resection demands that the lesion:
  - Be within 8 to 10 cm of the anal verge in order to technically reach the lesion
  - Must be mobile and not fixed to underlying tissue
  - Must involve less than 30% of the circumference of the rectal wall on endoscopic evaluation, as anything greater risks nodal involvement or narrowing the rectal lumen after excision is performed.
- Often, patients are referred for TAE of a rectal tumor after having undergone endoscopic evaluation that diagnosed a malignant mass or a benign mass not amenable to endoscopic resection.
- Established pathologic criteria for TAE of a malignant lesion include T1 lesions, no evidence of lymphovascular invasion (LVI) or perineural invasion (PNI), moderately to well-differentiated tumors, or an endoscopically removed polyp with indeterminate pathology.

IMAGING AND OTHER DIAGNOSTIC STUDIES

- Endoscopy plays an essential role in the management of mid- to low rectal lesions in patients who may be candidates for TAE. Endoscopy defines the anatomy of the lesion and special attention should be made to the anatomic location, as this will affect surgical positioning. The tumor diameter, location from the anal verge, and degree of circumferential involvement are noted as they dictate the appropriateness of TAE as well.
- Assuming that a malignant lesion is technically resectable via a transanal approach, one must ensure that the lesion is a T1 stage and without nodal involvement. The transanal approach for rectal tumors has garnered support because of the decreased morbidity compared with a transabdominal approach but lymph node metastasis has been reported in 10% to 18% of T1 lesions.
- Imaging therefore plays an essential role in the preoperative planning for patients considered candidates for TAE of rectal tumors. In the case of malignancy, staging imaging should include the following:
  - A chest x-ray and computed tomography (CT) of the abdomen and pelvis to assess for metastatic disease
  - Critical to the determination of the local resectability of a rectal lesion is the assessment of the T stage and N stage of the tumor. The accuracy of determining the depth of invasion by CT scan, magnetic resonance imaging (MRI), and endoscopic rectal ultrasound (ERUS) is 73%, 82%, and 87%, respectively. Nodal metastases are accurately assessed by CT scan, MRI, and ERUS in 66%, 74%, and 74% of cases, respectively. The use of endorectal coils during MRI has been found to be equivalent to ERUS for T stage determination but superior in terms of nodal status.

Table 1: Criteria for Transanal Excision of Rectal Tumors

Patient Factors	Anatomic Factors	Pathologic Factors
• Comorbidities that preclude transabdominal resection • Short life expectancy in need of surgical palliation • Refusal of abdominoperineal resection and resultant permanent colostomy	• Lesion ≤8–10 cm from the anal verge • Lesion involves ≤30% of rectal circumference • Lesion ≤3cm in diameter • Mobile and not fixed to underlying tissue • Negative margins achievable depending on pathology of primary lesion (0.3–1 cm)	• Moderately or well-differentiated tumor • T1 tumor • No lymphovascular or perineural invasion • Indeterminate pathology on polypectomy • No evidence of lymphadenopathy on preoperative imaging

- Any biopsies that are performed of the rectal tumor prior to definitive excision should be re-reviewed to confirm the tumor depth of invasion, differentiation, and the presence of LVI or PNI.

SURGICAL MANAGEMENT

Preoperative Planning

- In most cases, patients should be instructed to discontinue anticoagulation and antiplatelet medications 7 to 10 days prior to the planned procedure if medically feasible.
- A specific bowel preparation does not have to be performed except that the patient should self-administer a sodium phosphate enema the evening prior to the procedure in order to evacuate the rectal vault.

Patient Positioning

- Positioning of the individual depends on the anatomic location of the rectal tumor to be excised, which should be determined on preoperative physical examination and endoscopy.
- Because it is technically easier to visualize and resect rectal tumors when they are located closer to the operating room (OR) table, patients with a rectal tumor along the posterior rectal wall should be positioned in high lithotomy such that their coccyx can be easily palpated (**FIG 1**). In contrast, patients with lesions located along the anterior rectal wall should be placed in the prone jackknife position.
- For patients placed in the prone position, heavy tape should be applied to the buttocks so that they can be retracted laterally and secured to the OR table. A 2-in–wide tape should be used and secured to the buttocks with benzoin ointment to prevent the tape from slipping during the procedure.
- Once in position with pressure points appropriately padded, a digital rectal exam is performed to confirm tumor location and the rectum is irrigated with saline until all solid material has been removed. The perineum is then prepped with Betadine and appropriately draped.

FIG 1 ● Patient positioning. For posterior lesions, the patient is placed on a high lithotomy position. It is important that the coccyx can be palpated, which ensures that they are low enough on the bed and adequate exposure to the lesion can be obtained.

EXPOSURE OF THE LESION

- Because of the limited working area, exposure is key to safe TAE with adequate margins.
- The operating surgeon must have a high-intensity headlight to aid visualization and a long, narrow suction apparatus is helpful for both smoke evacuation and fluid removal.
- The goal of exposure for TAE is to bring the lesion closer to the anus and avoid retractors that tend to push the lesion away. There are several methods and instruments that are available to achieve this goal.
- A Lone Star retractor may be used to help evert the anus and gain better exposure. Alternatively, a series of nylon sutures placed circumferentially in a simple fashion from the internal sphincter to the thigh can achieve a similar result. The use of these techniques is particularly helpful for posterior lesions when the patient is in the lithotomy position.
- For men in the lithotomy position, it may be helpful to secure the scrotum to the inner thigh with a 2-0 silk or other similar suture in order to remove it from the operative field. This is not necessary in the prone jackknife position as gravity provides the necessary retraction.
- A Parks self-retaining retractor, with the option of the additional center blade, is then placed in the anus to provide exposure, with an assistant using an appropriately sized lighted Hill-Ferguson retractor for additional exposure (**FIG 2**). A variety of other self-retaining and handheld retractors may be considered depending on the patient's anatomy.

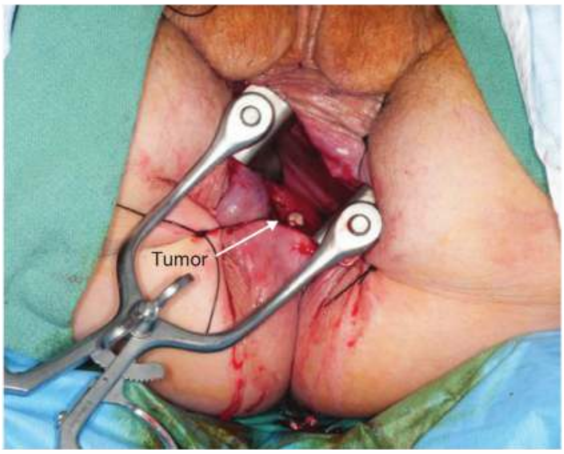

FIG 2 ● Exposure of the lesion. A self-retaining retractor, such as the Parks retractor, is placed into the anus and rectum and gently opened. A Lone Star retractor or a series of 2-0 nylon sutures placed around the periphery of the anus can be used to evert the anal canal and bring the lesion closer to the field prior to placing the Parks retractor. This is especially useful in obese individuals or for lesions that are at the maximum extent of reach (8 to 10 cm from the anal verge).

DEFINING THE SURGICAL MARGIN

- Once the lesion has been identified, electrocautery is used to score the mucosa circumferentially around the mass. This step is critical to define the appropriate margin: 1 cm for malignant lesions and at least 0.3 cm for benign lesions or those with indeterminate pathology on preoperative pathologic evaluation (FIG 3).
- It is important to flatten the surrounding mucosa with the use of the Hill-Ferguson retractor or a flat right-angle (Haney) retractor as the margin is being scored. The back end of DeBakey forceps is especially useful for this purpose as well (FIG 3). Failure to flatten the mucosa may result in a margin that is far greater or lesser than the intended margin because of mucosal folding.

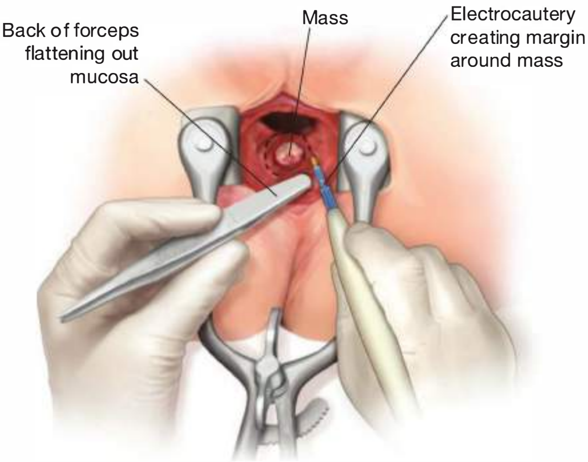

FIG 3 ● Defining the surgical margin. Once adequate exposure is obtained, electrocautery is used to mark out the surgical margin: 1 cm for malignant lesions and 0.3 cm for benign lesions or those of indeterminate pathology. Because mucosal folds can obscure the true margin and lead to a margin that is lesser or greater than intended, using the back of a DeBakey forceps or a handheld retractor such as the Hill-Ferguson retractor can help flatten the mucosal folds so an appropriate margin can be defined.

PLACEMENT OF RETRACTION AND ORIENTATION SUTURES

- For proximal lesions or in patients where visualization is less optimal, a 2-0 Vicryl retraction (stay) suture can be placed at the apex of the surgical specimen outside of the scored margin, tied into place, and used to bring the lesion closer to the operator, if necessary, during resection (FIG 4A).
- Next, sutures should be placed within the outlined margin to serve as orientation sutures once the specimen has been removed. A short proximal suture with one suture end cut and a long left lateral suture leaving both suture ends long avoids confusion and will ensure proper orientation of the specimen should additional margins need to be removed (FIG 4B).

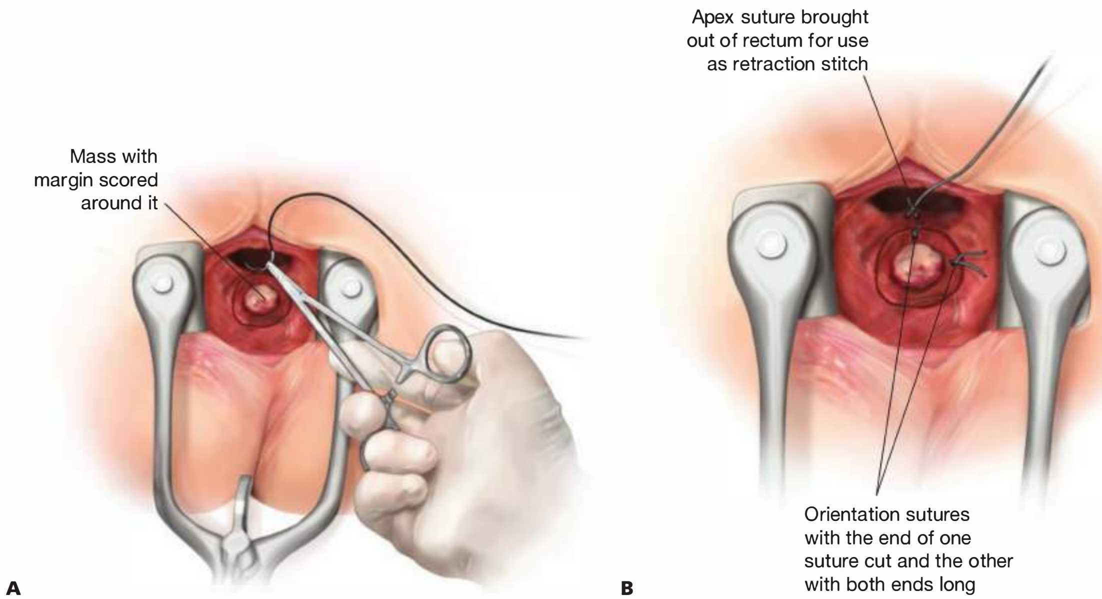

FIG 4 ● Placement of retraction and orientation sutures. **A.** Just outside of the most proximal extent of the surgical margin, a 2-0 Vicryl suture is placed and tied. The suture is left long and is brought out of the rectum and secured to the surgical drapes. This suture can be used during the excision for retraction and to help bring the lesion closer to the operator. **B.** Sutures of different length are then placed within the surgical margin that will serve as orientation sutures. As an example, a single short suture may be used for the proximal margin and a long suture for the left lateral margin. These sutures should be placed early in the case to maintain orientation for pathologic margin assessment.

FULL-THICKNESS EXCISION OF THE MASS

- Using electrocautery, a full-thickness excision of the mass is performed down to the deep perirectal tissue. A long needle-tip electrocautery device can often be helpful in providing access without obstructing visualization. It is easier to begin the dissection distally and work around the margins proximally; this allows for a more apparent identification of the perirectal tissue as it is encountered and helps to guide the rest of the proximal and deep extent of the excision (**FIG 5**).
- Special attention should be taken to create the electrocautery line of excision perpendicular to the rectal wall to avoid undermining the edges of the specimen and compromising the margins.

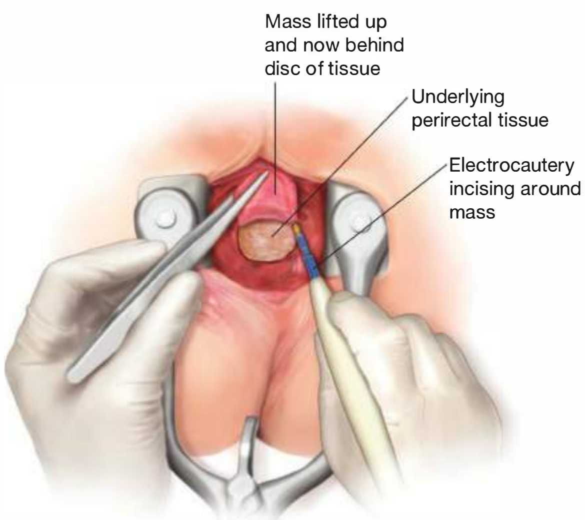

FIG 5 ● Full-thickness excision of the mass. Electrocautery is used to create a full-thickness defect through the rectal wall until the perirectal fat is identified. It is easier to begin at the most distal aspect of the lesion because visualization is better. Once the full-thickness defect is created, the free edge of tissue or a retraction suture is grasped to lift the mass and normal tissue away from the underlying perirectal fat as the excision proceeds proximally along the lateral aspects of the lesion, leaving the most proximal part of excision for last.

- Once the perirectal tissue is encountered, the mass is continually lifted away from this underlying tissue and detached from it using the electrocautery. The goal is to remove a disc of tissue that contains the mass, adequate margins, and a portion of tissue deep to the mass to ensure adequate full-thickness excision and pathologic evaluation. Special attention must be taken during the full-thickness excision of anteriorly located lesions because injury to the vagina or prostate can occur if the excision is carried too deeply.
- As the excision proceeds, gentle traction of the orientation and stay sutures can provide additional tension to facilitate the excision or to bring the tissue closer to the operator.

SUBMITTING THE SPECIMEN TO PATHOLOGY

- An important part of the TAE of a rectal mass is specimen orientation for the pathologist. After the mass has been excised, it should be fixed to a wax board with 22-gauge needles and hand delivered to the pathology suite so that the surgeon can speak directly to the pathologist for specimen orientation and margin assessment (**FIG 6**).
- The margins are inked and assessed. If tumor cells are present at any of the margins, additional tissue must be removed.

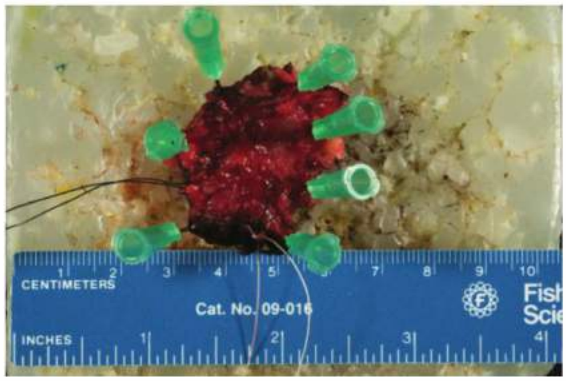

FIG 6 ● Submitting the specimen to pathology. The resected specimen is then secured to a wax board with 22-gauge needles for proper orientation. Because orientation sutures were placed early in the case, there should be no confusion about the specimen orientation. The surgeon then brings the specimen to the pathology suite to confirm orientation with the pathologist and the margins are inked and assessed. If tumor cells are present at any of the margins, additional tissue must be removed.

CLOSURE OF THE RECTAL WALL DEFECT

- Once appropriate hemostasis is obtained and no additional margins need to be taken, attention is turned to the closure of the resultant rectal wall defect (**FIG 7**). Interrupted Vicryl sutures are used to approximate the mucosa and submucosa. The sutures should be slightly spaced to allow for drainage to occur and to prevent hematoma formation (**FIG 8**). If there is difficulty obtaining adequate hemostasis, a running, locking suture can be used.
- The running suture is tied just before the end of the defect is reached, leaving a small opening for drainage to occur.
- Alternatively, the defect may be closed over a ¼-in Penrose drain secured into place with the final pass of the

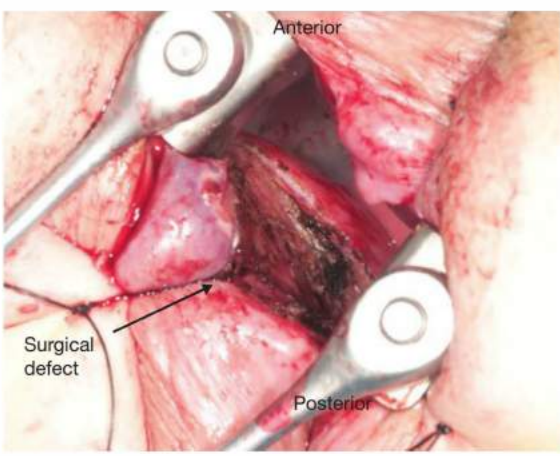

FIG 7 ● Hemostasis of rectal defect. The resultant rectal defect is irrigated and hemostasis is obtained prior to closure.

chromic suture to allow fluid to drain. The patient will eventually pass the drain once the chromic suture has dissolved.

- In the case of a large defect in which there is too much tension to reapproximate the mucosa, the defect may be left open to heal by secondary intention.
- After the defect has been closed, the retractors are removed and a digital rectal exam is performed to confirm patency of the rectum.
- A rolled-up piece of hemostatic agent (Fibrillar, Gelfoam) may be placed into the rectum, overlying the suture line, to provide additional hemostasis.

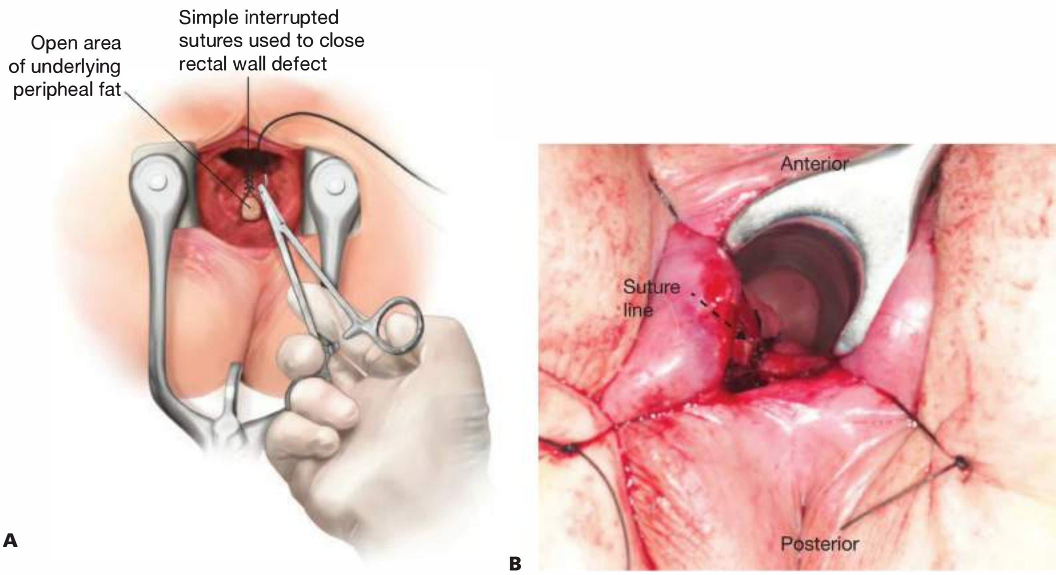

FIG 8 ● Closure of the rectal wall defect. **A.** After appropriate hemostasis is obtained, the rectal wall defect is closed with a 2-0 Vicryl suture. **B.** Beginning at the most proximal aspect of the defect, the full-thickness rectal wall is reapproximated in a running fashion. The sutures are locked to provide better hemostasis and the suture is tied just before the end of the defect is reached, leaving a small opening to allow drainage.

PEARLS AND PITFALLS

Preoperative	■ It is often more difficult to obtain adequate exposure in obese patients because of body habitus. Take extra time retracting the buttocks laterally with tape for prone cases, as well as using a Lone Star retractor to help evert the anus and create better exposure. ■ High recurrence rates occur with lesions greater than T2 or other aggressive pathology (PNI, LVI). Re-review the pathology to ensure the lesion is appropriate for TAE.
Intraoperative	■ Avoid retractors that "push" the lesion away and use sutures if necessary to help bring the lesion more distal. ■ Avoid grasping the typically friable mass but instead use sutures to provide traction. ■ Place marking sutures early so as to not lose the specimen orientation. ■ Full-thickness excision is confirmed by identification of perirectal fat. Pay special attention not to perform a partial thickness excision. ■ Excision of anterior lesions runs the risk of injury to the vagina or prostate. ■ Defects, especially when posterior, may be left open without reapproximating the rectal wall.
Postoperative	■ A consistent and aggressive bowel regimen is most important to prevent suture line disruption and keep the patient comfortable.

POSTOPERATIVE CARE

- Patients usually have minimal, if any, pain immediately after a TAE. Patients may have spasms of the anal sphincter that can be treated symptomatically with muscle relaxants but these are typically self-limited.
- Because of the fresh suture line, it is important that the patient be placed on an aggressive bowel regimen postoperatively to prevent suture line disruption. This should include a combination of stool softeners and fiber bulking agents, as well as mineral oil to lubricate the stool. Using such a bowel regimen will increase the postoperative comfort for the patient as well.

OUTCOMES

- Five-year survival rates after TAE for patients with a T1 rectal cancer without nodal metastasis, LVI, and PNI are comparable to surgical resection and range from 70% to 87% for TAE compared to 80% to 93% for standard surgical resection.
- Local recurrence rates have been shown to be statistically higher when TAE is performed versus standard surgical resection with local recurrence rates of 6% to 12.5% after TAE versus 2% to 7% after standard resection.
- Salvage surgery in the form of a standard resection (low anterior or abdominoperineal resection) can be performed in cases of tumor recurrence after TAE, but R0 resection rates are typically low and survival is poor unless immediate salvage is performed at the time of recurrence diagnosis.
- Treatment of T2 lesions with TAE is still controversial but a recent phase II trial (American College of Surgeons Oncologic Group [ACOSOG] Z6041) treated 90 patients with uT2N0 lesions by ERUS with preoperative chemoradiation followed by local excision. The margin-negative rate was 98%, with 44% of patients having a complete pathologic response. More data is still needed to support the local excision of T2 lesions but may be warranted in patients with multiple comorbidities who are unable to tolerate a large surgical resection.
- TAE for the treatment of T3 lesions is not considered standard of care. There are case reports of successful outcomes using TAE for locally advanced tumors after downstaging with neoadjuvant chemoradiation therapy. Further prospective evaluation is needed to establish patient/pathologic criteria that will predict for successful outcome using TAE in more advanced tumors.

COMPLICATIONS

- Bleeding
- Infection/pelvic sepsis
- Injury to the prostate or vagina for anteriorly located lesions
- Pain (if resection involves the dentate line) or from postoperative scarring
- Stenosis of the anus or rectum
- Incontinence
- Urinary retention

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Chapter 41 Transanal Endoscopic Microsurgery

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DEFINITION

- Transanal endoscopic microsurgery (TEM) is a minimally invasive technique that was originally developed by Dr. Gerhard Buess in 1983 to extend transanal access to benign and select malignant tumors. It is used to treat a variety of rectal lesions including benign adenoma, low-risk carcinoma, and more advanced cancers after neoadjuvant therapy.
- This procedure is performed transanally with specially designed microsurgical instrumentation. This surgical approach is both a single-port surgery and a natural orifice transluminal endoscopic surgery (NOTES).
- TEM is preferable over radical resection in select patients due to the ability to safely eradicate the disease with a wide full-thickness local excision while simultaneously sparing the morbidity of a major transabdominal surgery and preserving sphincter function.

DIFFERENTIAL DIAGNOSIS

- Adenomas and other types of polypoid lesions found in the colon and rectum include hyperplastic polyps, serrated adenomas, flat adenomas, hamartomatous polyps, and inflammatory polyps.
- Most colorectal cancers are adenocarcinomas (90% to 96%), but other rare malignancies include signet-ring cell carcinoma, squamous carcinoma, undifferentiated neoplasms, neuroendocrine tumors, gastrointestinal stromal tumors (GISTs), carcinoids, and melanoma.

PATIENT HISTORY AND PHYSICAL FINDINGS

- The TEM procedure is primarily used to treat benign or malignant rectal lesions. In order to determine if TEM is the appropriate procedure for the patient, a full history and physical examination must be performed to evaluate both the general health of the patient and the extent of disease. Patients that are medically compromised may not be able to tolerate a radical procedure, making a local excision the only option.
- Ideal candidates for TEM are patients with early, nonextensive tumors. This procedure can be used for patients in good health and is also a wonderful option for those who are medically compromised, as the approach is less invasive than radical abdominal surgery and extends the transanal approach up to the level of the rectosigmoid.
- The fundamental objectives of rectal cancer management are complete tumor control and patient survival. However, perhaps in no other cancer are quality-of-life issues of such importance as the need for a permanent colostomy hangs in the balance.
- There are several secondary goals that are desirable and must be considered when deciding upon the best treatment option for rectal cancer. These include preserving sphincter function, minimizing patient morbidity and mortality, minimizing patient trauma, maintaining bladder and sexual function, and avoiding a permanent colostomy. The primary goal of cancer control along with the secondary goals can be achieved with TEM surgery under appropriate conditions.
- It is important to inquire about bowel habits, anal sphincter function, bladder and sexual function, past medical history, and past surgical history. It is important to discuss the genetic risk of colon cancer with the patient so that they can inform their relatives to get proper surveillance colonoscopy. Suspicious symptoms include change in bowel habits, rectal bleeding, rectal pain, or mucous discharge.
- A thorough digital rectal exam is the single most important component of the preoperative evaluation for lesions in the bottom half of the rectum. The status of sphincter tone must always be checked as this impacts significantly on treatment decisions.
- We recommend using both flexible sigmoidoscopy and rigid proctoscopy as part of the physical examination. Rigid proctoscopy offers a more accurate localization of the lesion's position, whereas the flexible sigmoidoscope provides a much clearer image of the lesion. The most important tumor characteristics to evaluate are level in the rectum (from the anorectal ring and the anal verge), mobility/fixation, position of mass (midpoint), size of the tumor, circumference involvement, obstruction, ulceration, and the estimation of the clinical stage of disease.

IMAGING AND OTHER DIAGNOSTIC STUDIES

- A full colonoscopy should be performed to assess the remainder of the rectum and the entire colon for potential synchronous lesions.
- In malignancy, a computed tomography (CT) of the chest, abdomen, and pelvis along with serum testing for carcinoembryonic antigen (CEA) are obtained.
- Patients should also get an endoscopic rectal ultrasound (ERUS) to view the depth of invasion of the tumor and to evaluate for lymph node involvement (**FIG 1**). ERUS can predict mesorectal adenopathy (N status) with 70% accuracy and can assess depth of invasion (T status) in early stage rectal cancers with 90% accuracy. The ability to assess lymph node involvement is essential because it could be a cause of locoregional treatment failure.
- Rectal protocol magnetic resonance imaging (MRI) is increasingly used in rectal cancer staging due to its ability to assess, in addition to T and N stages, potential adjacent

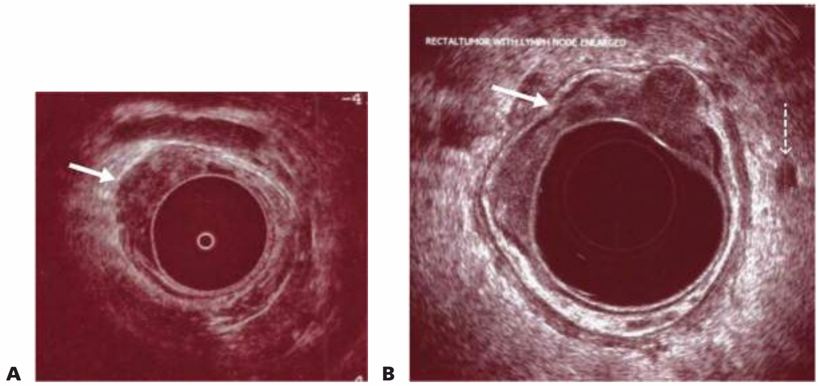


FIG 1 ● ERUS in rectal cancer. **A.** This tumor *(block arrow)* extends into but not beyond the muscularis propria with no evidence of nodal disease (ERUS T2N0). **B.** This tumor extends through the muscularis propria *(block arrow)* and exhibits nodal disease in the mesorectum *(dashed arrow)*. Therefore, it is an ERUS T3N1 tumor.

organ involvement and the relationship with the mesorectal margin (**FIG 2**). However, MRI, like ERUS, is challenged in trying to differentiate between T1 and T2 stages due to the limited resolution in delineating the layers of the rectal wall.

- If the patient has a malignant lesion that is unfavorable (≥T3 or N+) at any level in the rectum or a favorable cancer in the distal one-third of the rectum (0.5 to 6.0 cm above the anorectal ring), neoadjuvant chemoradiation is recommended. Surgical decision making is based on the evaluation of the tumor at 8 to 12 weeks after completion of neoadjuvant chemoradiation in order to maximize the effect of tumor downstaging.

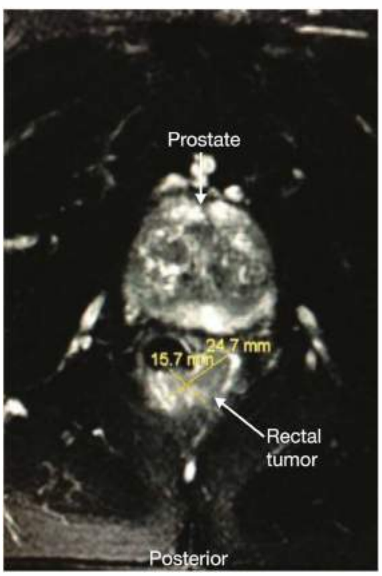


FIG 2 ● Rectal-protocol MRI showing a rectal tumor involving the posterior and lateral rectal walls. There is a clear plane of separation from the prostate anteriorly, ruling out a T4 lesion.

- Table 1 summarizes the ideal TEM candidates as well as the absolute contraindications for TEM. In general, local excision is the preferred option for patients with adenoma, or cancer with favorable features (≤3 cm in diameter; T1, grade I or II, and no venous or lymphatic invasion; and no evidence of lymph node metastasis) after chemoradiation. An ideal patient for local excision has a tumor that is small, mobile, located in the distal rectum, and posteriorly based.
- Contraindications for patients to undergo a TEM procedure after completion of neoadjuvant radiation include lymph node involvement, T3 or greater cancer after neoadjuvant chemoradiation, or tumors that remain fixed, deeply ulcerated, or have adjacent visceral organ involvement. In general, a maximum size of 4 cm is considered the limit for TEM after chemoradiation. Tumors greater than 3 to 4 cm in size can be challenging to excise transanally after neoadjuvant therapy due to the difficulty in closing the large defect that might be greater than one-half the circumference of the rectal wall.

Table 1: Candidates and Contraindications for Transanal Endoscopic Microsurgery and Lymphovascular Invasion

Candidates	Contraindications
Adenomas (and other benign lesions)	After chemoradiation:
Rectal cancer:	• N+
• <3 cm in diameter	• T3 or greater
• T1	• Fixed tumors
• Grade I or II	• Deeply ulcerated
• No LVI	• >4 cm in size
• N0	• >½ of rectal circumference
• Mobile	

LVI, lymphovascular invasion.

SURGICAL MANAGEMENT

Preoperative Planning

- Patient preparation for TEM is the same for benign or malignant lesions.
- The patient will undergo standard bowel preparation.
- Standard preoperative antibiotics are administered.
- It is important to have a conversation with the patient preoperatively to discuss the potential need for laparoscopy or laparotomy and a possible diverting stoma.

Patient Positioning

- The positioning of the patient depends on the tumor location. In general, the patient is positioned so that the tumor is in the dependent position during the procedure.
- The tumor should be at the center of the operating rectoscope throughout the procedure; the bevel of the TEM scope should face down at the tumor. This is essential as the optics reside in the upper portion of the operating proctoscope, limiting the reach of the instruments to the bottom 180 to 210 degrees of the lumen. Therefore, patient positioning becomes very important.
- Patients with posterior lesions are placed in the modified lithotomy position (**FIG 3**). Patients with anterior lesions are placed in the prone position (**FIG 4**). Patients with left or right lateral lesions are placed in the left or right decubitus position, respectfully.

Operating Team Setup

- The surgeon should be in a seated position in between the patient's legs (**FIG 5**). The assistant should be seated to the left of the surgeon. The scrub nurse is to be positioned opposite the endosurgical unit. The monitors are placed in front of the surgeon.

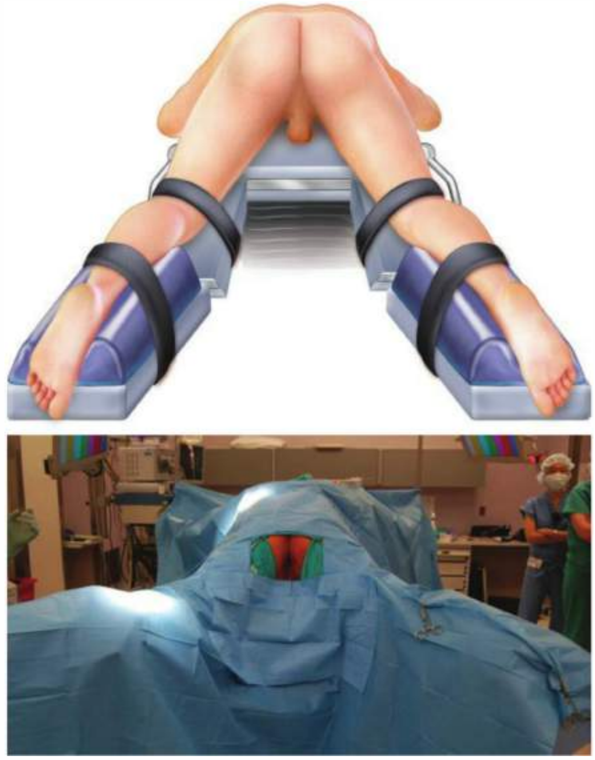


FIG 4 • Prone position: ideal for patients with anteriorly located lesions. The arms are resting without straining on arm boards. The lower extremities are resting on a split-table configuration. The patient is firmly secured to the table position changes during the procedure. All pressure points are padded to prevent nerve and/or vascular injuries.

FIG 3 • Modified lithotomy position: ideal for patients with posteriorly located rectal lesions. The legs are placed on Yellofin or Allen stirrups. The patient is firmly secured to the table to allow table position changes during the procedure. The arms are tucked and all pressure points are padded to prevent nerve and/or vascular injuries.

FIG 5 • Surgical team setup. The surgeon *(1)* is in a seated position in between the patient's legs, with the assistant *(2)* positioned to his or her left side and with the scrub nurse *(3)* positioned to his or her right side. The monitors are placed in front of the surgeon. The operating rectoscope is fixed to the operating table with a Martin arm for stability.

TRANSANAL ENDOSCOPIC MICROSURGERY SETUP

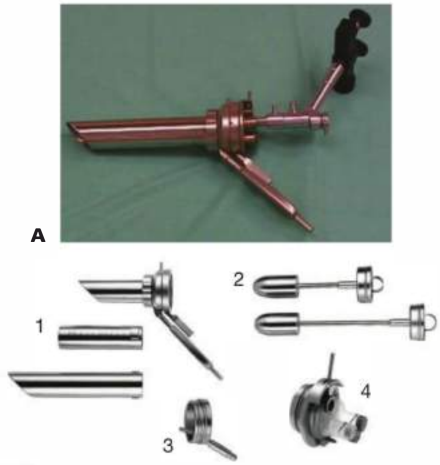
- All of the instruments that we use during the TEM procedure are from the Richard Wolf TEM Instrument System. Some of the instruments used to do the dissection are displayed in **FIG 6**. However, similar instruments and equipment are offered by Karl Storz and others use standard laparoscopic instruments.

A

B

C

FIG 6 ● **A.** Important TEM instruments. From *top* to *bottom*: curved monopolar grasping forceps for left and right hands, straight monopolar grasping forceps for left and right hands, suction tube, suture clip forceps, articulated monopolar knife, and straight monopolar knife. All black instruments are insulated so that they may be used for cautery. The angle at the end of the instrument allows a range of motion in the TEM lumen. **B.** Close-up of curved forceps. **C.** Close-up of straight forceps.



A

B

FIG 7 ● Richard Wolf TEM rectoscope. **A.** Assembled rectoscope. **B.** Rectoscope components. *(1)* Three different length shafts are available for different tumor locations. *(2)* Different length obturators allow for atraumatic rectoscope insertion. The working adapter *(3)* and the working insert *(4)* allow for connection to insufflator, camera, and working instruments.

- The operating rectoscope has a rectoscope tube that is 4 cm in diameter (**FIG 7A**). There are three different lengths of shafts (with their correspondent obturators; **FIG 7B**) that can be used during the surgery, depending how far the tumor is from the anal sphincter. The rectoscope tube is attached to the adapter and working insert (**FIG 7B**) and is then fixed to the operating table with a Martin arm (**FIG 5**).
- Once the patient is prepped and draped, the anus is gently dilated and the rectoscope (with the obturator) is inserted into the patient's anus (**FIG 8**). There is a 20-cm shaft with an oblique edge for higher lesions, a 12-cm

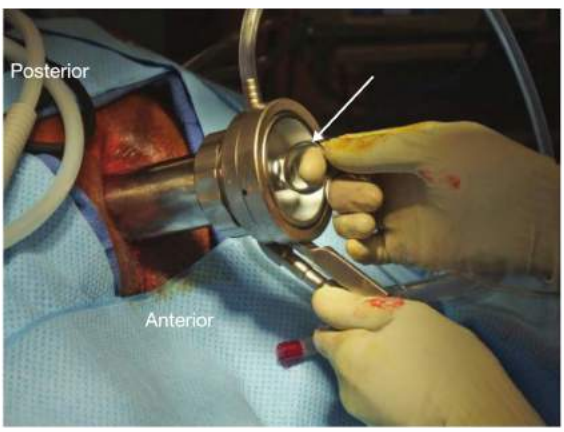


FIG 8 ● Insertion of the TEM rectoscope. After gentle dilation of the anus, the rectoscope is inserted with an obturator *(arrow)* in place for an atraumatic entry.

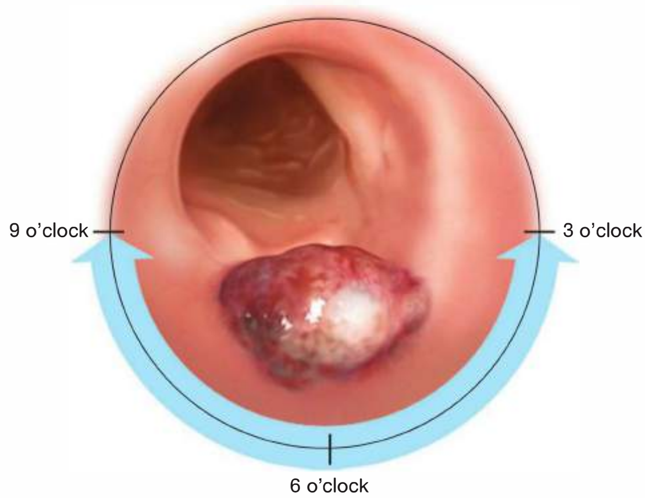


FIG 9 ● Ideal location of the target lesion. The scope and the patient are adjusted so that the lesion is positioned in the center of view at the 6 o'clock position. This ensures that the positioning is ideal and that the surgeon will have proper reach with the instruments.

shaft with an oblique edge for masses lower in the rectum, and a 13.7-cm shaft with a flat edge for lesions that extend into the anus (**FIG 7B**). The flat-edged shaft is ideal for very low lesions, as it allows access without losing insufflation extending down to the upper anus. The obturator can be removed and the working faceplate is secured.

- The light source is then connected and the rectum is insufflated. At this point, the TEM is functioning as a large rigid proctoscope. The scope can then be adjusted so that the lesion is positioned in the center of view at the 6 o'clock position (**FIG 9**). This assures that the positioning is ideal and that the surgeon will have proper reach with the instruments.
- After the ideal view of the lesion is found, the TEM scope is then secured to a Martin arm (**FIG 5**), and this arm is connected to the operating table. The application of the Martin arm is one of the most important aspects of the operation, as the arm is frequently repositioned to keep the lesion in the lower middle of the field, as explained earlier. It is essential to make certain that each of the three joints on the Martin arm is not maximally angled so as to maintain flexibility of positioning. If they are maximally flexed, the arm needs to be adjusted.
- All of the rubber sleeves and caps can then be lubricated with mineral oil to reduce the chances of drying and cracking. If the caps tear, it will lead to air leaking and loss of rectal distention. After lubrication, the sleeves and caps are placed into the ports on the faceplate.
- Lastly, the four pieces of tubing can be placed into their respective ports in the apparatus (**FIG 10**). The four ports are used for continuous insufflation, irrigation, suction, and the light source. The connecters are all different to avoid attaching the tubes to the wrong location.
- TEM equipment gives access to lesions at any location in the rectum from the anal canal up to the rectosigmoid region and sometimes even higher.

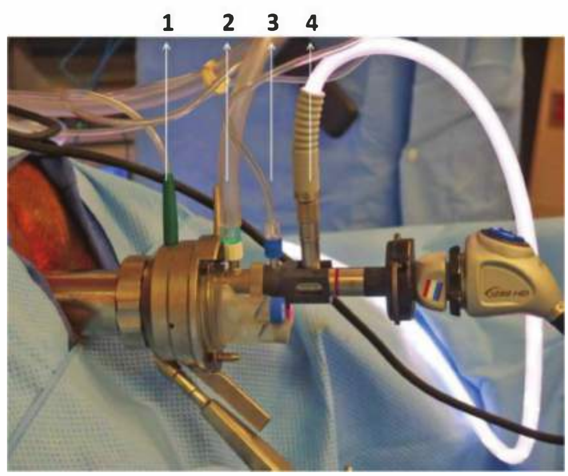
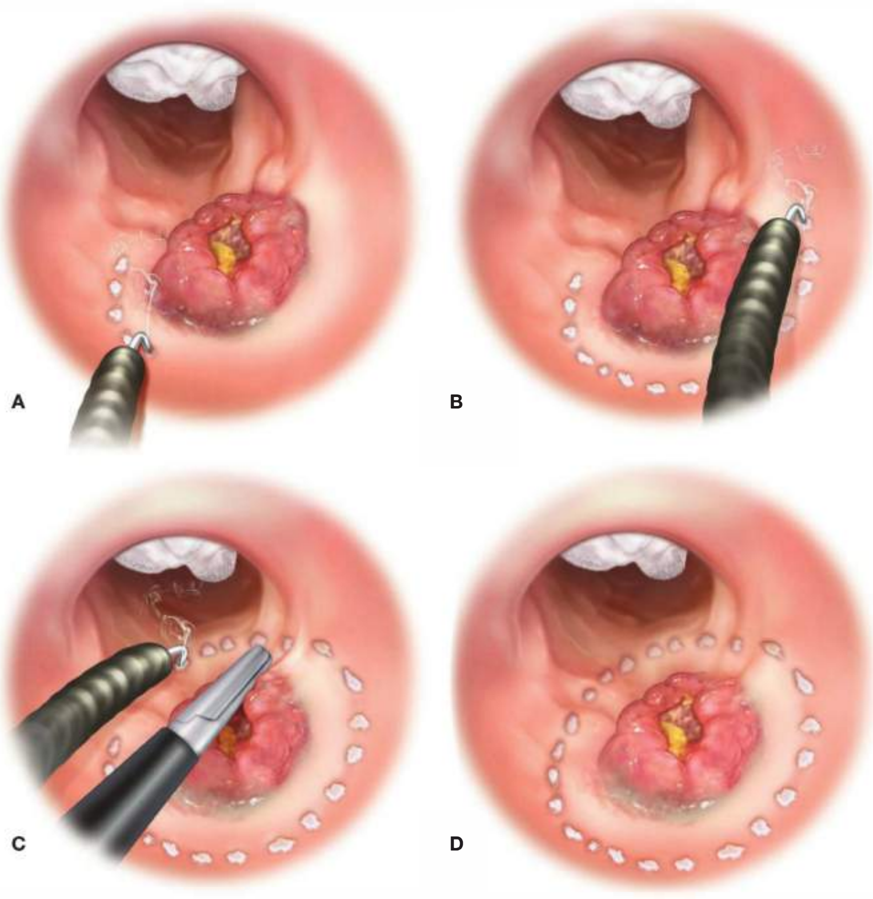


FIG 10 ● Finalized assembly of the TEM rectoscope. The four pieces of tubing are connected into their respective ports in the apparatus. The four ports are used for suction *(1)*, continuous insufflation *(2)*, irrigation *(3)*, and for the light source *(4)*. The connectors are all different to avoid attaching the tubes to the wrong location.

MARKING THE LESION

- Once proper setup is complete, the area around the lesion can be infiltrated using local anesthetic with epinephrine. The purpose of this step is to aid in hemostasis.
- The margin of the lesion can then be marked circumferentially using electrocautery (**FIG 11**). Marking the lesion is an important initial step in this surgery. It ensures the reach with the instruments to get an adequate margin circumferentially around the lesion and, most importantly, it aids in the visualization of the proper margin at all times. The latter is important because cautery artifact, blood, and smoke may obscure the edges of the lesion later in the procedure, which can impair the ability to have a negative margin.
- Although TEM can be performed safely by an experienced surgeon for lesions anywhere in the rectum, a less experienced surgeon should avoid performing TEM for lesions in the upper rectum and for higher lesions that are based anteriorly due to the potential of entering the peritoneal cavity, which leads to a challenging closure.



A B C D

FIG 11 ● **A–D.** Marking of the lesion. The margin of the lesion is marked circumferentially using electrocautery. This ensures the ability to reach with the instruments to get an adequate margin circumferentially around the lesion and, most importantly, it aids in the proper visualization of the margins of resection at all times.

DISSECTION

- Using the markings made circumferentially, electrocautery is used to "connect the dots" to dissect around the entire lesion (**FIG 12**). Malignant lesions must have a full-thickness excision into and/or including the perirectal fat. Adenomas only need to be excised submucosally. However, often it is difficult to avoid a full-thickness excision. It is essential to have at least a 10-mm margin for suspected malignancy and at least a 5-mm margin for adenomas.
- Ideally, the area around the lesion is connected circumferentially and then the base of the lesion is excised. For larger lesions, the inferior hemicircumference is incised and the dissection is brought around and under the lesion and then the superior aspect can be reached.
- A marking suture is placed at the inferior border of the specimen prior to removal to ensure the maintenance of proper orientation of the specimen (**FIG 13**).

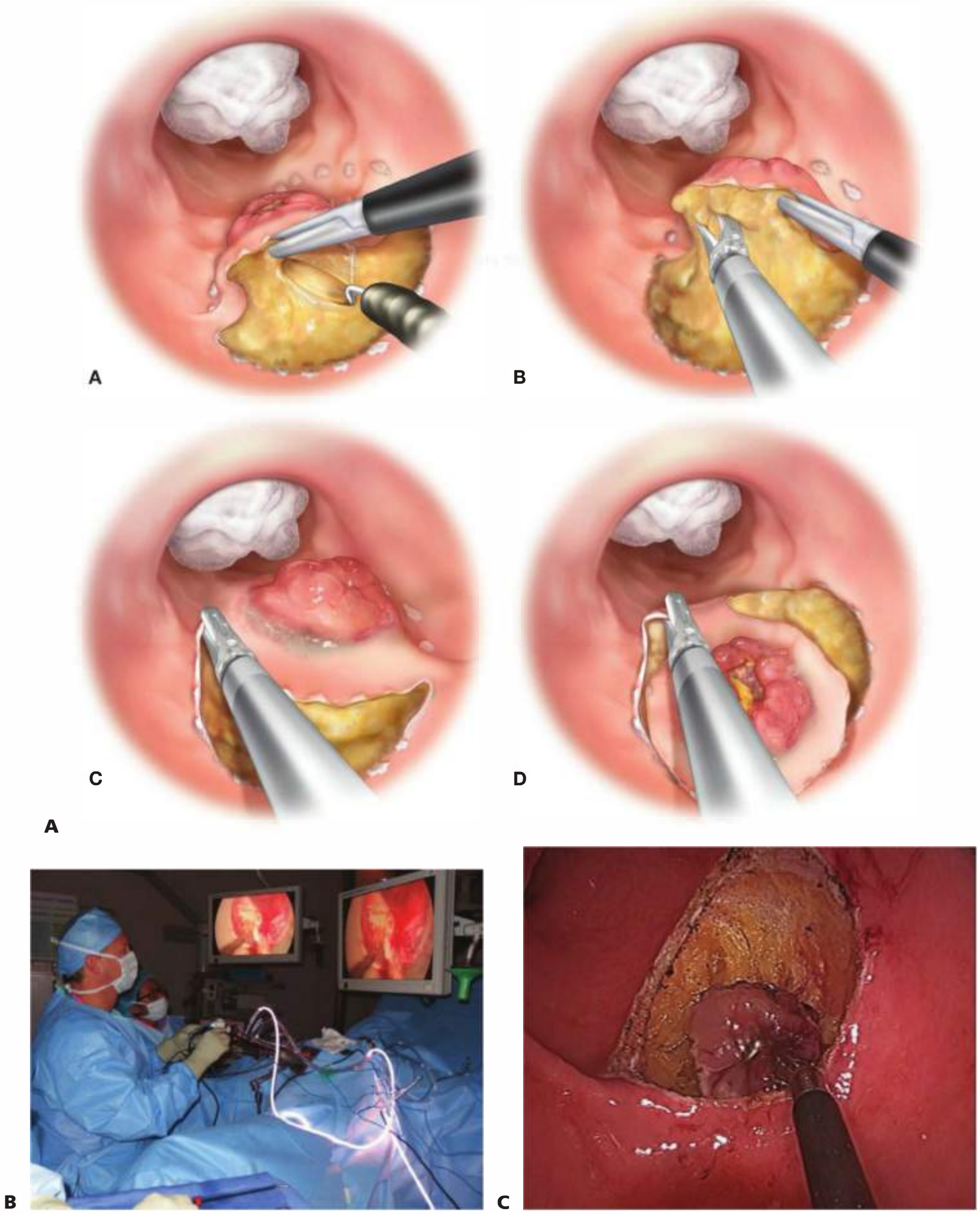


FIG 12 ● Dissection of the target lesion. **A.** It is easier to start the dissection distally, then laterally, and finally proximally (*A* through *D* in the illustration). **B.** The operative team during the dissection phase. **C.** The operative picture shows the full-thickness circumferential dissection of a malignant lesion with a 1-cm margin all around. Notice that the dissection is carried through the entire rectal bowel until the yellow fat of the perirectal tissues is reached.

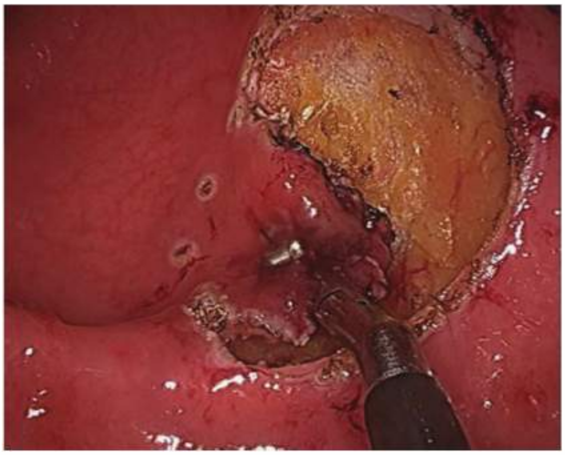


FIG 13 ● Placement of a marking suture. Prior to complete excision, a marking suture is placed in the distal margin of the target lesion for orientation.

CLOSURE

- After the lesion is dissected and ready to be removed, the insufflation is turned off and the tumor is grasped and pulled into the operating proctoscope. The faceplate is removed and the specimen is delivered.
- Two steps are taken to reduce the risk of tumor implantation/local recurrence. First, the defect, the faceplate, and the instruments are washed and irrigated with dilute Betadine, and second, the gloves must be changed after removal of the specimen.
- Following these protective steps, the closure of the rectal wall defect is performed in a running, full-thickness fashion with a 2-0 polydioxanone (PDS) suture (**FIG 14**). Closure begins at the proximal aspect of the defect and is then advanced in a full-thickness fashion from proximal to distal.
- Sewing within the confines of the TEM operating system represents a significant challenge originally. Because of the length and diameter of the operating proctoscope, there is no movement in a left to right fashion. The suture is advanced by inserting the needle driver into the lumen of the rectum and pulled out in a pistonlike motion. The closure progresses to the left. The upper left aspect of the wound closure always represents the most challenging aspect of the anastomosis.
- For large lesions, a 2-0 PDS monofilament suture is used to bisect the defect during the procedure (**FIG 15A**). If the defect is very large, it is beneficial to use two sutures to trisect it (**FIG 15B**). This can be helpful because it functions as a handle during the dissection and it also facilitates the closure process by keeping the edges of the wound closer together. Without these sutures in place, there is tension on the suture line, pulling it apart. Because there is no one holding the suture for you as the closure is performed, these stay sutures are a great help to take pressure off the suture.
- Once the closure is complete, any slack in the suture line can be fixed by gently pulling up on one end of the suture and applying another clip to tighten it.

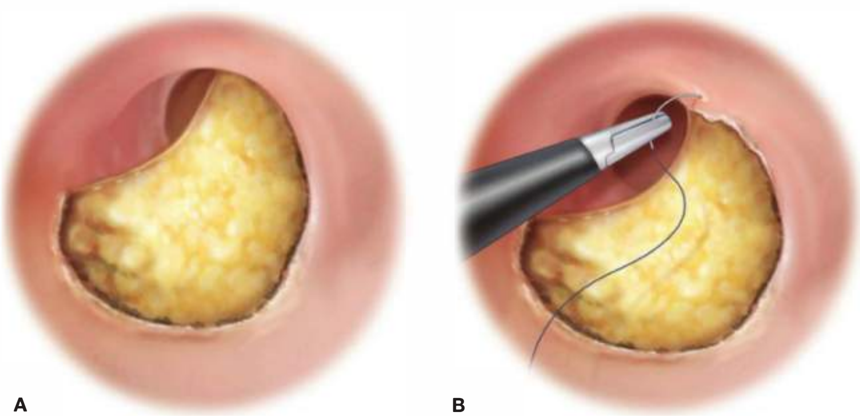


FIG 14 ● Closure of the defect. For smaller defects, a running suture with 2-0 PDS, progressing from proximal to distal (*A* through *D* in the illustration) is performed. The operative picture shows the completely closed defect. *(continued)*

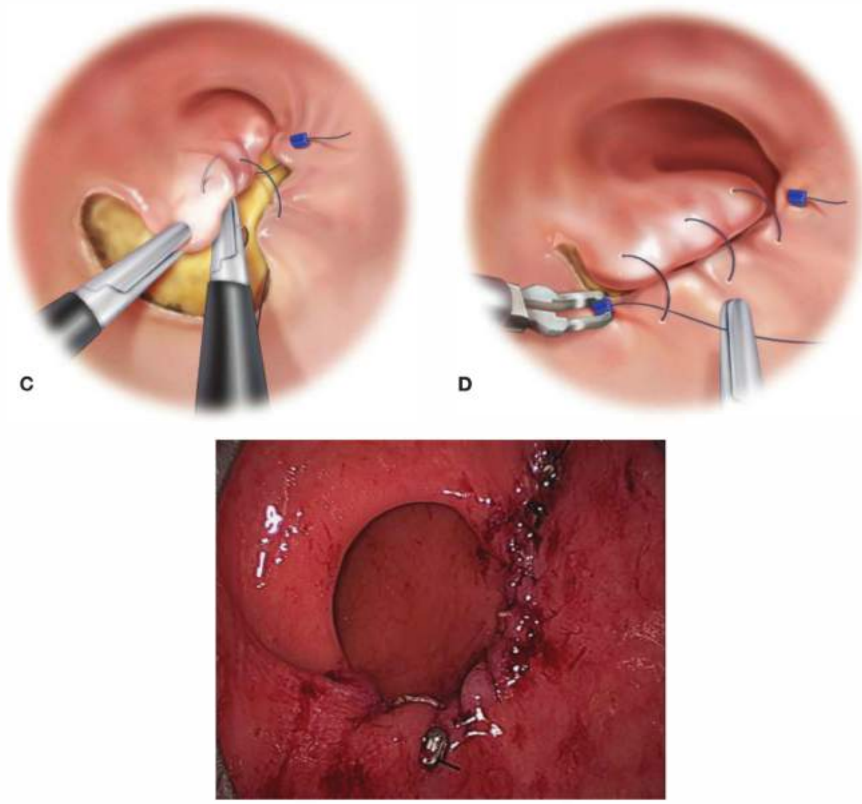


FIG 14 ● *(continued)*

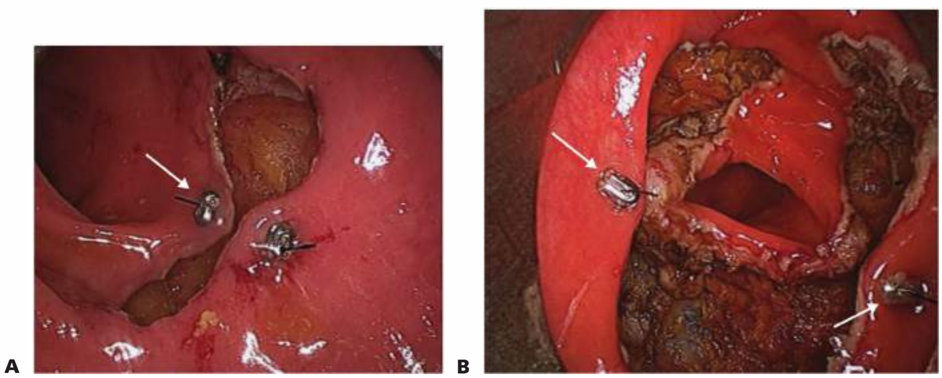


FIG 15 ● Closure of the defect. For larger lesions, it is easier to bisect **(A)** or even trisect **(B)** the defect with interrupted sutures *(arrows)* to approximate the edges, creating smaller defects in order to reduce the tension, and to facilitate the placement of the running sutures.

SPECIMEN SENT TO PATHOLOGY

- On the back table, the specimen is pinned to a corkboard (FIG 16) and the sides are labeled superior, inferior, left, and right for orientation of the lesion in the rectum.
- This is an important step, as the edges will otherwise roll in and result in an indeterminate read of the margins, or worse yet, a false-positive margin reading.

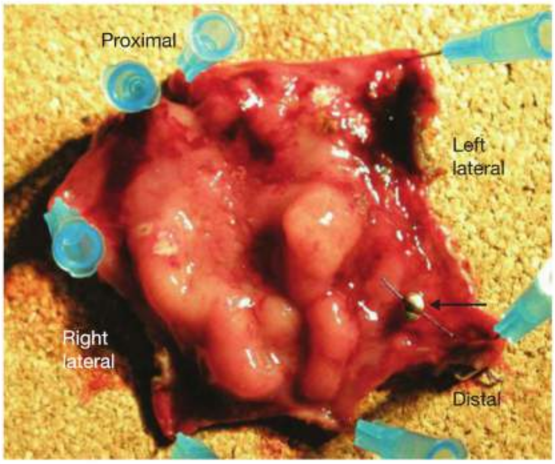


FIG 16 ● Specimen orientation. After resection, the specimen is pinned to a corkboard, oriented, and sent to pathology. This is critical to adequately evaluate the margins in cancer patients. Notice the clip placed on the distal margin for orientation prior to resection *(arrow)*.

PEARLS AND PITFALLS

Patient positioning	■ One of the most important steps of the procedure ■ Placing the lesion properly centered beneath the scope facilitates the dissection and closure. ■ The location of the tumor (anterior, posterior, or right/left lateral) must be carefully noted in the preoperative evaluation and rechecked the morning of surgery.
Using TEM instruments: key factors	■ Instruments should always remain in parallel and can only be moved in and out. There is no up and down or left and right movement. Rotating to the left and right adds significantly to the reach and mobility of the angled instruments. ■ All instruments should be well lubricated to reduce friction and decrease wear and tear of caps on the faceplate. A tear here will lead to loss of the air seal, which can lead to loss of visibility. ■ It is beneficial to keep the suction catheter in the proximal neck of the rectoscope so that it is out of view, does not interfere with the reach of the operating instruments, and increases the mobility of working instruments.
Measures to prevent tumor implantation/local recurrence	■ The defect, the faceplate, and the instruments are washed and irrigated with dilute Betadine. ■ The gloves must be changed after specimen removal. ■ Additionally, the use of neoadjuvant chemoradiation along with TEM surgery reduces local recurrence.
Facilitating suture closure	■ Keep the suture material short in length to reduce the amount of time taken to pull the suture through the tissue. We recommend a 10-cm suture length. ■ For larger lesions, bisect or even trisect the defect by placing interrupted sutures. This reduces the tension facilitating the placement of running sutures.

POSTOPERATIVE CARE

- Patients with smaller incisions can be sent home the same day of surgery.
- Full-thickness excision patients should be admitted overnight for intravenous (IV) antibiotics and observation. Patients receive Ancef and Flagyl for 24 hours and then doxycycline for 2 weeks.
- Clear liquids are given on the day of the surgery; advance to a soft diet later that day or the following day.
- We give 1 oz of milk of magnesia beginning on the day after surgery through postoperative day 5 in order to keep the stool loose without causing excessive diarrhea. Patients are instructed to take fiber supplements. The goal is to avoid a large hard bowel movement that can disrupt the suture line.
- In order to avoid potential wound complications, patients are discharged home with instructions to avoid heavy lifting and straining.
- Long-term postoperative care includes the following:
  - A surveillance exam at 3-month intervals for the first 12 months
  - A flexible sigmoidoscopy is performed at months 6, 18, and 24.
  - A full colonoscopy is obtained at the 1-year marker.
  - It is important during these examinations to carefully evaluate the suture line to rule out any potential suture line recurrence.
  - CEA tests should be monitored on the same schedule as office visits.
  - CT scans should be performed annually or as necessary to follow cancer patients depending on symptoms or findings during examinations.

OUTCOMES

- One of the major benefits of the TEM procedure is the decrease in postoperative morbidities compared to radical transabdominal surgery due to the minimally invasive nature of the TEM procedure, the lack of incision, and the avoidance of a diverting stoma.
- In our experience of more than 300 TEM procedures, we have only had two patients with transient incontinence after the surgery. These patients likely had decreased capacitance of the rectal wall after a large resection, but the urgency improved over time.
- Local recurrence after TEM remains a conflicting topic for many colorectal surgeons. In a study where we compared our experience with a total of 72 patients with T2 rectal cancers treated with neoadjuvant chemoradiation and either a TEM or a total mesorectal excision (TME), we found that there was no significant difference in local recurrence (3.3% vs. 2.3%, respectively). Five-year survival was also not significantly different with 95% in the TEM group and 97% in the TME subset. Saclarides and Floyd performed a larger study looking at 221 patients with T1 rectal cancer treated with TEM and found a local failure rate of 6.3%.
- Moore et al. has shown that TEM has a significantly better reliability of achieving negative margins and avoiding fragmentation when removing the specimen than the traditional transanal approach. Additionally, TEM offers several advantages over traditional transanal excision such as clearer visualization, better exposure, and access to higher lesions in the rectum.

COMPLICATIONS

- Air leakage is a frustrating complication that can occur during a TEM procedure because it leads to loss of pneumorectum and ultimately can inhibit view of the lesion. Some precautions that should be taken to avoid this problem include checking all equipment tubes and connections to make sure they are airtight and to make sure there are no cracks or pinholes in the rubber caps. When an air leak is encountered, a systematic review of the equipment is needed to troubleshoot the problem.
- During a TEM procedure, it is not uncommon to enter the peritoneal cavity while dissecting the specimen. Although this was previously thought to be detrimental for the patient's recovery, recent studies have found that entrance into the peritoneal cavity is not a contraindication for transanal resection of rectal lesions.
- Entrance into the peritoneal cavity occurs more commonly in anterior and lateral lesions due to the level of peritoneal reflection in these locations and it occurs less commonly in posterior lesions, which are invariably extraperitoneal. If the peritoneal cavity is entered during the procedure, it should be have a two-layer closure with a braided, absorbable, figure-of-eight suture (3-0 Vicryl), with a full-thickness closure on top of this.
- Early in the surgeon's experience, high anterior lesions should be avoided so as to ensure the peritoneal cavity is not breached.
- Postoperative complications for TEM patients are minimal (range from 6.7% to 9.8%) and include bleeding, perforation, and wound dehiscence.
- Other complications reported include fever, fistula formation, rectal stenosis, and urinary dysfunction.
- In our experience, wound separation is the most common complication with most of these (91%) healing without additional surgery.
- It is mandatory to always discuss with the patient the possible need for an abdominal operation, a stoma, additional surgery, and the possibility of fecal incontinence.

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Chapter 42

Transanal Single Port Excision of Rectal Lesions

Avo Artinyan   Daniel Albo

DEFINITION

- The first description of transanal excision (TAE) of rectal lesions is often attributed to Parks and colleagues. The classic technique described by Parks[1] involves the excision of low rectal lesions under direct vision with the aid of transanal retractors and standard surgical instruments. Although relatively effective for low rectal lesions, TAE is extremely difficult for lesions in the midrectum and effectively impossible for lesions in the upper rectum.
- The advantages associated with TAE versus radical surgery include the following: lower morbidity, less pain, shorter operating times, shorter hospital stays, no wound complications, faster/more complete recovery, and avoidance of permanent colostomy.
- Transanal endoscopy microsurgery (TEM) generally refers to an approach for the local excision of lesions in the mid- to upper rectum first described by Buess et al.[2] in the early 1980s.
- Although several variations in technique and instrumentation have been described, common to all of these are the following: (1) endoscopic visualization of the rectum, (2) gas/CO_2 insufflation, and (3) the use of laparoscopic and/or other specialized instrumentation that allows for bimanual surgical dissection and suture repair.
- The procedure is notably distinct from endoscopic mucosal resection (EMR) and other techniques that rely on flexible gastrointestinal endoscopy with associated limited instrumentation introduced via the working channels of these scopes.
- Other terms such as transanal minimally invasive surgery (TAMIS) describe the same procedure with slight variations in instruments, especially with respect to the transanal access platform. In this chapter, we use the term transanal endoscopy microsurgery to include all of these procedures and variations.
- The procedure has recently seen an increase in popularity with the introduction of newer, less expensive instrument platforms as well as expanding interest in, and indications for, the local excision of rectal cancer.

DIFFERENTIAL DIAGNOSIS

- TEM can be used to treat a wide variety of both malignant and benign rectal conditions, including but not limited to large rectal adenomas, early rectal cancers, neuroendocrine tumors, endometriomas, and rectal strictures.
- These lesions encompass a wide variety of pathophysiologic entities with many common underlying complaints that alert the clinician to pathology within the distal large bowel and rectum.
- TEM can serve as both a diagnostic procedure as well as an effective therapeutic procedure in the appropriate setting.

PATIENT HISTORY AND PHYSICAL FINDINGS

- Patients with rectal lesions (usually rectal polyps and rectal cancers) generally present with occult or clinically evident rectal bleeding. Those with early or small lesions may be completely asymptomatic with rectal pathology discovered on screening colonoscopy.
- A thorough history and physical examination should be performed, important components of which include the following:
  - Presence of ***rectal pain and/or tenesmus***, which can often alert the surgeon to a more extensive lesion with sphincter/levator ani involvement
  - Presence of ***obstructive symptoms***
  - Description of ***anorectal function***, with any fecal incontinence or leakage documented preoperatively
  - ***Urinary and erectile function***, with dysfunction documented preoperatively
  - A ***detailed oncologic history*** including both personal and family history of colorectal cancer, other malignancies, and hereditary cancer/polyposis syndromes
- Physical examination should include the following:
  - ***Routine abdominal examination***, with particular attention to the presence of any surgical incisions, which may become pertinent should laparoscopy or laparotomy be necessary.
  - ***Digital rectal examination*** with gross assessment of sphincter function
  - ***Bilateral inguinal nodal examination*** for clinically evident nodal metastases
  - ***Rigid proctoscopy by the surgeon*** to define the anatomic parameters of the lesion
- Rigid proctoscopic examination is the most critical portion of the physical examination and is the key to proper selection of patients for TEM. Examination should be standardized and should document the following findings:
  - The distal and proximal extent of the lesion measured from the ***anal verge***
  - Position of the lesion within the circumference of the rectum (anterior, posterior, or lateral)
  - Total circumference of the rectal wall involved by the lesion

IMAGING AND OTHER DIAGNOSTIC STUDIES

- A ***complete colonoscopy*** should be performed on all patients preoperatively. In the setting of possible colorectal neoplastic disease, the location of all polyps should be described, and all suspicious lesions should be endoscopically excised or biopsied if excision is not feasible. Lesions that are unresectable or are suspicious for invasive adenocarcinoma should be tattooed to facilitate resection if necessary in the future.

- For all suspicious rectal lesions (≤15 cm from anal verge on rigid proctoscopy), locoregional staging with ***endorectal ultrasound (EUS)*** **or** ***rectal magnetic resonance imaging (MRI)*** should be performed to define the depth of the lesion and the potential for nodal involvement.
- With all suspected or confirmed colorectal neoplastic disease, ***complete staging computed tomography (CT) of the chest, abdomen, and pelvis*** should be performed to rule out metastatic disease.
- ***Positron emission tomography (PET)/CT*** should be used selectively for patients with suspected metastatic disease or those that are poor candidates for intravenous (IV) contrast secondary to renal insufficiency or contrast allergy.
- ***Anal physiologic studies with manometry*** should be strongly considered for patients with preoperative symptoms and signs of fecal incontinence to document preoperative sphincter function.

SURGICAL MANAGEMENT

Indications for Transanal Endoscopy Microsurgery

- ***Large rectal polyps not amenable to colonoscopic resection*** (usually sessile adenomatous polyps)
- ***Rectal adenocarcinoma***—The indications for the local excision of rectal adenocarcinoma continue to evolve, particularly with the recent completion of multidisciplinary trials such as the American College of Surgeons Oncology Group (ACOSOG) Z6041 trial. Because TEM is used to excise local disease and does not adequately address nodal disease, the degree to which the procedure is appropriate and successful is directly proportional to the likelihood of nodal metastases. In the combined literature, the risk of nodal disease is best predicted by T stage and is on the order of 5% to 10% for T1 lesions, 15% to 25% for T2 disease, and 35% to 75% for T3 disease. Other pathologic factors are also useful in predicting risk of nodal disease and recurrence, and these are potentially applicable for patient selection (Table 1). ***The desire to perform/undergo a minimally invasive procedure*** **should not** ***supplant sound oncologic principles.***
  - ***Low-risk T1 disease***—Definitive therapy for rectal cancer should be reserved only for patients with low-risk T1 disease. This is also the current position of the National Comprehensive Cancer Network (NCCN).
  - ***High-risk T1 or any T2 disease with combination therapy***—Patients with high-risk T1 or any T2 disease who undergo TEM with curative intent should ideally be treated in a clinical trial setting with either preoperative or postoperative chemoradiation. Given that TEM is not the standard of care in this setting, the risks and benefits of TEM versus radical resection need to be carefully discussed with the patient and appropriate consent obtained and documented.
  - Lesions of any stage, technically amenable to TEM, in ***patients who refuse radical resection***, appropriate discussion and consent must be documented
  - Lesions of any stage, technically amenable to TEM, for ***palliative purposes***
- Other ***less common indications*** that have been reported include rectal carcinoids, endometriomas, angiodysplasia, rectal ulcers, rectal strictures, and other benign pathologies. Just as with rectal adenocarcinoma, the decision to perform TEM in these settings should be based on sound clinical judgment.

Table 1: Additional Factors Associated with Increased/High Risk of Lymph Node Involvement/ Local Recurrence

Poorly differentiated lesion
Lymphovascular invasion
Perineural invasion
Sm3 Kikuchi classification
Lesion diameter >4 cm

Anatomic Considerations

- TEM is ideally suited for lesions whose *entire* extent falls within 5 to 15 cm from the anal verge.
  - The technical "sweet spot" for TEM is between 6 and 10 cm (midrectum), beyond which the surgeon has to contend with instrument limitations, diminished visualization and exposure, and the potential for peritoneal entry.
- TEM has been described for lesions proximal to 15 cm. However, peritoneal entry is much more likely with full-thickness excision in this setting, and extensive expertise is required to perform an adequate and safe suture repair.
  - The likelihood of peritoneal entry is dependent on the circumferential location of the lesion (Table 2). For example, the mean distance to the peritoneal reflection anteriorly in men is at 9.7 cm, compared to 15.5 cm posteriorly. Dissection in the posterior midline can also result in entry into the intraabdominal colonic mesentery, without frank intraperitoneal entry.[3]
- Lesions distal to 5 cm are usually covered in part or completely by the transanal access device. These lesions are more suited for conventional TAE.
- There is no absolute contraindication based on the total circumferential extent of the lesion, and complete circumferential excisions have been described. However, excision of lesions that occupy more than 40% of the circumference is technically much more challenging, may be associated with more advanced lesions, and can lead to compromised margins. Sound judgment and careful patient selection are required.

Preoperative Preparation

- The key to the technical success of the TEM operation is adequate visualization and exposure. As a result, preoperative

Table 2: Distance of Peritoneal Reflection from Anal Verge (Mean with Range, cm)

Location	Females	Males
Anterior	9 (5.5–13.5)	9.7 (7–16)
Lateral	12.2 (8.5–17)	12.8 (9–19)
Posterior	14.8 (11–19)	15.5 (12–20)

Adapted from Najarian MM, Belzer GE, Cogbill TH, et al. Determination of the peritoneal reflection using intraoperative proctoscopy. *Dis Colon Rectum.* 2004;47(12):2080–2085, with permission.

mechanical bowel preparation is invaluable. We ask our patients to have a normal lunch and take a clear liquid diet with adequate hydration thereafter and nothing by mouth after midnight. We prefer a mechanical bowel preparation with two bottles of magnesium citrate in the afternoon the day before surgery, with a Fleet enema the night before and the morning of the procedure.

- In addition, we administered one dose of IV cefoxitin antibiotic within 1 hour of initiation of surgery.
- Appropriate informed consent should be obtained. In addition to the possibility of the more common complications, the consent should also address the following:
  - The likelihood of technical success of the procedure
  - The potential need for reoperation based on pathologic findings (either repeat TEM or radical resection)
  - Oncologic outcomes in comparison to radical resection, particularly local recurrence
  - The likelihood of peritoneal entry for upper rectal lesions. For upper rectal lesions where peritoneal entry is a significant possibility, we routinely consent for possible laparoscopy and/or laparotomy with primary repair or radical resection.

Positioning

- Appropriate patient positioning is critical to the technical success of the procedure. Every effort should be made to position the patient such that the lesion is down at the 6 o'clock position.
- For posterior lesions, we prefer a high lithotomy position (**FIG 1A**).
- For anterior lesions, we prefer to place the patient in prone jackknife position on a split-leg table, with the surgeon positioned between the legs (**FIG 1B**).
- For lateral lesions, we place the patient in either one of the aforementioned positions and rotate the table to turn the lesion to 6 o'clock as much as possible. If the lesion cannot be placed completely down, then we have found that it is easier to perform the excision, as well as the repair, when the lesion is oriented toward the dominant hand of the surgeon. The "circumferential sweet spot" for a right-handed surgeon in our experience is presented in **FIG 1C**.

Equipment

- Multiple transanal access platforms have been used and are appropriate for TEM. The standard procedure described by Buess et al.[2] uses the operating transanal proctoscope by Wolf. Other transanal access platforms that have been used have incorporated equipment for single-incision laparoscopic surgery. These platforms have now gained U.S. Food and Drug Administration (FDA) approval for transanal access. Although we have used a number of these systems, our preferred transanal access platform is currently the GelPOINT Path system manufactured by Applied Medical.
- We routinely use both standard and articulating laparoscopic instruments designed for single-incision laparoscopic surgery. In a typical case, we often use a 5-mm scope operated by the assistant, a standard Maryland grasper in the left surgeon's hand for grasping and retraction, and an

A

B

C

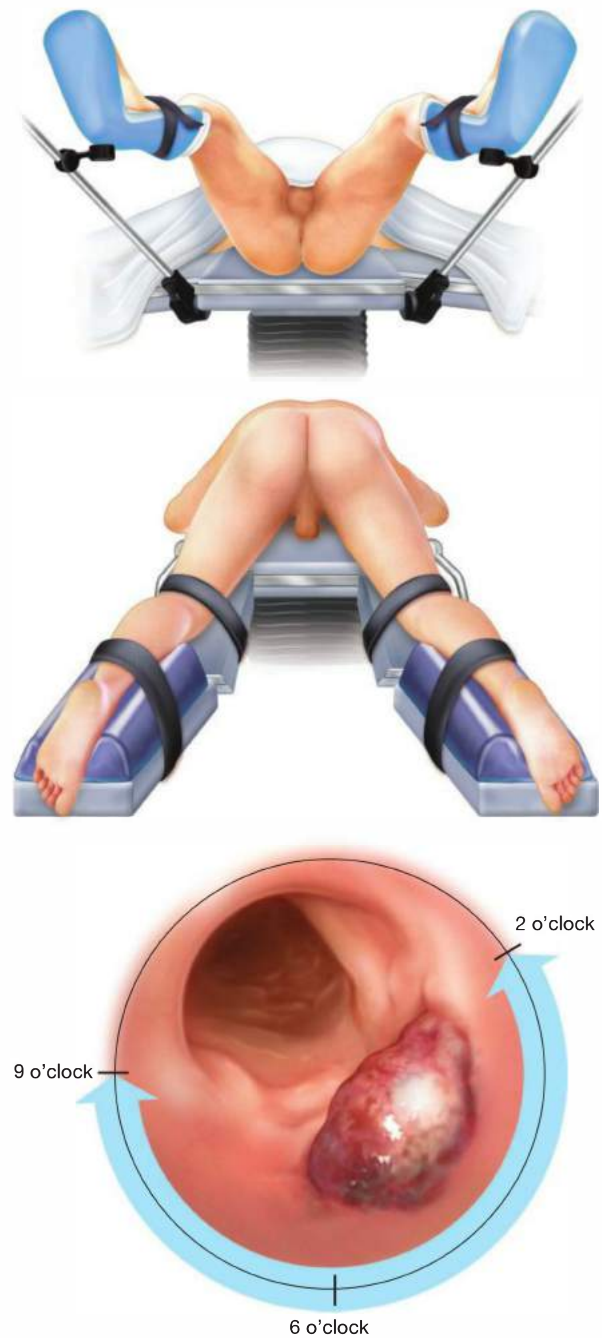

FIG 1 ● **A.** High lithotomy position, perineal view (for posterior lesions). **B.** Modified prone jackknife on a split-leg table, posterior view, ideal for anterior lesions. **C.** Circumferential sweet spot for operative dexterity for a right-handed surgeon. Lesion, excision, and repair should ideally fall within 2 o'clock to 9 o'clock positions.

articulating hook cautery or harmonic scalpel in the right surgeon's hand for excision. For repair, we use a standard laparoscopic needle driver.

- Our preferred energy sources are monopolar cautery and ultrasonic shears such as a harmonic scalpel.

FIG 2 ● The transanal port is folded in and grasped with ring clamps to facilitate insertion into anal canal.

- The patient is placed under general endotracheal anesthesia, a Foley catheter is routinely inserted, and the patient is appropriately positioned.
- A minimal sterile preparation of the perineum is performed, and the patient is draped in standard fashion.
- We perform an intersphincteric block with 1% lidocaine with epinephrine.
- The transanal access port is heavily lubricated, folded in and grasped from inside the port with a ring clamp (**FIG 2**), and then introduced gently into the rectum. Occasionally, gentle manual dilation of the sphincter is necessary to allow atraumatic placement of the port. We have found that the anal port naturally hugs the sphincters and stays in place and, therefore, do not routinely anchor the device with sutures.
- The instrument ports are first placed into the gel cap, and the gel cap is applied to the transanal port (**FIG 3**). Prior to applying the cap, we place a lightly lubricated Ray-Tec sponge into the rectum, which we later push into the proximal rectum in order to allow adequate insufflation of the distal rectum (**FIG 4**). The rectum is insufflated to 15 mmHg.
- Placing one or more proximal Ray-Tec sponges limits the amount of insufflation to the remainder of the colon and helps maintain a clean working space free of any remnant fecal material (**FIG 4**).

FIG 3 ● Transanal access device with cap and ports inserted into anal canal.

FIG 4 ● Lightly lubricated Ray-Tec is inserted proximally to minimize proximal insufflation and limit soiling of operative field.

- One of the difficulties we have found is periodic pneumorectum collapse. This can be limited by the following:
  - Inserting proximal Ray-Tecs as described earlier
  - Assuring an adequate prep, as we have noted that feculent material in the rectum and rectosigmoid will cause large bowel peristalsis
  - Avoiding excessive torque on the instruments to prevent loss of insufflation around the transanal access device
  - Higher insufflation pressures may be necessary to obtain adequate exposure.
- The excision technique is divided into the four critical steps:[4]
  - Delineation of the excision margins (1 cm grossly in most instances) (**FIG 5**)
  - Full-thickness incision of the rectal wall into perirectal tissue (**FIG 6**)
  - Circumferential dissection and specimen removal (**FIG 7**)
  - Suture repair (**FIG 8**)
- We routinely mark 1-cm margins using a hook cautery device. These cautery marks can become extremely helpful later during the excision, particularly if visualization becomes compromised (**FIG 5**).
- A full-thickness incision is made 1 cm ***distal*** to the lesion using hook cautery, with the left hand lifting up the rectal wall to supply countertraction (**FIG 6**). The perirectal tissue is usually easily recognized by the presence of perirectal fat. Anteriorly the perirectal space may consist only of loose areolar tissue. This

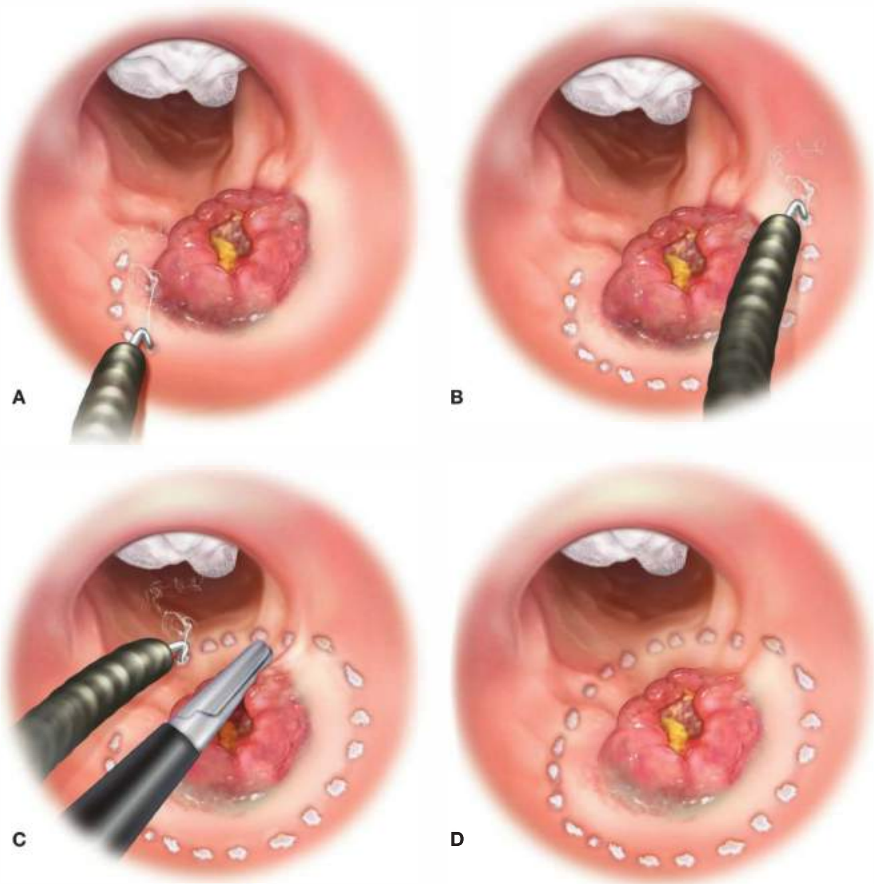

FIG 5 ● Delineation of margins of excision, 1 cm in the majority of cases. (**A–D** demonstrate progression of circumferential margin delineation)

initial step must be performed with extreme caution with anterior and lateral lesions in order to prevent injury to genitourinary and vascular structures adjacent to the rectum.

FIG 6 ● Full-thickness incision of the rectal wall into perirectal fat.

- Once the perirectal space is entered, the perirectal fat is pushed away from the rectal wall with a combination of blunt and cautery dissection, and the rectal wall above is progressively divided either with hook cautery, hot scissors, or harmonic scalpel along the cautery line marked earlier in the case (**FIG 7**).
- This dissection is continued until the specimen is entirely free. Of note, the perirectal plane is *relatively* avascular, with occasional small vessels to the rectum easily controlled with cautery. If the dissection does not proceed in a straightforward manner or is unusually bloody, the usual culprit is dissection within an incorrect plane, or the lesion is more advanced than initially recognized.
- Once the specimen is free, the lesion is grasped, taking care to maintain appropriate orientation; the cap is lifted off; and the specimen is removed. The specimen is then properly oriented on a piece of Telfa dressing and is walked over by the surgeon to the pathologists for gross examination. We perform frozen section

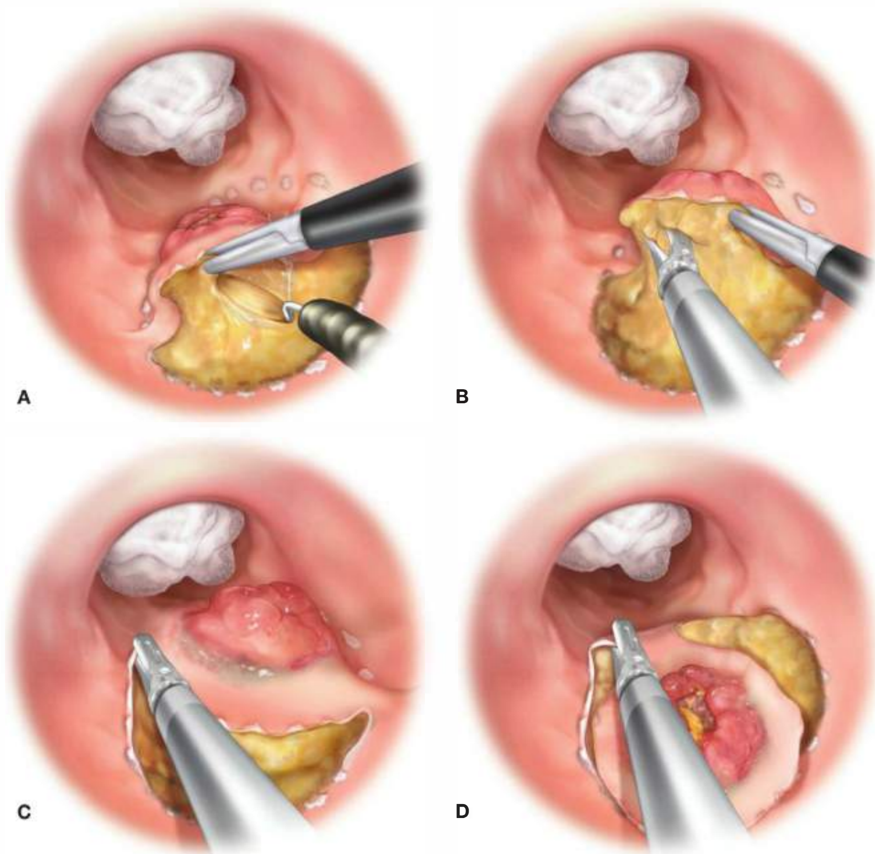

FIG 7 ● Circumferential dissection of the lesion with 1-cm margins. The deep fat is taken with either hook cautery or harmonic scalpel. The rectal wall is then taken also with either cautery or harmonic scalpel. (**A–D** demonstrate progression of circumferential dissection)

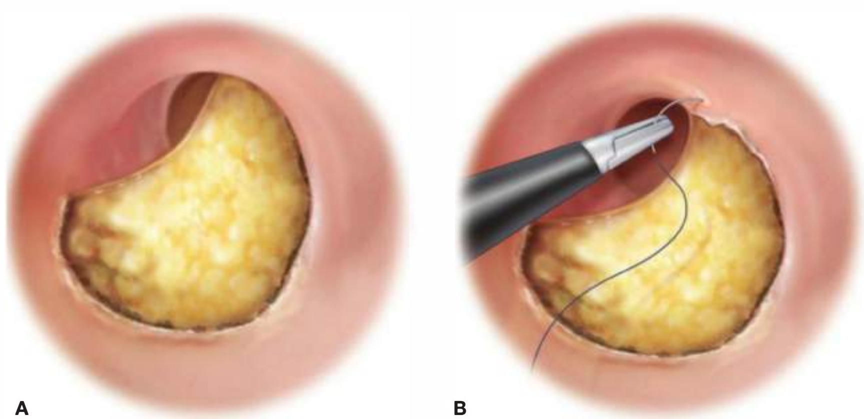

FIG 8 ● Suture repair is completed transversely from right to left (surgeon's dominant to non-dominant side). The sutures are secured on both ends with Lapra-Tys. A single running suture or two to three shorter running sutures may be used. (**A–D** demonstrate progression of suture repair) *(continued)*

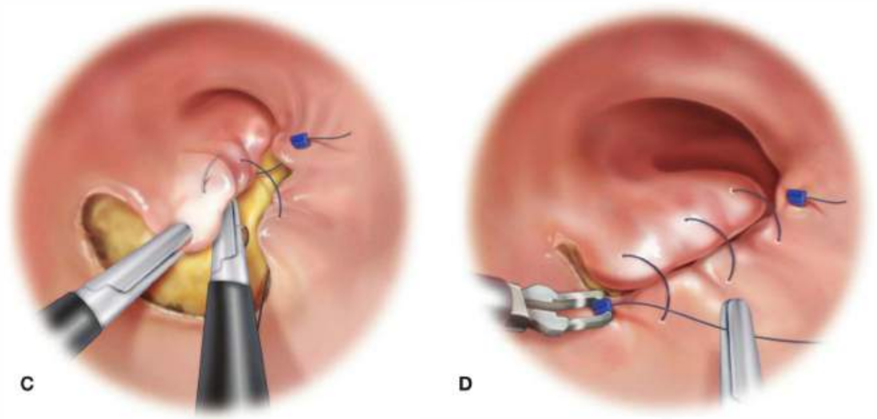

FIG 8 ● *(continued)*

examination selectively, only for suspicious margins on gross evaluation (FIG 9).

- Once the margins have been assessed and have been cleared, we proceed to perform a suture repair of the defect. The pneumorectum—which causes the size of the defect to appear more pronounced—can be decreased to facilitate closure. Even without this maneuver, very large defects can be reapproximated without significant difficulty.
- The defect can be repaired with a single running suture, or multiple interrupted sutures, transversely from right to left (FIG 8). Given that a single suture tends to be long and is somewhat tedious to handle in a small space, we prefer to place multiple shorter running sutures. We prefer a multifilament Vicryl suture, secured on one end with a Lapra-Ty. After running the suture for a number of throws, another Lapra-Ty is used to secure the remaining end, thus avoiding intracorporeal tying. Using this approach, we usually end up placing two to three running sutures to close a 180-degree defect.
- Once the repair is completed, the sponges are removed, the pneumorectum is released, and the transanal access device is gently pulled out. We place a rolled Gelfoam sponge soaked in lidocaine jelly into rectum. The sponge is removed and/or evacuated by the patient on postoperative day (POD) 1.

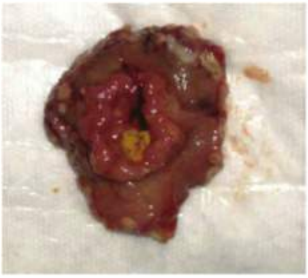

FIG 9 ● Excised specimen is placed on Telfa, appropriately oriented and taken to pathology for gross and/or frozen examination.

PEARLS AND PITFALLS

Indications/patient selection	■ Appropriate patient selection is critical both with respect to disease and size and location of lesion. ■ Appropriate lesions are those 5–15 cm from anal verge, with sweet spot 6–10 cm (midrectum). ■ Lesions >40% present a greater technical challenge, can lead to compromised margins, and may be associated with more advanced disease. ■ Risk of peritoneal entry varies by circumferential position (anterior lesions carry the highest risk of peritoneal entry).
Positioning	■ Always position the patient such that the lesion is down (6 o'clock). ■ If 6 o'clock position is not completely possible, err toward surgeon's dominant hand.
Preoperative preparation	■ Adequate mechanical bowel preparation is required to facilitate visualization. ■ With poor prep, fecal material has tendency to migrate into the field.

Exposure	▪ Ray-Tec sponge(s) placed proximally can limit insufflation of the colon and keep the operative field clean.
Excision	▪ Marking the margins with cautery and starting with a distal full-thickness incision facilitate the remainder of the dissection. ▪ Harmonic scalpel is extremely useful but can cause a blanching artifact of the mucosa that can obscure the margins during dissection.
Repair	▪ Defect is closed transversely from right to left using single running suture or two to three shorter running sutures. ▪ Use of Lapra-Tys or self-locking sutures obviates need for tying in a confined space.

POSTOPERATIVE CARE

- The patient is usually admitted overnight for observation. In the absence of significant pain, fevers, bleeding, or urinary retention, the patient is discharged home on POD 1. If low-grade fevers are noted, we have opted to use empiric antibiotics with observation until resolution.
- For the purposes of oncologic surveillance, given the concern for local recurrence, we survey the excision site with flexible sigmoidoscopy every 3 months for the first 6 months, then every 6 months for 2 years, followed by yearly and/or appropriate endoscopy and cancer screening, for a total of 5 years. In patients with invasive cancer, we perform CT scans of the abdomen and pelvis every 6 to 12 months for the first 3 years, then annually, for a total of 5 years, with the frequency determined by degree of suspicion.

OUTCOMES

Oncologic Outcomes

- The oncologic success of TEM for rectal adenocarcinoma is dependent both on the ***adequacy of technique*** and on ***appropriate patient selection.***
  - Local/locoregional recurrence is frequently the result of residual disease.
    - Luminal recurrences are likely related to residual disease at the excision site (suboptimal technique).
    - Nodal/regional recurrences are likely secondary to unrecognized nodal disease (suboptimal patient selection).
    - The risk of locoregional recurrence in low-risk T1 lesions excised with negative margins is comparable to radical resection (~5% *in most series*).
    - The risk of locoregional recurrence in unselected T1 and T2 patients is 10% or more and 30% or more, respectively, without additional therapy.[5]
    - Local recurrences are not always salvageable with radical surgery and may entail multivisceral resection. Therefore, although clinical trials with combined therapy are currently underway, TEM is currently *not* the standard of care in the United States for high-risk T1 and T2 lesions.
  - Overall survival with TEM is likely comparable to radical resection in appropriately selected patients.

Complications

- The TEM procedure, in large part, avoids the most severe complications of radical resection, including superficial and deep surgical site infections; anastomotic leaks; ventral hernia; postoperative bowel obstruction; and functional complications such as erectile dysfunction, urinary retention, and fecal incontinence.
- The risk of operative mortality is significantly lower than that of radical surgery and is less than 1% in major series.
- The risk of minor morbidity is less than 15% in most large series, with the risk of major morbidity of less than 5%.
- Specific perioperative complications are as follows:
  - ***Bleeding***—Postoperative bleeding is usually self-limited, with an infrequent need for transfusions. In a minority of cases, transanal ligation/cauterization may be necessary, with a very small likelihood of laparotomy and anterior resection.
  - ***Functional complications***—Urinary retention and anal incontinence occur relatively infrequently, and, in almost all cases, are transient. A brief period of anal leakage is often associated with traction injury from the transanal access device and usually resolves completely within a few months.
  - ***Suture dehiscence***—Dehiscence can occur in approximately 15% of patients, although most dehiscences of the extraperitoneal rectum are likely subclinical.
    - Suture dehiscences of the extraperitoneal rectum may present clinically with fevers. Although transanal repair of dehiscence can be performed, most instances can be managed nonoperatively with systemic antibiotics. These patients need to be observed, ideally as inpatients, for possible progression of pelvic sepsis. Signs of refractory and progressive pelvic sepsis should prompt consideration of abdominal exploration with fecal diversion and possibly radical resection.
  - ***Peritoneal entry***—Unintended peritoneal entry is more common with anterior and lateral lesions and more common with upper rectal lesions. In most instances, this is recognized intraoperatively and can be managed with transanal suture repair. With high upper rectal lesions, peritoneal entry may be planned and, in this setting, should not be considered a complication.

Significant expertise is required to perform an airtight repair, as suture dehiscence in this location will almost always lead to peritoneal soiling and peritonitis, necessitating abdominal exploration with repair or resection.

- ***Rectal stricture***—The risk of stricture long term is less than 5% for primary excisions.
- Relatively rare complications include intraoperative injury to genitourinary structures; rectovaginal, rectourethral, and rectovesical fistulae; complications related to positioning; and medical complications not related to the technical portion of the procedure, such as *Clostridium difficile infection* and anesthetic complications.

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Chapter 43

Laparoscopic Diverting Colostomies: Formation and Reversal

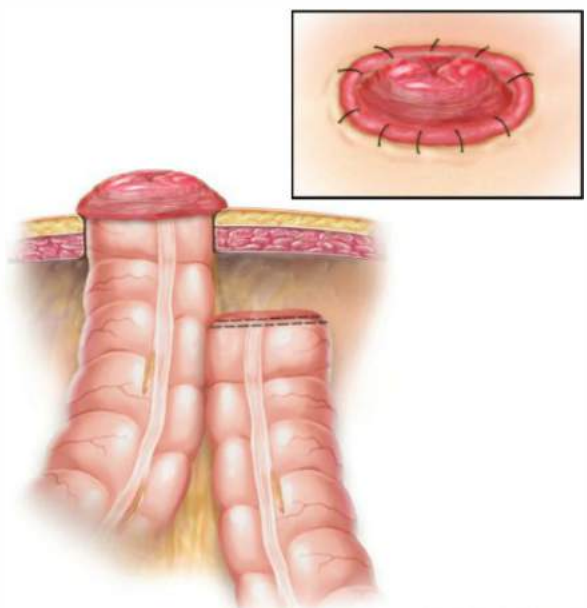
David Taylor   Andrew Stevenson

DEFINITION

- A colostomy is a surgically created communication through the body wall between the colon and the skin. There are several different kinds of colostomies, including the following:
  - End colostomy: a colostomy in which a divided end of colon passes through the stomal trephine to open externally with a circumferential colocutaneous anastomosis (**FIG 1A**). A stomal trephine is a surgically created defect through layers of abdominal wall through which the colon passes to the external opening.
  - Double-barreled colostomy: a colostomy in which two divided ends of colon pass through the stomal trephine to open externally, each via a circumferential anastomosis (**FIG 1B**).
  - Loop colostomy: a colostomy in which a loop of colon passes through the stomal trephine to open externally via a colocutaneous anastomosis. A variable portion (usually 50% to 75% of the circumference) of the antimesenteric colonic wall is used for colocutaneous anastomosis. A variable portion (usually 25% to 50% of the circumference including the mesenteric border) of the colonic wall remains in continuity (**FIG 1C**).
  - Tube colostomy: a colostomy in which a prosthetic tube passes from the colonic lumen through the abdominal wall to open externally.

PATIENT HISTORY AND PHYSICAL FINDINGS

- Diverting colostomies may be temporary or permanent. The possibility and likelihood of a stoma reversal must be taken into consideration prior to its formation.
- Diverting colostomies may be indicated by any combination of distally located pathology (i.e., malignancy, obstruction, sepsis, fistula, inflammatory bowel disease [IBD]), functional disorders (i.e., pelvic floor or anal sphincter dysfunction), or recent or concurrent surgical procedure.
- Patient factors such as age, gender, body habitus, current medical comorbidities, and previous medical and surgical conditions along with psychological, social, and cultural issues must be elicited and taken into consideration.
- Prior to embarking on reversal of colostomies, detailed knowledge is needed of the stoma creation and other operative procedures. Details such as type of stoma, resection of colon, peritoneal contamination, mobilization of splenic flexure, and marking of distal colon or rectum, if present, with a nonabsorbable suture are helpful in the operative planning process. In addition, up-to-date knowledge of the original pathology or indication necessitating formation of the stoma in the first instance is essential.
- Physical examination primarily focused on the patient's body habitus, abdominal contour, and presence of abdominal scars is important in the consideration of the type and site of the stoma to be formed.



A

FIG 1 ● **A.** End colostomy. *(continued)*

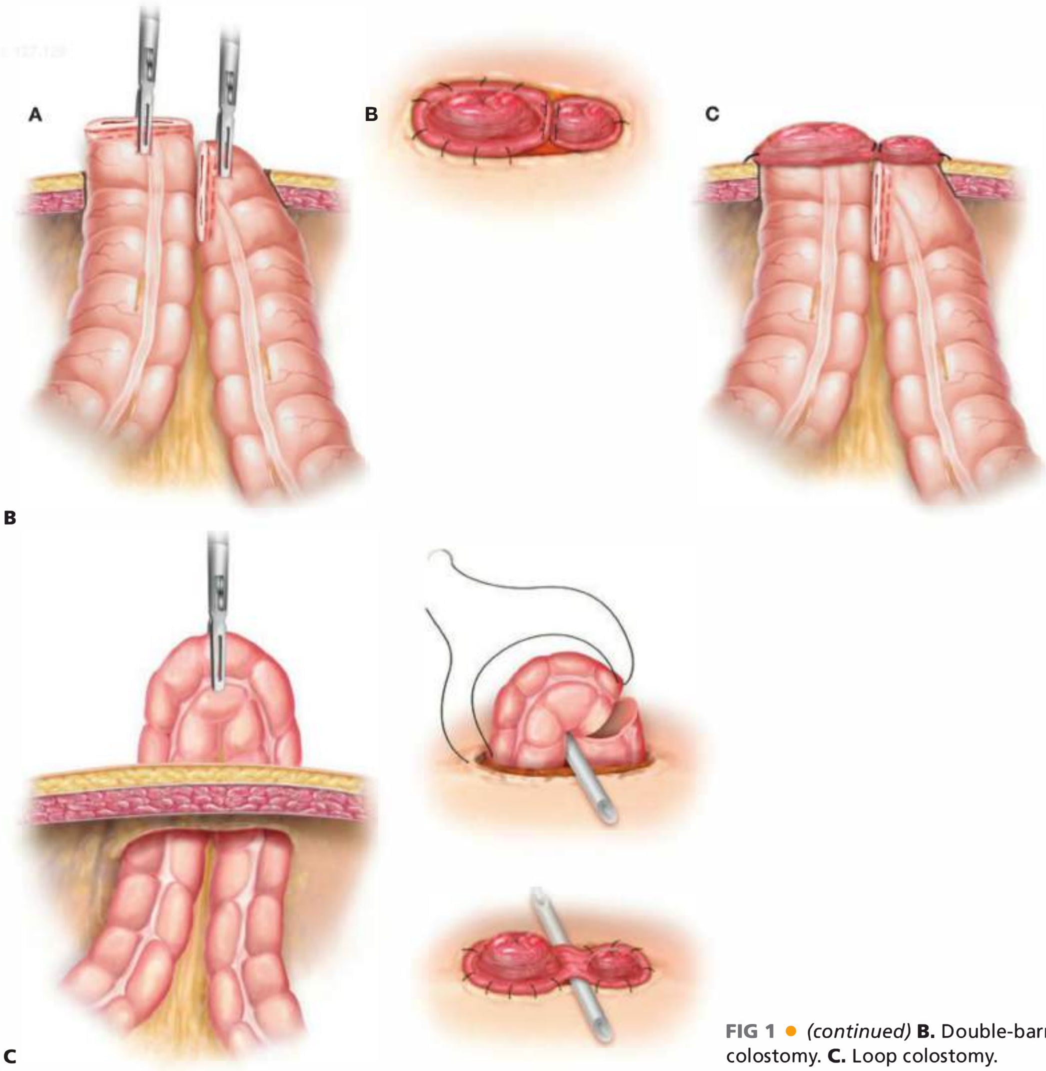


FIG 1 ● *(continued)* **B.** Double-barreled colostomy. **C.** Loop colostomy.

IMAGING AND OTHER DIAGNOSTIC STUDIES

- Preoperative investigation will be directed toward the underlying condition necessitating fecal diversion to exclude pathology proximal and/or distal to the intended colostomy site.
- Unrecognized Crohn's colitis, ileocolonic IBD strictures, synchronous tumors or other pathology may result in stomal complications or failure.
- Colonoscopy, computed tomography (CT) scan and/or colonic transit studies may help plan the type and site of stoma formation.

SURGICAL MANAGEMENT

Preoperative Planning

- It is critical to determine preoperatively which section of colon is to be used and if an end, double-barreled, or loop colostomy is to be formed.
- In the setting of proximal diversion for distal pathology, we prefer to use the sigmoid colon. Should this not be possible, we often opt for a diverting loop ileostomy. Alternatively, a transverse colostomy is an adequate option.
- The decision-making process regarding formation of an end, double-barreled, or loop colostomy is more complex and is illustrated in Table 1.
- Preoperative assessment and education, as well as preoperative stoma marking by an experienced stomal practitioner in conjunction with the surgeon, is highly recommended.
- Identifying the optimal stomal site should involve assessment of the patient standing, sitting, and supine. Factors involved in stomal site assessment are also listed in Table 1.

Perioperative Care

- Deep vein thrombosis (DVT) prophylaxis is recommended in the form of antithromboembolic compression stockings,

Table 1: Decision Making Regarding Stoma Site and Type

Stoma position	Preferable: readily visible, accessible, and transrectus Avoid: skin creases, belt lines, scars/incisions, hernia, and bony prominences; lateral ostomies may interfere with arm motion while walking.
Sigmoid colostomy	Ideal site: LLQ, transrectus at a point one-third the distance between the umbilicus and the ASIS
Transverse colostomy	Ideal site: RUQ, transrectus at a point one-third from the distance between the umbilicus and the junction of the costal margin and midclavicular line.
Stoma type	End colostomy: preferable for permanent stomas. Technically easier to construct and associated with a reduced complication rate. Advantageous in the difficult-to-construct stoma (e.g., the obese abdomen). Double-barreled colostomy: usually reserved for stomas constructed during an operation in which a segment of colon has been resected and an anastomosis was not undertaken, but subsequent reversal is likely. Loop colostomy: preferable for temporary stomas and/or when there is distal obstruction
Obese patients	Consider an end colostomy. Division of the colon and part of the mesentery will give more length and allow easier passage of the stoma through the ST. Consider siting the stoma in the upper abdomen where there is thinner abdominal wall. (The lower abdomen adiposity is most pendulous.) Visualization and therefore appliance manipulation is compromised if the stoma is situated on the underside of an adipose roll or pendulous abdomen.

ASIS, anterosuperior iliac spine.

sequential compression devices, and/or prophylactic heparin or low-molecular-weight heparin (LMWH).
- A single 2-g dose of Cefoxitin is administered prior to incision unless contraindicated.

Patient Positioning

- For creation of sigmoid colostomy and reversal of end colostomy, the patient is positioned in a modified Lloyd-Davies position (**FIG 2A**) on a nonslip pressure area care mat (Jelly Mat). The right upper limb is secured in the neutral position by the patient's side padded with jelly cushions to protect potential pressure points. These patients are prepped with an aseptic solution and draped with legging drapes and an under-buttock drape followed by square draping to expose the entire anterior and lateral abdominal wall.
- For creation of a transverse colostomy, and for the reversal of loop or double-barreled sigmoid colostomies, the patient is positioned supine, with the arms secured in the neutral position by the patient's side padded with jelly cushions to protect potential pressure points (**FIG 2B**). For patients in the supine position, standard square draping is adequate.
- Bladder decompression with a urinary catheter is not necessary except for closure of end sigmoid colostomy.
- Gastric decompression with an orogastric tube, which is to be removed prior to completion of the general anesthetic, is used.
- The laparoscopic equipment is assembled with all cords and tubes exiting/entering the sterile field over the right side of the patient's chest.

Laparoscopic Equipment

- All ports used are 5-mm balloon-tipped clear ports, with the exception of a 12-mm balloon-tipped port used through the stomal site.
- We use a 5-mm 0-degree camera for insufflation-assisted optical entry into the peritoneal cavity and a 5-mm 30-degree camera at all other times.
- Monopolar diathermy attached to laparoscopic scissors is adequate in almost all laparoscopic techniques described in this chapter. Advanced energy devices are reserved for difficult dissections and for the closure of end colostomies. For intracorporeal stapling and dividing, we use 60-mm reticulating linear endostaplers with 1.8-mm cartridge for division of colon and 1.2-mm cartridge for division of mesentery.
- For extracorporeal stapling and dividing, we use 75–80 mm linear staplers with 1.8-mm closed staple height for colonic division, 1.5-mm closed staple height for the longitudinal staple line of double-stapled side-to-side anastomosis, and 1.8-mm closed staple height for the transverse staple line of double-stapled side-to-side anastomosis.

Surgical Team Positioning

- Five surgical team configurations are described in this chapter (**FIG 3**).

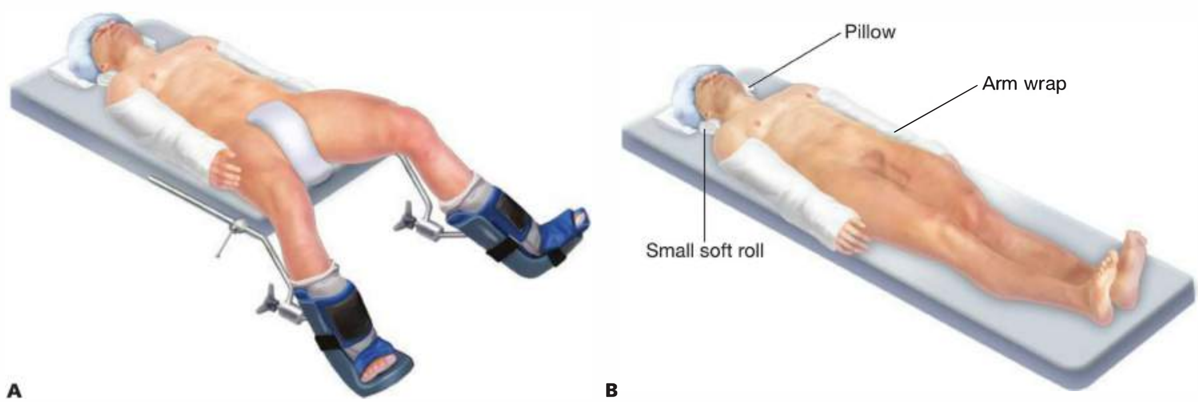


FIG 2 ● **A.** Patient positioning: laparoscopic formation of sigmoid colostomy and laparoscopic reversal of end sigmoid colostomy. The patient is placed on a modified Lloyd-Davies position, with the legs on stirrups and the arms tucked to the side. All pressure points are padded to prevent neurovascular injuries. **B.** Patient positioning (lap formation of transverse colostomy).

- Configuration 1. The operating surgeon stands to the patient's left side, with the surgical assistant to the patient's right side and the instrument nurse adjacent to the patient's right knee.
- Configuration 2. The operating surgeon stands adjacent to the patient's right side with his or her right hand dissecting with the energy device via the right lower quadrant (RLQ) or suprapubic (SP) port and with his or her left hand using a bowel grasper via right upper quadrant (RUQ) port. The assistant stands to the surgeon's left side, with the camera in his or her right hand via the midline (ML) port and the bowel grasper via the stomal trephine (ST) or left lateral (LL) port site. The instrument nurse is adjacent to the patient's right knee. The monitor is placed adjacent to patient's left hip.
- Configuration 3. The operating surgeon stands to the patient's right side, with the dissecting energy device in his or her right hand via the ST or LL port and a bowel grasper in his or her left hand via the RUQ port. The assistant stands to the surgeon's left side, with the camera in his or her right hand via ML port site. The instrument nurse or a second assistant stands between the patient's lower limbs with a bowel grasper on his right or left hand via the RLQ port site. The monitor is placed adjacent to left side of the patient's chest.
- Configuration 4. The operating surgeon stands to the patient's right side with the assistant to the patient's left side and the instrument nurse adjacent to the patient's right knee.
- Configuration 5. The operating surgeon stands to the patient's left side, with the dissecting energy device in his or her right hand via the LUQ port and the bowel grasper in his or her left hand via ST port (three-port transverse colostomy formation technique) or via the left lower quadrant (LLQ) port (four-port transverse colostomy formation technique). The assistant stands to the surgeon's left side with the camera in his right hand via the ML port, and bowel grasper in his left hand via the ST port. The instrument nurse stands adjacent to the patient's right knee. The monitor is placed adjacent to the right side of the patient's chest.

Port Placement

- Port placement planning and marking is important. The key to port placement is the RLQ port. The RLQ, RUQ, and ML ports should be placed a hand's breadth distance from each other.
- The RLQ port (5 mm) is inserted medial to, and at or just cranial to the level of the anterior superior iliac spine, just lateral to the path of the inferior epigastric vessels.
- The RUQ port (5 mm) is inserted a hand's breadth cranially along a craniocaudal line from the RLQ port.
- The ML port (5 mm) is placed via a small incision in the umbilicus or supraumbilically in obese patients with pendulous abdomens.
- The LL port (5 mm) is placed as laterally as possible at the level of the ML port. This port is optional, especially when the ST is created as the first step.
- The ST port (5- or 12-mm) is placed at the preoperatively marked stoma site. If an endoscopic linear stapler is to be used, a 12-mm port is mandatory.

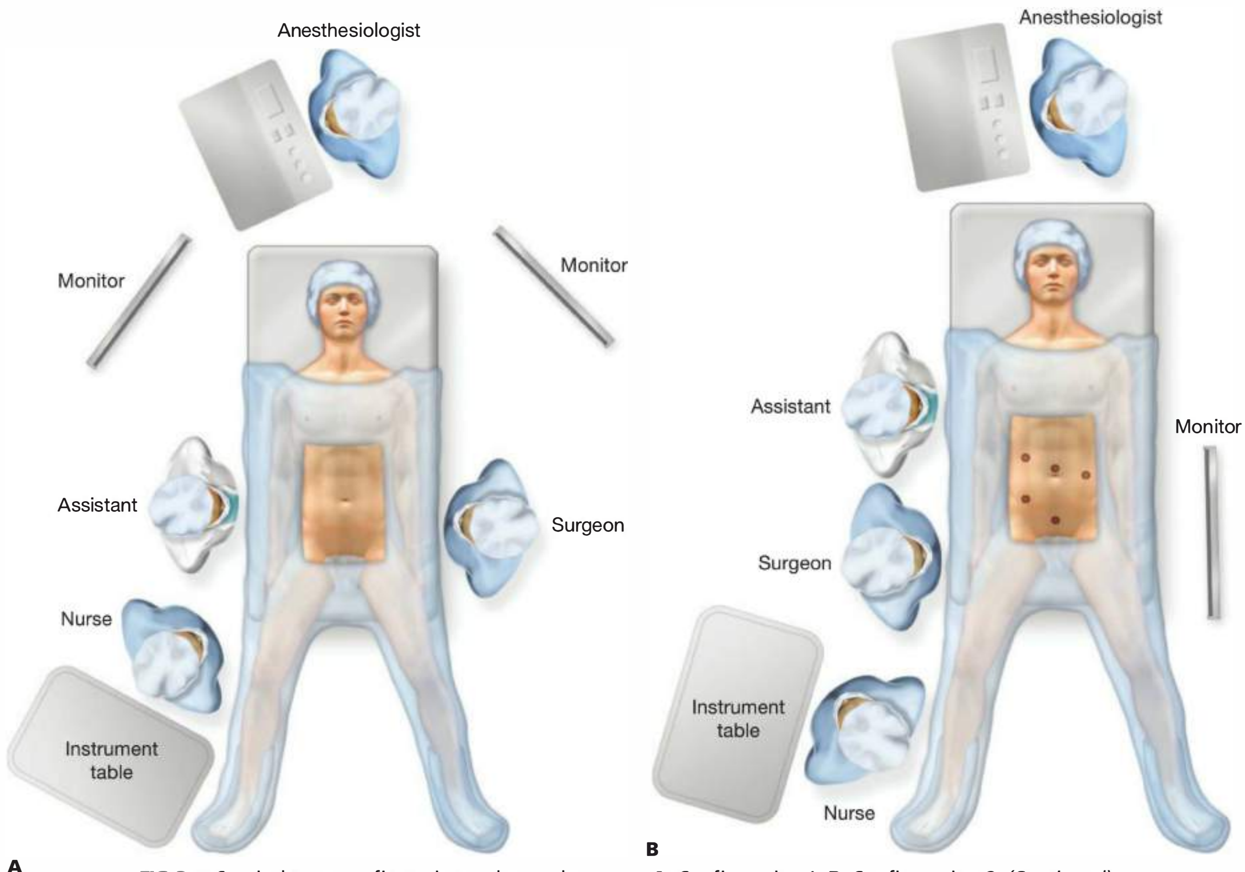


FIG 3 ● Surgical team configuration and port placement. **A.** Configuration 1. **B.** Configuration 2. *(Continued)*

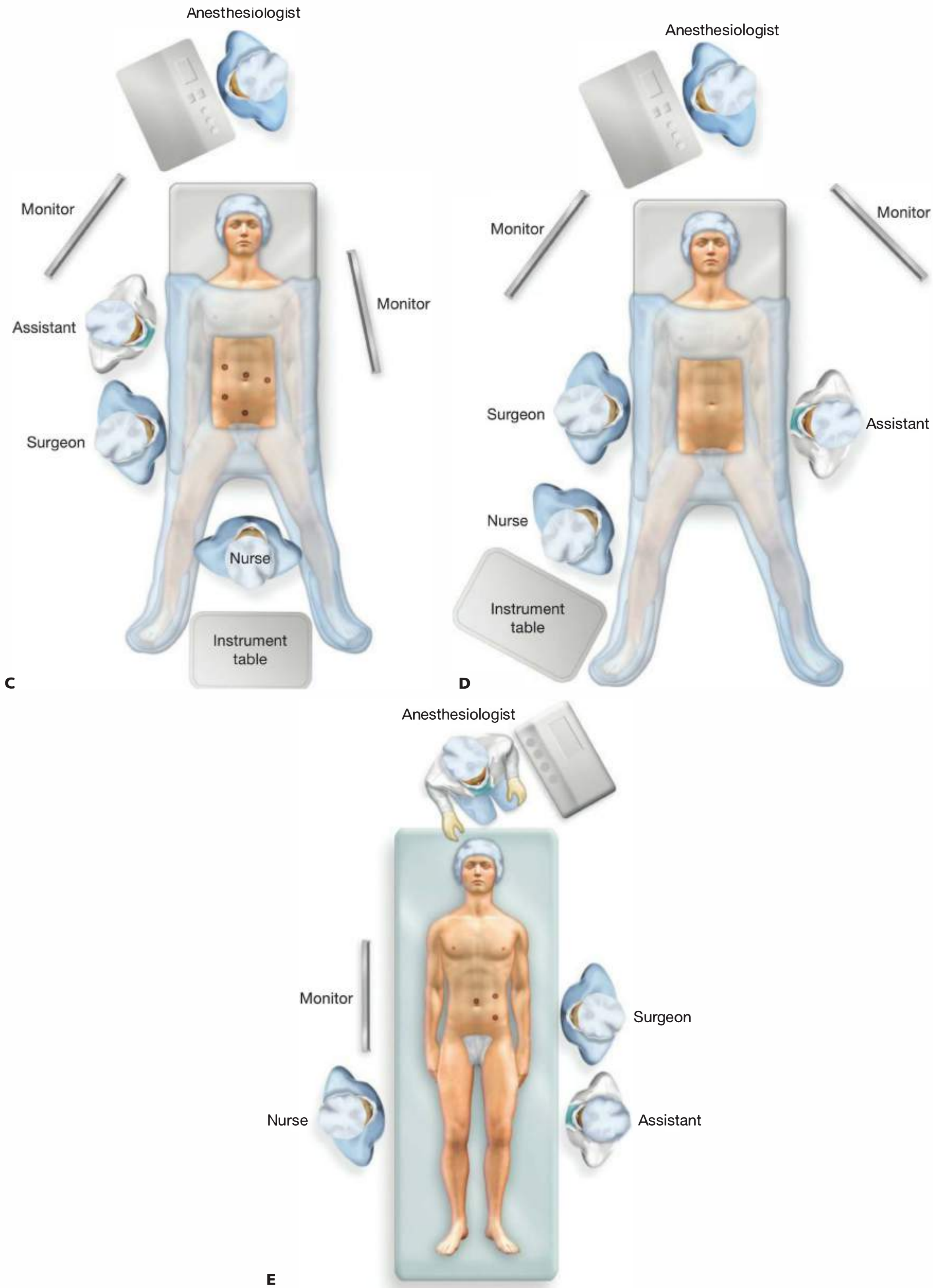


FIG 3 • *(Continued)* **C.** Configuration 3. **D.** Configuration 4. **E.** Configuration 5.

LAPAROSCOPIC FORMATION OF SIGMOID COLOSTOMY

Creation of the Stomal Trephine

- When sure about the need of a colostomy, we prefer to create the ST as the first step before the contour and layers of the abdominal wall have been altered by a pneumoperitoneum or surgical incisions.
- Using surgical team configuration 1 as previously described, a disc of skin at the preoperatively marked site is excised. Dissection through the subcutaneous adipose tissue proceeds to the anterior rectus sheath.
- The anterior rectus sheath is incised longitudinally enough to safely allow subsequent passage of the sigmoid colon but not excessive such that the patient is subjected to an unacceptably high risk of development of a parastomal hernia. The rectus muscle fibers are separated longitudinally.
- A small (<1 cm) incision is made in the posterior rectus sheath. The peritoneum is grasped and incised. A 5-mm or 12-mm balloon port is inserted via the peritoneal defect. A 12-mmHg pneumoperitoneum is insufflated.
- A 5-mm 30-degree high-definition laparoscope is inserted.
- If unsure about the need of a colostomy, we delay formation of the ST until a later stage of the procedure. In these cases, we insufflate the pneumoperitoneum using a 5-mm insufflation-assisted optical entry port via the RUQ.

Lateral to Medial Colon Mobilization

- Configuration 2 is used. The operating table is placed in a Trendelenburg position rotated with the right side down.
- The bowel grasper in the surgeon's left hand retracts the rectosigmoid junction medially and cranially. The assistant's left hand grasper may retract the proximal sigmoid colon or provide countertraction to the lateral wall of the pelvic brim.
- Energy device dissection begins at the pelvic brim. The sigmoid is mobilized from lateral attachments (**FIG 4A**). The dissection proceeds in a lateral to medial direction toward the apex of the sigmoid mesentery.
- At this stage, the left ureter and gonadal vessels should be identified and preserved intact in the retroperitoneum (**FIG 4B**). As the mobilization of the sigmoid and descending colon mesentery continues proximally, anterior to the ureter and gonadal vessels, it is often advantageous to use configuration 3. The grasper held by the instrument nurse/second assistant retracts the colon distal to that retracted surgeon's left hand grasper. The sigmoid and descending mesentery should be mobilized to the midline.
- A technical tip for the medial colonic retraction is that the colon is initially lifted anteriorly and then retracted medially. This ensures the colon acts as a "blanket" under which the small bowel is trapped, keeping it off the operative field.
- It is not usually necessary to mobilize the splenic flexure from its attachments. Although the extent of descending colon mobilization is variable, we recommend "overmobilization" to avoid undue tension. Inadequate mobilization at this stage will result in subsequent difficulty and frustration during passage of the colon through the ST and stomal maturation, resulting in an imperfect and often retracted stoma.

Sigmoid Colon Delivery through Stomal Trephine

- Configuration 2 is used. The sigmoid colon is assessed to select the optimal segment for stomal formation (most often it is the sigmoid apex). Maximum mobility from proximal and distal colon and the mesentery and proximity to the intended stomal site are the most significant factors in this selection.
- The intended segment is grasped with a locking bowel grasper via the ST port. Correct orientation is confirmed and the assistant is instructed to ensure orientation is

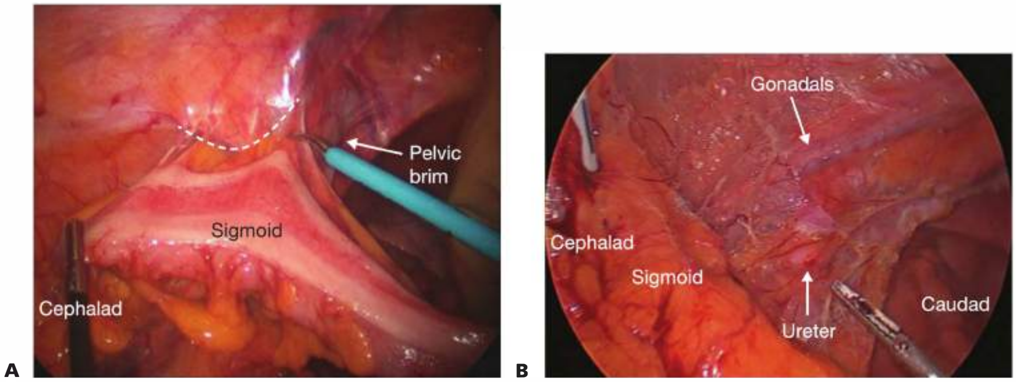


FIG 4 ● Laparoscopic sigmoid colostomy: medial to lateral mobilization of the sigmoid colon. **A.** The sigmoid is mobilized by transecting the lateral peritoneal attachments *(dotted line)*, starting at the level of the pelvic brim. **B.** After transecting the lateral peritoneal attachments and mobilizing the sigmoid to the ML, the left ureter and gonadal vessels can be identified in the retroperitoneum as they cross the common iliac artery.

maintained by holding the shaft of the bowel grasper. An additional bowel grasper may be placed and locked to the colon distal to the intended site if there are any concerns regarding loss of correct orientation.

- With the assistant holding the ST grasper, the surgeon moves to the left side of the patient to use configuration 1. The camera is withdrawn. The surgeon places two handheld retractors along the ST, retracting the rectus muscle fibers medially and laterally. The medial retractor is transferred to the assistant's right hand with the surgeon's right hand maintaining the lateral retractor. The surgeon's left hand takes control of the ST grasper and subsequently the assistant's left hand takes control of the lateral retractor.
- The pneumoperitoneum is released. The surgeon's right hand extends the posterior sheath and peritoneal vertical incision to an adequate length. The balloon of the port is deflated. The port is externalized along the shaft of the grasper. The colonic loop is then carefully externalized through the ST by extracting the ST grasper aided if required by nontraumatic bowel grasping (Rampley) forceps (**FIG 5**).

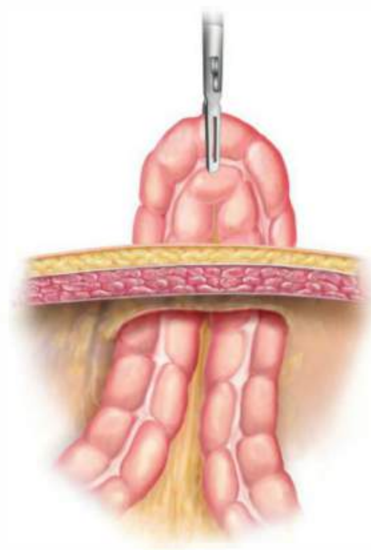


FIG 5 ● Laparoscopic sigmoid colostomy: extraction of the sigmoid loop with a laparoscopic grasper inserted through the ST port site (the port has been removed).

COLOSTOMY CREATION

Loop Colostomy Creation

- A supporting "rod" (optional) may be passed through a 5-mm defect in the mesentery adjacent to the apex of the externalized loop and sutured to the skin edge of the ST in the 3 o'clock and 9 o'clock positions (**FIG 6A**). Confirmation of correct colonic loop orientation is possible laparoscopically if deemed necessary.
- The ports are removed and port site incisions are closed with a 4-0 absorbable suture and occlusive dressings are applied.
- The apex of the colonic loop is opened by means of a transverse antimesenteric colotomy extending for 50% to 75% of the colonic circumference. The resulting proximal and distal limbs of the stoma are subsequently matured using between 8 and 12 seromuscular to subcuticular interrupted 3-0 absorbable sutures (**FIG 6B**). The stomal appliance is applied.

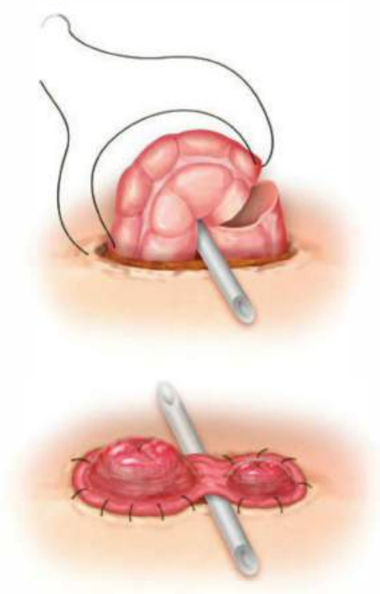


FIG 6 ● Creation of a loop sigmoid colostomy. The apex of the colonic loop is opened transversely for 50% to 75% of the colonic circumference. The resulting proximal and distal limbs of the stoma are subsequently matured flush to the skin with interrupted absorbable sutures.

Double-Barreled Colostomy Creation

- With an adequate length of sigmoid colonic loop externalized, a defect is created in the mesentry adjacent to the apex of the loop. The colon is then divided at this level with a linear stapler; the ends of the colon are grasped with nontraumatic bowel (Rampley) forceps (**FIG 1B**).
- The port site incisions are closed with 4-0 absorbable sutures and occlusive dressings are applied.
- The staple line of the proximal limb is excised. Three seromuscular–subcuticular interrupted 3-0 absorbable sutures are placed (but not tied) in the 3, 9, and 12 o'clock positions of the skin edge of the ST and the cut edges of the opened proximal colon.
- A 10-mm length of one end of the staple line of the distal colonic limb is excised. Three seromuscular–subcuticular interrupted 3-0 absorbable sutures are placed (and tied)

in the 5, 6, and 7 o'clock positions of the ST and the small opening of the distal limb.

- The proximal sutures are tied. Additional seromuscular to subcuticular interrupted 3-0 absorbable sutures are placed at intervals between already placed sutures as necessary. A stomal appliance is applied.

End Colostomy Creation

- For an end colostomy formation, instead of delivering the intact loop of sigmoid colon through the ST, the mobilized colon is transected intracorporeally.
- After identifying the optimal site for colonic division, a defect is created in the adjacent colonic mesentry with the energy device. The colon is then transected intracorporeally at this level with a 60-mm endoscopic linear stapler (**FIG 7**) inserted via the ST 12-mm port. Depending on the thickness of the adjacent mesentry and abdominal wall, a variable distance (between 30% and 50%) of mesentery is divided radially using an energy device, a linear cutting stapler with a vascular cartridge, or between ligation clips.
- The proximal colonic end is grasped with a locking bowel grasper via the ST port. Correct orientation is confirmed and the assistant is instructed to ensure orientation is maintained by holding the shaft of the bowel grasper.
- The proximal colonic end is brought out through the ST port site as discussed previously.
- The port site incisions are closed with 4-0 absorbable sutures and occlusive dressings are applied.
- The stoma is then matured with 8 to 12 seromuscular to subcuticular interrupted 3-0 absorbable sutures. A stomal appliance is applied.

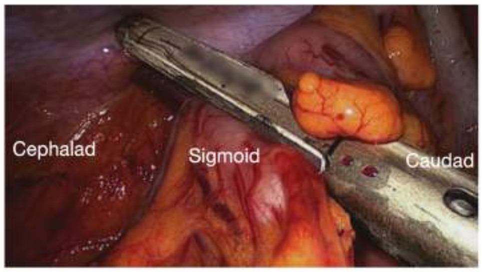


FIG 7 ● Laparoscopic end sigmoid colostomy. The distal sigmoid colon is transected intracorporeally.

LAPAROSCOPIC FORMATION OF END TRANSVERSE COLOSTOMY

Creation of the Stomal Trephine and Port Placement

- Using surgical team configuration 4, the ST is created at the preoperatively marked site (if sure about the need of the colostomy). A 12-mm or 5-mm balloon port is inserted and the pneumoperitoneum is insufflated.
- If unsure about the need of a colostomy, we delay formation of the ST until a later stage of the procedure. In these cases, we insufflate the pneumoperitoneum using a 5-mm insufflation-assisted optical entry port via the left upper quadrant.
- We use 5-mm ports in the LUQ and periumbilical locations and a 12-mm ST port (three-port technique) as described in the "Port Placement" section. An accessory LLQ port (four-port technique) is required in difficult omental mobilization cases.

Mobilization and Formation of Stoma

- Configuration 5 is used.
- The omentum is separated from proximal transverse colon with an energy device (**FIG 8**).
- After identifying the optimal site for colonic division, a defect is created in the adjacent colonic mesentry with the energy device.
- The transverse colon is then transected at this level with an Endo GIA 60-mm linear cutting stapler inserted via the ST 12-mm port.
- Depending on the thickness of the adjacent mesentry and abdominal wall, a variable distance (between 30% and 50%) of mesentry can be divided radially. This may be performed using an energy device, a linear cutting stapler, or between ligation clips (**FIG 8**).
- The proximal colonic end is grasped with a locking bowel grasper via the ST port. Correct orientation is confirmed and the assistant is instructed to ensure orientation is maintained by holding the shaft of the bowel grasper.
- The process of extracting the proximal colonic end or loop of transverse colon through the ST is identical to that described earlier.
- The port site incisions are closed with 4-0 absorbable suture and occlusive dressings applied.
- The stoma is then matured with 8 to 12 seromuscular–subcuticular interrupted 3-0 absorbable sutures. A stomal appliance is applied.

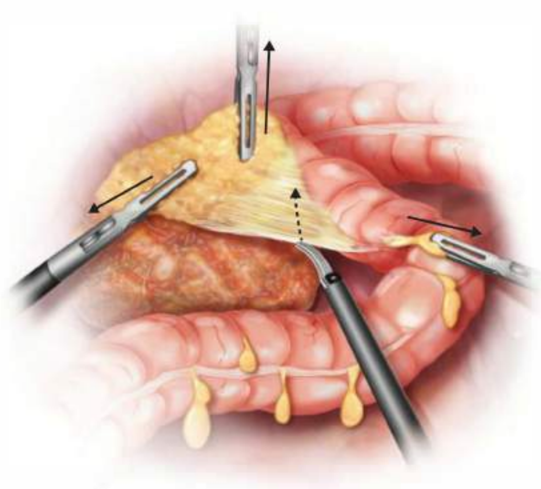


FIG 8 ● Laparoscopic transverse colostomy. The omentum is separated from the transverse colon with an energy device.

CLOSURE OF A LOOP OR DOUBLE-BARRELED COLOSTOMY

Mobilization and Closure of Stoma

- In patients with a thin abdominal wall, we incise the mucocutaneous border circumferentially. In a patient with a thicker abdominal wall due to obesity or muscle bulk, we use an elliptical skin incision inclusive of the stoma with the long axis of the ellipse oriented transversely.
- The stoma is mobilized to the peritoneal cavity by means of sharp dissection. The colonic loop or ends should be adequately mobile to comfortably externalize beyond the skin.
- Closure of the colonic loop defect or anastomosis of the colonic ends can be achieved using either a hand-sewn single-layer seromuscular technique with 3-0 absorbable suture or a side-to-side double-stapled anastomotic technique with a linear stapling device (**FIG 9A,B**).
- The reanastomosed colon is internalized within the peritoneal cavity. The fascial defect is closed craniocaudally with interrupted 0 absorbable sutures.
- The wound is lavaged with saline. Long-acting local anesthetic is infiltrated into the fascia and subcutaneous tissues.
- If a circumferential incision was used initially, the skin defect is reduced to 5- to 10-mm diameter defect by means of a subcuticular purse-string 3-0 absorbable suture. An absorbent occlusive dressing is applied.
- If an elliptical incision was initially used, the skin is closed with interrupted 3-0 absorbable subcuticular sutures. An occlusive dressing is applied.

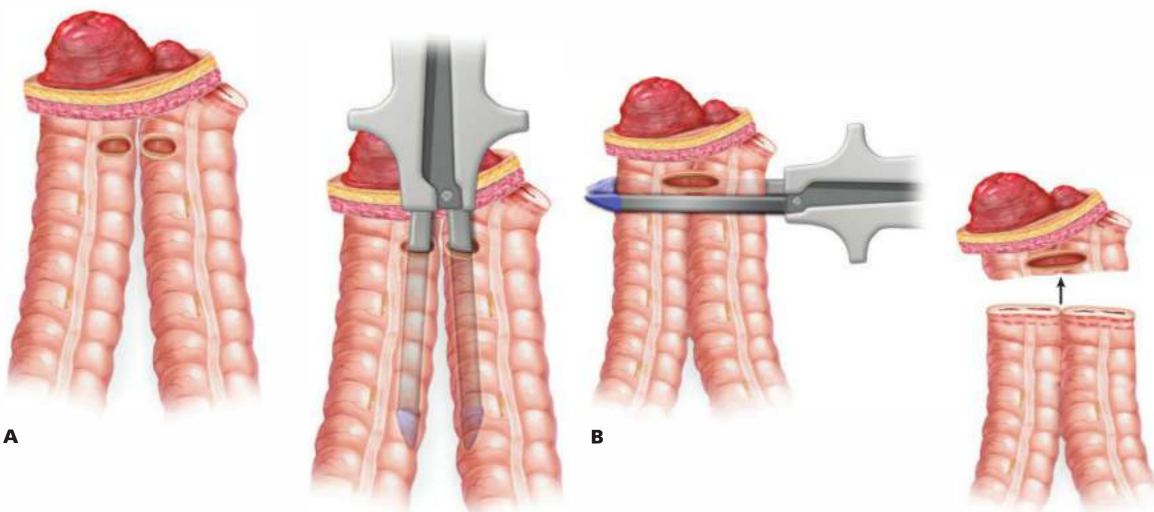


FIG 9 ● Reversal of loop colostomy. **A.** The colostomy is resected with a linear stapler. **B.** A side-to-side stapled colocolonic anastomosis is performed with a linear stapler.

LAPAROSCOPIC CLOSURE OF END SIGMOID COLOSTOMY

Team Setup and Port Placement

- Surgical team configuration 2 is used.
- The peritoneum is insufflated to 12 mm of pressure using a 5-mm insufflation-assisted optical entry port via the RUQ.
- The 5-mm ports are inserted in the RLQ and RUQ ports and ML and LL locations. The LL port is useful during mobilization of the descending colon and splenic flexure. It may not be necessary when a splenic flexure mobilization is not necessary.
- A 12-mm ST port may be inserted after the stoma site after the stoma has been mobilized into the abdominal cavity. A 12-mm SP (optional) is inserted if the rectum and/or the inferior mesenteric artery (IMA) require transection using an endoscopic linear stapler and it is not ergonomically feasible to do so via the 12-mm ST port.
- The peritoneum is insufflated to 12 mm of pressure using a 5-mm insufflation-assisted optical entry port via the RUQ.

Mobilization (+/− Resection)

- With adequate Trendelenburg and right side rotated down positioning, further adhesiolysis proceeds as required to mobilize small bowel and omentum from the pelvis and remainder of the operative field.
- With no Trendelenburg but ongoing right side down positioning (using configurations 2 and then 3), the descending colon and splenic flexure (**FIG 10**) are mobilized toward the ML as required to ensure adequate colonic length for a tension-free anastomosis, ensuring protection of the left ureter and gonadal vessels.

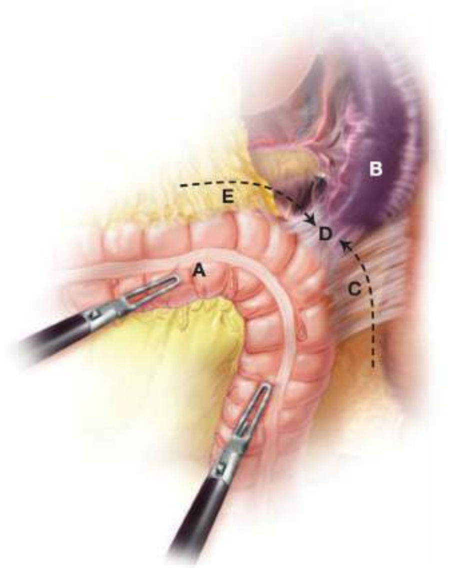


FIG 10 ● Mobilization of the splenic flexure. The surgeon retracts the splenic flexure of the colon *(A)* downward and medially, exposing the attachments of the splenic flexure to the spleen *(B)*. The phrenocolic *(C)* and splenocolic *(D)* ligaments are transected in an inferior to superior and lateral to medial direction. The gastrocolic ligament *(E)* is then transected in a medial to lateral direction until both planes of dissection meet and the splenic flexure is fully mobilized.

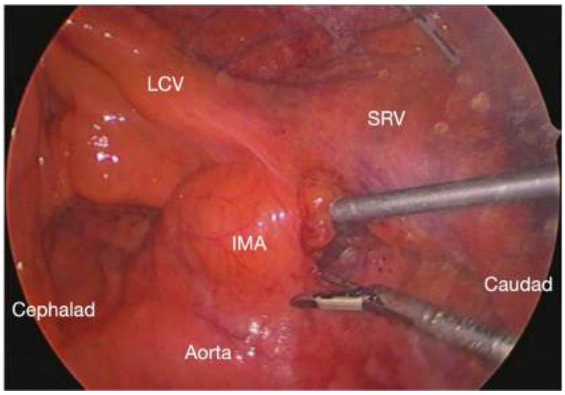


FIG 11 ● IMA dissection. With the assistant retracting the rectosigmoid junction anteriorly and cranially, the peritoneum is incised deep to the arch of the superior rectal vessels (SRV). At this point, the IMA, taking off the aorta, can be seen with its terminal branches, the SRV and the LCV.

- At this point, there are two basic scenarios that the surgeon may encounter: (1) There is a distal sigmoid stump, with an intact IMA and (2) there is a distal rectal stump; the IMA may be intact or transected.
  - When there is a distal sigmoid with an intact IMA from the previous surgery
    - Using configuration 2, the distal sigmoid stump is identified and mobilized from adhesions along with its mesentry along the lateral border ("lateral mobilization") toward the ML, ensuring protection of the left ureter and gonadal vessels (**FIG 4B**). This dissection continues distally to mobilize the left aspect of the upper mesorectum.
    - With the assistant retracting the rectosigmoid junction anteriorly and cranially, the peritoneum is incised deep to the arch of the IMA/superior rectal vessels (SRV) (**FIG 11**).
    - Dissection of the avascular window deep to the IMA/SRV arch continues from medial to lateral until it becomes confluent with the previously performed LL mesocolon mobilization.
    - The camera is rotated 90 degrees clockwise to allow better visualization through the created window to the left pelvic sidewall and brim. The ureter should be visualized through this window (**FIG 12**).
    - The second assistant or scrub nurse helps expose the retroperitoneal structures in this window by retracting the rectosigmoid junction and mesentry toward the anterior abdominal wall using the passing the suction/irrigator via the SP port under the IMA/SRV (**FIG 12**). The assistant's left hand grasper can then be repositioned proximally on the sigmoid stump to facilitate superior exposure for further dissection. Dissection continues cranially to identify and isolate the origin of the IMA off the aorta.
    - If a "high" IMA division, proximal to the origin of the left colic vessels (LCV), is mandated for the purposes of a tension-free anastomosis, the IMA can be divided with an endoscopic linear stapler or between Hem-o-lok® clips (**FIG 13**), ensuring preservation of the left ureter and gonadal vessels.
    - If adequate mobility and colonic length will permit subsequent colorectal anastomosis without high division of the IMA, the IMA is divided distal to the origin of the left colic artery (LCA) (termed a "low" IMA division; **FIG 13**).

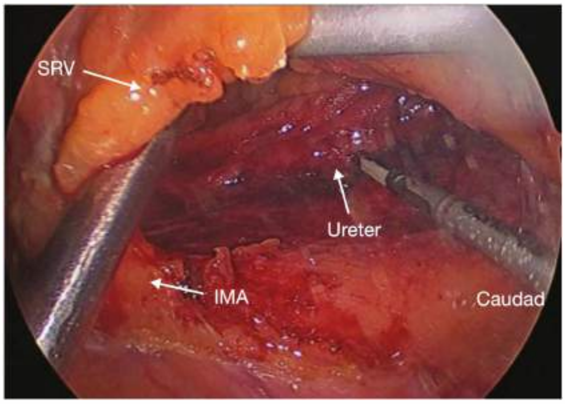


FIG 12 ● Identification of the left ureter. After dissection of the IMA/SRV off the retroperitoneum, the left ureter is visualized and preserved intact prior to IMA transection.

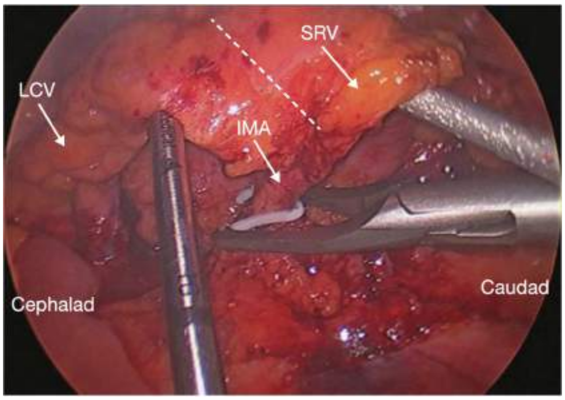


FIG 13 ● IMA transection. The IMA is transected between endovascular clips at its origin off the aorta ("high" IMA ligation). If a high IMA ligation is not needed to achieve a tension-free anastomosis, a "low" transection can be performed across the LCV *(dotted line)*, preserving the IMA/SRV intact.

- The rectosigmoid junction and mesentery are further mobilized. The upper mesorectum is divided with the energy device and the upper rectum is divided with an endoscopic linear stapler via the 12-mm SP port. The specimen is placed in endoscopic pouch and can subsequently be removed via the ST at a later stage.

- When there is a rectal stump from the previous surgery
  - If the IMA and upper rectum were divided at the time of the initial procedure, the rectal stump is identified and its end is mobilized. Rectal stump mobilization can be aided by per anal insertion of lubricated rectal "sizers" (by a second assistant or the scrub nurse).
  - If the proximal colonic end has adequate length to ensure a tension-free anastomosis, no further proximal mobilization is required.
  - If necessary, additional mobilization of the descending colon, splenic flexure, and high division of the IMA (if not previously transected) using surgical team configuration 3 may be required.
  - It is better to "overmobilize" rather than "undermobilize" the colon to achieve a tension-free anastomosis.

Colorectal Anastomosis

- Using surgical team configuration 1, the stoma is mobilized. In patients with a thin abdominal wall, we incise the mucocutaneous border circumferentially. In obese patients with a thicker abdominal wall, we use an elliptical skin incision inclusive of the stoma with the long axis of the ellipse oriented transversely.
- The stoma is mobilized to the peritoneal cavity by means of sharp dissection. A short segment of the colonic end is resected to ensure the subsequent anastomosis is formed using a healthy, scar-free, colonic end.
- A purse-string applicator clamp is placed across the colon at the resection site. The colon is cut distal to but flush with the purse-string clamp. The short colonic segment is discarded. The clamp is released and the cut edges are gently grasped with two Babcock forceps. The anvil of a 28 or 29F end-to-end anastomosis circular stapling device is inserted into the colonic end and the purse string ligated to ensure closure of the colonic end around the stem of the anvil. The colonic end and anvil are internalized into the peritoneal cavity.
- If a resection of distal sigmoid/rectal stump has occurred, the specimen can be removed in a bag via the ST defect after insertion of an appropriate wound protection device.
- The ST fascial defect is closed craniocaudally with interrupted 0 absorbable sutures.
- Using surgical team configuration 2 with Trendelenburg positioning and after re-instigation of the pneumoperitoneum, an end-to-end the stapler colorectal anastomosis is fashioned (**FIG 14**).

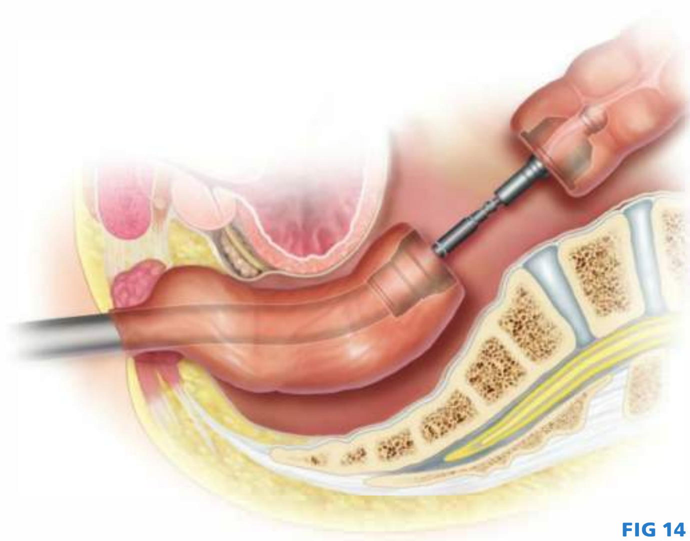


FIG 14 ● Stapled end-to-end colorectal anastomosis.

- The stapler is inserted per anally, either by the surgeon or an experienced assistant, to the proximal limit of the rectal stump under laparoscopic visualization.
- The stylet of the stapler is advanced through the proximal end of rectal wall. The anvil and colonic end are grasped and the shaft of the anvil is "docked" onto the stylet. Colonic and mesenteric orientation is checked. The stylet, with anvil attached, is retracted into the head of the stapling device until appropriate tissue compression is achieved, ensuring no adjacent structures (e.g., vagina) are incorporated.
- The stapling device is deployed. The stapling device is partially opened and removed per anally. Proximal and distal "donuts" are assessed for completeness.
- The colonic mesentery is inspected to ensure no small bowel is herniated deep to it.
- The integrity of the anastomosis is tested by air insufflation under water. The presence of air bubbles would indicate an anastomotic leak, necessitating a revision of the anastomosis. A pelvic drain is not used unless the anastomosis is extraperitoneal.
- Ports are removed. The fascial defect of any 12-mm ports are closed with a 0 absorbable suture and the port site skin incisions are closed with 4-0 absorbable suture.
- The ST wound is lavaged with saline. Long-acting local anaesthetic is infiltrated into the fascia and subcutaneous tissues.
- If a circumferential incision was initially used, the skin defect is reduced down to a 5- to 10-mm diameter defect by means of a subcuticular purse-string 3-0 absorbable suture. An absorbent occlusive dressing is applied.
- If an elliptical incision was initially used, the skin is closed with interrupted 3-0 absorbable subcuticular sutures. An occlusive dressing is applied.

PEARLS AND PITFALLS

Important principles	■ Adequate preoperative preparation and planning ■ Adequate mobilization ■ Good blood supply ■ Appropriate aperture diameter
Permanent stomas	■ End colostomies are preferable over loop or double-barreled colostomies. ■ Consider prophylactic mesh placement, especially in patients at risk of parastomal hernias. We use the laparoscopic "buttonhole" or Sugarbaker techniques.
Transverse colostomies	■ Avoid compromise to the left branch of the middle colic vessels, especially in situations in which the IMA may have been divided or compromised.
Tips in the obese patient	■ Aggressive preoperative weight loss is advisable: It reduces the thickness of the abdominal wall and the mesenteric bulk. ■ More extensive mobilization is required due to thicker abdominal wall. ■ Site the stoma further cranially than the standard position: The abdominal wall adipose tissue will be displaced caudally when the patient sits or stands. Also, the abdominal wall is thinner in the upper abdomen. ■ End colostomies are easier to construct and associated with fewer complications. The length available is superior, the mesenteric bulk is less, and the trephine aperture required is less. ■ A small Alexis™ wound protector/retractor placed through the ST often aids passage of the stoma. Cutting the inner ring aids removal of the device.

POSTOPERATIVE CARE

- Routine postoperative DVT prophylaxis is standard. An enhanced recovery style progression is routine with early mobilization and return to full diet.
- If a stoma has been created, stomal education should commence as early as possible (on the first postoperative day), as competency of stomal care is often the determining factor delaying patient discharge.
- When a colorectal anastomosis has been performed, our practice is to leave a rectal catheter in situ for 3 to 5 days. The rectal catheter is flushed with 20 mL of saline three times per day and remains in situ until the patient is passing flatus via or past the rectal catheter.

COMPLICATIONS

- Bleeding
- Anastomotic leak
- Wound infection
- Parastomal abscess
- Fistula
- Stomal retraction/stenosis
- Skin irritation/ulceration
- Stomal prolapse
- Parastomal or incisional hernia

SUGGESTED READINGS

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Chapter 44

Surgical Management of Hemorrhoids

Bidhan Das

DEFINITION

- Hemorrhoids are a normal constituent of normal anorectal anatomy. The terms "hemorrhoid" or "hemorrhoidal disease" effectively refer to conditions related to the vascular cushions of the anal canal. The goal of any hemorrhoid treatment plan is the control of symptoms, rather the removal of these vascular cushions as a rule.
- Hemorrhoids by their definition classically by Thomson in 1975 are specialized structures that act as vascular cushions contained within the submucosal space of the anal canal. It is thought that they serve to maintain closure of the anal canal and contribute to fecal continence.
- Hemorrhoidal tissue is not necessarily limited to the three cardinal "quadrants," and commonly, additional hemorrhoids in between these quadrants are found. Interestingly, hemorrhoidal tissue is neither artery nor vein, noting that histologically, they have no muscular wall and are, in fact, sinusoids.
- Hemorrhoid pathology is classified as either internal or external (**FIG 1**), relative to its position at the dentate line, and internal hemorrhoids are graded according to severity of symptoms. It is exceedingly important to understand this functional anatomy before choosing the type of operative therapy.
- Operative hemorrhoidectomy classically describes the removal of both internal (proximal to the dentate line) and external hemorrhoidal tissue (distal to the dentate line). However, new advances and procedures such as Doppler-guided hemorrhoidal ligation or transanal hemorrhoidal dearterialization (THD) can be performed with less pain and enhanced recovery times, as there is no cutting of the anoderm, and the operative field is proximal to the dentate line.
- Excisional hemorrhoidectomy remains the gold standard operation to which all treatments are compared, as its safety as well as durability has withstood the test of time. However, it remains a painful operation, and other measures may be weighed against a possibly higher recurrence rate with substantially reduced postoperative pain.
- Furthermore, with the rising population of patients on full anticoagulation because of the growing ability to treat severe cardiovascular diseases as chronic illnesses, older techniques such as sclerosant therapy become handy operative tools for the acutely bleeding patient, in whom further suturing runs the risk of further bleeding.

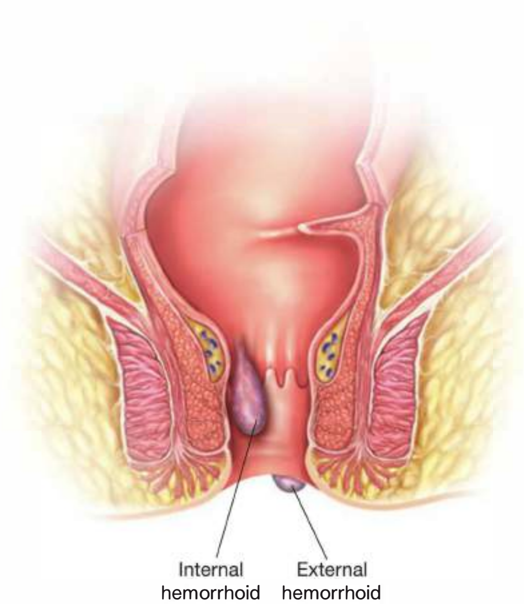


FIG 1 ● Internal versus external hemorrhoids. Position of the hemorrhoids relative to the dentate line *(dotted arrow)* classifies them as internal (proximal to the dentate line) or external (distal to the dentate line).

DIFFERENTIAL DIAGNOSIS

- Anal cancer, particularly melanoma
- Rectal prolapse (**FIG 2A,B**)
- Anorectal varices
- Perianal cyst disease
- Anal condyloma
- Pedunculated polyps
- Protruding anal papillae
- Anal skin tags, particularly sentinel tags associated with anal fissures
- Crohn's disease

PATIENT HISTORY AND PHYSICAL FINDINGS

- In order to treat hemorrhoids effectively, the other items in the differential diagnosis must be ruled out. Additionally, when considering surgical options, the pain of a traditional hemorrhoidectomy may be avoided by other methods that treat internal hemorrhoidal disease. Accurate diagnosis and determination of internal versus external hemorrhoidal disease must be ascertained to decide on the best operation for the patient.
- A thorough history and physical should be performed prior to treatment, including a detailed past medical history, present medications and allergies, and particularly conditions such as cirrhosis or previous treatment with radiation.
- Toileting behaviors, alteration in bowel function, and dietary changes must also be noted.
- Conditions that impair venous drainage, push vascular cushions outward, behavioral/toileting abnormalities, and changes in sphincter function are all commonly believed to contribute toward worsening hemorrhoidal symptoms. Ultimately, venous congestion with subsequent hypertrophy of internal hemorrhoidal cushions leads to symptomatic hemorrhoids.

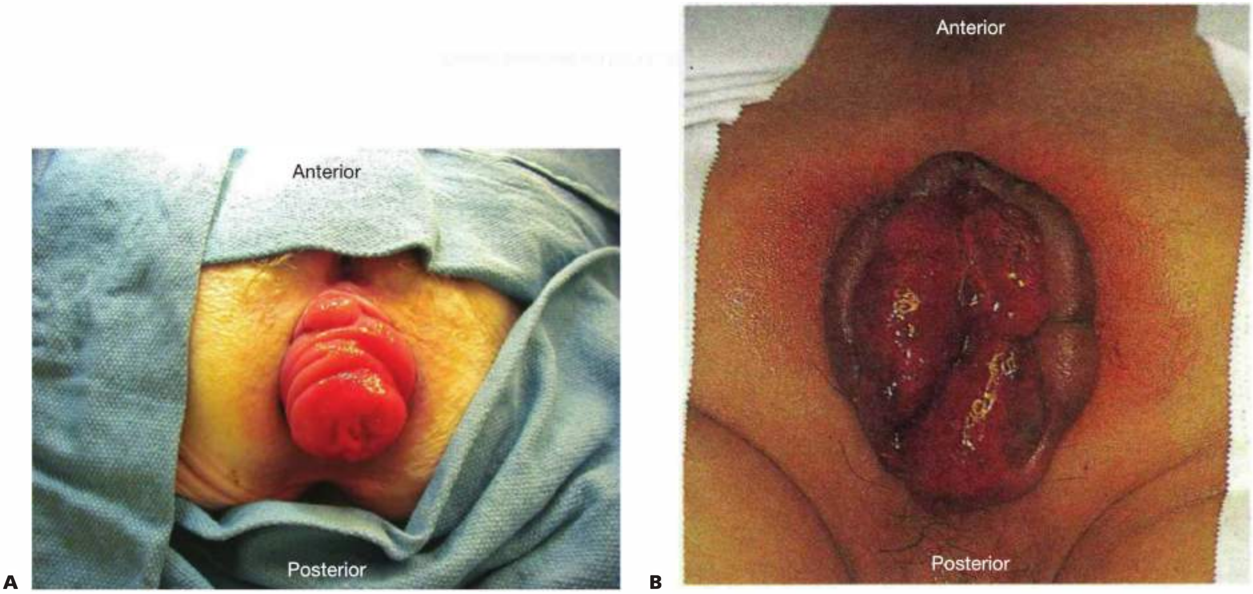


FIG 2 ● Rectal prolapse. It is important to differentiate **(A)** rectal prolapse from **(B)** prolapsing internal hemorrhoids.

- Prolonged straining increases abdominal pressure, which then impairs venous return, thus making the hemorrhoidal cushions unable to decompress transient congestion. Supportive tissues of the cushions then become gradually more and more attenuated, leading to prolapse of the cushion. Further prolapse then increases the possibility of trapping blood in the cushions with less abdominal pressure, thus causing progressive enlarging. Continued prolonged straining is an important preoperative history point because the behavior will need to be modified in the postoperative period to reduce pain and can worsen the efficacy of suture ligation operations.
- Dietary factors and toileting behavior are also critical issues because they not only impair postoperative recovery, but they can also promote postsurgical anal fissures, compounding a difficult postoperative recovery.
- Cirrhotic patients are at high risk for having anorectal varices, which are often mistaken for hemorrhoidal cushions. Elective hemorrhoidectomy for anorectal varices is fraught with excessive bleeding even to the point of hemodynamic instability in the stable patient once dissection for a misdiagnosis has started.
- A complete rectal examination, which includes not just a digital rectal examination (DRE) but anoscopy and proctoscopy, is essential to the diagnosis. It is important to distinguish between rectal prolapse versus mucohemorrhoidal protrusion. Proctoscopy aids in the diagnosis of inflammatory bowel disease while allowing control of bleeding and biopsy. The number, location, grade designation, and relative size of hemorrhoids should be noted.

IMAGING AND OTHER DIAGNOSTIC STUDIES

- Given a thorough physical examination, imaging or other diagnostic modalities are rarely indicated.

SURGICAL MANAGEMENT

Preoperative Planning

- Patients do not require bowel preparation for hemorrhoidectomy of any kind. Often, a simple enema before operation is sufficient for evacuation of the rectum. A rigid proctoscopy in the operating room before starting the procedure not only completes the preparation but also reviews the rectal mucosa for any signs of inflammation that may alter the surgical therapy or alert the surgeon to a heretofore unknown cause of straining.
- The operation can be performed using a number of anesthetic choices and options, including: general anesthesia, local anesthesia with intravenous sedation, or even regional anesthesia.
- Sequential compression devices (SCDs) are placed on the patient prior to the induction of general anesthesia.
- When performing a THD procedure, a patient should be examined for the presence of external hemorrhoidal disease. The operating surgeon may feel that there is more benefit in performing a traditional hemorrhoidectomy when there is a substantial external component that could be worsened by an internal ligation procedure, which could cause subsequent levator spasm and tenesmus postoperatively.
- When performing rubber band ligation of internal hemorrhoids, an office setting is most often well tolerated.

Positioning

- Multiple positions are excellent for hemorrhoidectomy operations, including lateral Sims position (**FIG 3**), prone jackknife (**FIG 4**), or high lithotomy (**FIG 5**) using C-type "candy cane" footholders. Anesthesia concerns and surgical needs often are satisfied with the use of high lithotomy position. It is important to note that for prone jackknife, the folding mechanism of

FIG 3 ● Sims position.

the operating table should be at the patient's hip for maximal exposure, whereas in lithotomy the sacrum should be at the very edge of the bed. In smaller patients, a flattened and folded blanket or bedroll can be placed under the sacrum to provide some elevation of the perineum and forward projection.

- Lithotomy patients using the C-type footholders often benefit from 45-degree angling of the footholder base toward the patient's head, whereas the "C" should be orthogonal to the patient's body. SCD/Venodyne boot cords can be tucked behind the adjustment flanges of the footholders. Such a position pushes the patient's knees cephalad and feet medially.
- For lithotomy patients undergoing either traditional hemorrhoidectomy or THD, an under-the-buttocks drape with a plastic drain pocket can be used to store the Doppler device or to clip instruments while suture ligating or sewing for ready access.

FIG 4 ● Prone jackknife position.

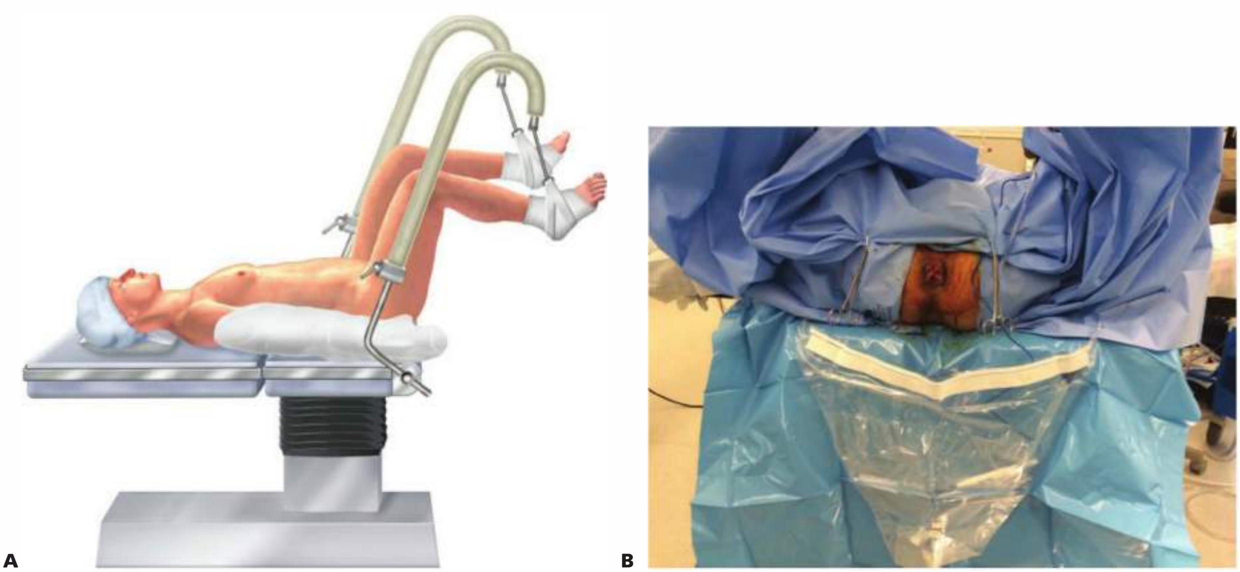


FIG 5 ● **A.** Lithotomy position with C-type (candy canes) footholders. **B.** Final Setup for High Lithotomy with Under-the-Buttocks drape with plastic pouch; white band can be used to hold instruments.

TRADITIONAL EXCISIONAL HEMORRHOIDECTOMY (CLOSED FERGUSON TECHNIQUE)

Delineation of Hemorrhoidal Cushions and Skin Incisions

- After performing a proper anoscopy using serial dilation of graded Hill-Ferguson retractors, a hemorrhoidal bundle can be readily exposed. Using a forceps or hemostatic clamp, the hemorrhoidal cushions can be gathered to facilitate the skin incision, which should spare the anoderm but include the hemorrhoidal bundle. This incision can be minimized by undermining directly underneath the hemorrhoidal bundle at the distal aspect and cutting inward directly into the anal canal to start the dissection (**FIG 6**).

Dissection of the Hemorrhoidal Vascular Tissue from the Internal Sphincter

- After cutting directly under the hemorrhoid bundle distally and through the dermis, a Metzenbaum scissor

FIG 6 ● Delineation of hemorrhoidal cushions and skin incision. Elevation of the anoderm with a clamp distal to the hemorrhoidal cushion allows for a precise incision.

carefully and sharply separates the vascular submucosal tissues from the adherent, often fibrous internal sphincter and intersphincteric groove (**FIG 7**).

- A rule of thumb: Dissect the sphincter from the hemorrhoid rather than hemorrhoidal tissue from the sphincter.

Continued Skin Excision and Pedicle Isolation

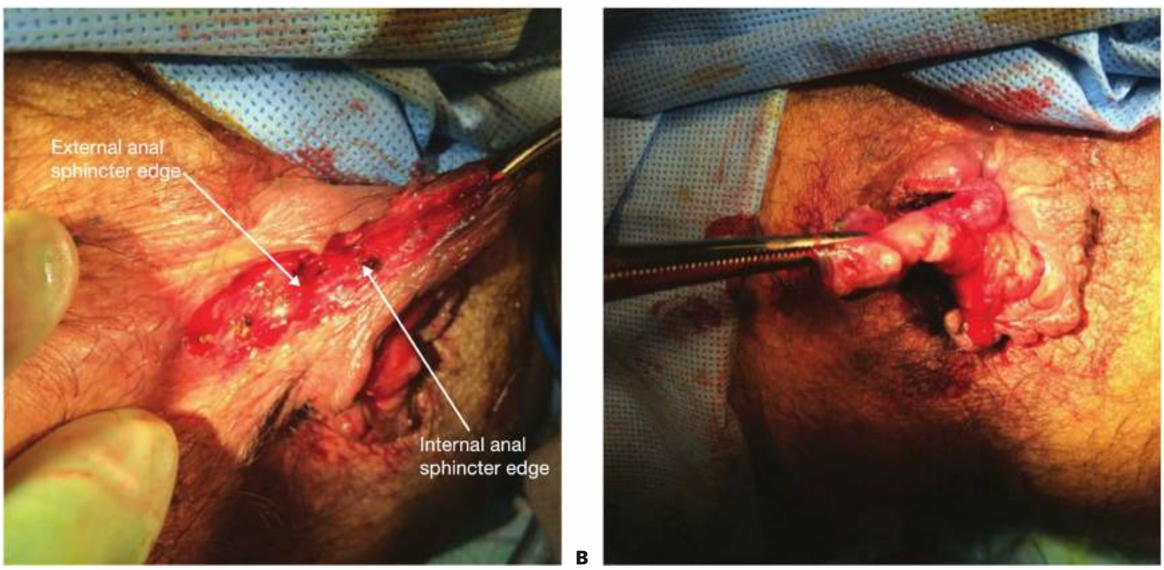
- As the surgeon dissects the sphincter off the hemorrhoid, a substantial "tunnel" is created; to save anoderm, the edges of the "tunnel" are simply cut directly toward the proximal aspect of the hemorrhoid, which can help make the operation progress by better easily delineating the hemorrhoidal bundle.
- As the incision reaches a point proximally, the hemorrhoid bundle is delineated completely and isolated cephalad, and in such a manner the vascular pedicle of the hemorrhoid is effectively isolated.

Pedicle Clamp, Specimen Removal, and Suture Ligation

- With the hemorrhoidal tissue narrowed down to a pedicle, this vascular structure can be clamped with a hemostat, the specimen cut and removed, and a suture ligature of absorbable suture can be applied, leaving the tail long (**FIG 8**).

Closure

- Using the same suture and the pedicle suture ligation as an elevated anchor, continuous (**FIG 9**) or running, locking bites can be taken to close the incision, grabbing small fibers of the internal sphincter as one works distally to anchor the cut edges and promote hemostasis.
- Upon leaving the limits of the anal sphincter and thus the mucosa, no further deeper tissue anchoring is used. One variant of the closure is to tie the suture to itself, every two bites, which can effectively act as a mucosal proctopexy until the end of the mucosal opening is reached. The suture is tied to itself at the distal aspect of the anoderm.
- The same process is repeated in the other two quadrants and can be modified for areas that are not in the traditional quadrants.

A 

B

FIG 7 ● **A.** Dissection of the hemorrhoidal vascular tissue from the internal sphincter. Using scissors, dissect the sphincter from the hemorrhoid rather than hemorrhoidal tissue from the sphincter. **B.** The pedicle is isolated.

A

B

FIG 8 ● **A.** Suture ligation of hemorrhoidal vascular pedicle. After the hemorrhoidal pedicle has been transected at its origin and the hemorrhoidal tissue has been removed, the pedicle is suture ligated for hemostasis. **B.** Suture is kept long, as an anchoring stitch.

Hemostasis Assessment and Packing

- After completion of hemorrhoidectomy, a repeat examination using Hill-Ferguson retractors is performed to ensure continued hemostasis. After verification of hemostasis, a Surgicel is tucked into the anal canal, which can be removed at any time or with first flatus or defecation. Should bleeding be encountered, an interrupted suture or figure-of-eight suture can be applied liberally.

FIG 9 ● Closure. Using the same suture and the pedicle suture ligation as an elevated anchor, continuous or running, locking bites can be taken to close the incision, grabbing small fibers of the internal sphincter as one works distally to anchor the cut edges and promote hemostasis.

RUBBER BAND LIGATION OF HEMORRHOIDS

Isolation of the Hemorrhoidal Cushion

- Anoscopy is performed using serial dilation of either graded Hill-Ferguson retractors or office anoscopy (Buie, Hirschman, lighted Welch Allyn) to demonstrate that there is an internal hemorrhoid of grade II or III classification.
- Pressure can then be placed against the anoscope, which will make the already protruding hemorrhoid even more prominent (**FIG 10**).

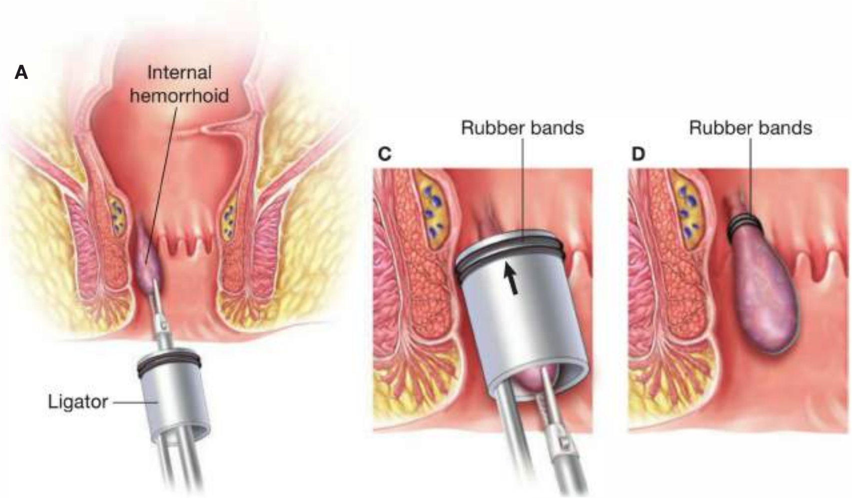
FIG 10 ● Hemorrhoidal banding: isolation of the hemorrhoidal pedicle with an anoscope.

Rubber Band Application

- With the anoscope pressure being maintained, a Barron ligator is used to ligate the hemorrhoid (**FIG 11**) by first passing the hemorrhoid-seizing forceps through the window of the ligator after the ligator has been loaded.
- The forceps then grab the protruding internal hemorrhoid as broadly as possible (**FIG 11A,B**) and the ligator is pushed directly down onto the hemorrhoid until the base of the hemorrhoid is reached while seizing forceps has the hemorrhoid still elevated.
- The ligator fires the rubber band around the base of the hemorrhoid (**FIG 11C**). It is of the *utmost* importance that the ligation is performed definitively proximally to the dentate line (**FIG 11D**).

Maintenance of Band Ligation

- To complete the procedure, a fine gauge short needle (25 gauge) is used to instill 2 to 3 mL of local anesthetic submucosally on the "cap" of the ligated hemorrhoid to create a large "mushroom" that will prevent slippage of the rubber band.



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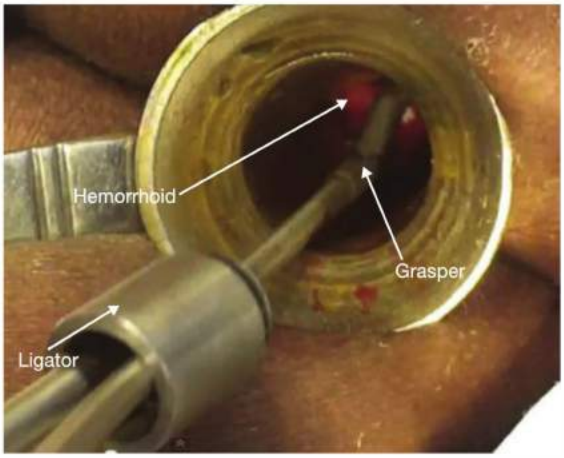


FIG 11 ● Rubber band application. **A,B.** The forceps grab the protruding internal hemorrhoid as broadly as possible. **C.** The ligator is pushed directly down onto the hemorrhoid until the base of the hemorrhoid is reached. **D.** The ligator fires the rubber band around the base of the hemorrhoid. It is of the *utmost* importance that the ligation is performed definitively proximally to the dentate line *(dotted arrow)*.

SUTURE LIGATION OF INTERNAL HEMORRHOIDS

Suture Ligation

- After anoscopy demonstrates the internal hemorrhoid, a figure-of-eight suture of absorbable suture material is placed to completely encompass the hemorrhoidal bundle without passing the needle through the cryptoglandular interface and thus reducing the chance of abscess.
- The suture is tied in such a way that the knot lies toward the most cephalad portion of the internal hemorrhoid. Such a placement can sometimes gather and fixate the internal hemorrhoid proximally in addition to the vascular ligation.

DOPPLER-GUIDED LIGATION OF THE HEMORRHOIDAL TERMINAL ARTERY BRANCHES AND MUCOSAL PROCTOPEXY USING TRANSANAL HEMORRHOIDAL DEARTERIALIZATION DEVICE

Isolation of Distal Branches of the Hemorrhoidal Arteries

- The THD device is a specifically designed anoscope/proctoscope equipped with a Doppler probe that faces outward and a light source attached to a pivot cage for a specifically designed suture and needle driver set (**FIG 12A**). Continuous Doppler audio waveform is provided with a double crystal that is made to focus and capture the larger diameter arteries located in the superficial layers of the rectal wall.
- Following lubrication and a thorough anoscopy using serial dilation with graded Hill-Ferguson retractors, the proctoscope is inserted through the anal canal reaching the distal rectum (roughly 6 to 7 cm from the anal verge).
- By moving the proctoscope with the Doppler ultrasound activated, one can hear the waveforms generated and isolate the six strongest waveforms that correlate to six equidistant positions around the anal canal (**FIG 12B**).

Transfixion with Suture Ligature

- Once a hemorrhoidal artery is located, the rectal mucosa and submucosal wall are transfixed with a figure-of-eight/"Z-stitch" to ligate the artery (**FIG 12C**). This transfixion suture is performed with the provided 2-0 absorbable polyglycolic acid with a $^{5}/_{8}$-in needle at the prefabricated notch, inserting the needle driver tip into the provided pivot cage (**FIG 12D**), which is in the center of the proctoscope's lumen. The pivot cage is used twice to perform an appropriate figure-of-eight/Z-stitch to ligate the artery.
- The suture is then tied after the Doppler probe is removed. This removal allows the operating surgeon's finger to slide deep into the anal canal to set the knot. The tail is left long, as this suture will act as an anchor for the upcoming mucosal proctopexy.

Mucosal Proctopexy

- Holding the THD proctoscope as a continued retractor and holding the long anchor tail against the scope, mucosal and submucosal bites can be taken to eliminate the prolapse of the hemorrhoid or mucosa. These bites are taken distal to the transfixion site at a step size of half a centimeter and can be tied back to the anchor stitch to create the "mucopexy" (**FIG 13**).
- Note that this mucopexy terminates at least 5 mm proximally to the dentate line and is tied to the first anchor stitch for a substantial mucosal proctopexy and to avoid potential abscess formation.
- This procedure is repeated five more times for a completed procedure.
- At the conclusion an anoscopic examination of each suture site is performed to verify no undue bleeding which can be treated with suture ligation. A Surgicel light packing is placed in the anal canal and can be removed any time or by first flatus or defecation.

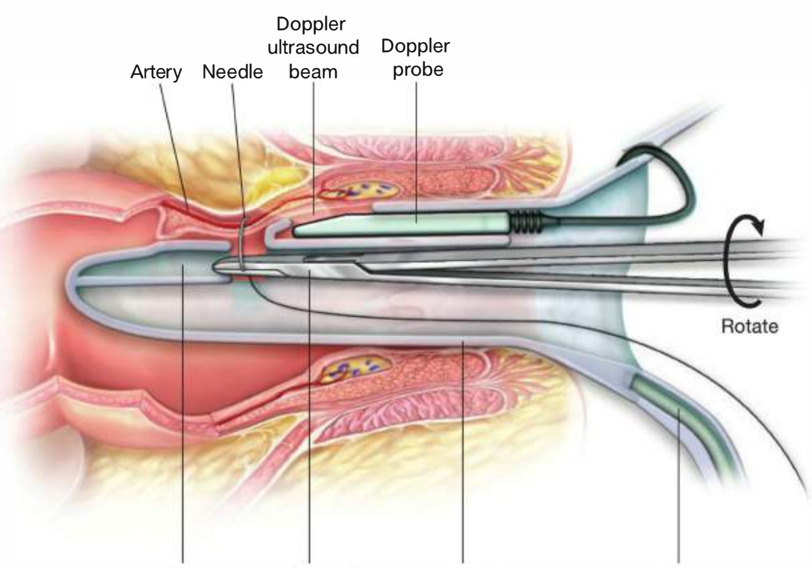
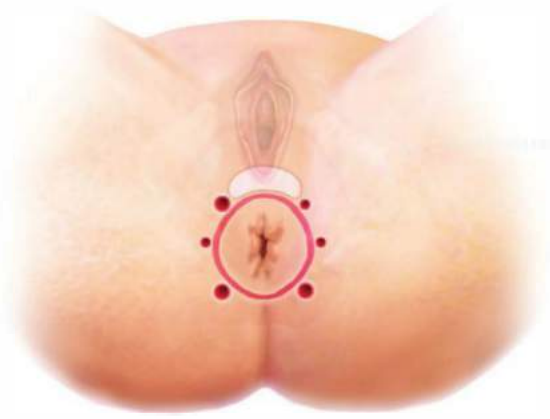


FIG 12 ● The THD device. **A.** This device is a specifically designed anoscope/proctoscope equipped with a Doppler probe that faces outward and a light source attached to a pivot cage for a specifically designed suture and needle driver set. *(Continued)*



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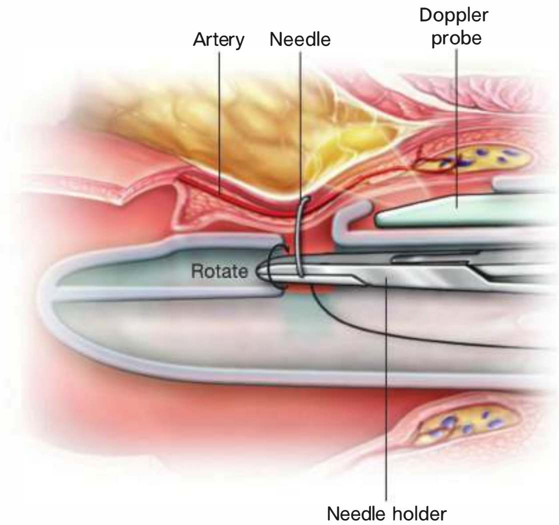

C

D

FIG 12 ● *(Continued)* **B.** Using the Doppler ultrasound, one can hear the waveforms generated and isolate the six strongest waveforms that correlate to six equidistant positions around the anal canal. **C.** Once a hemorrhoidal pedicle is located, the rectal mucosa and submucosal wall are transfixed with a figure-of-eight/Z-stitch to ligate the pedicle. **D.** Detailed view of needle holder with the provided 2-0 polydioxanone (PDS) suture on a 5/8-in needle inserted into the pivot.

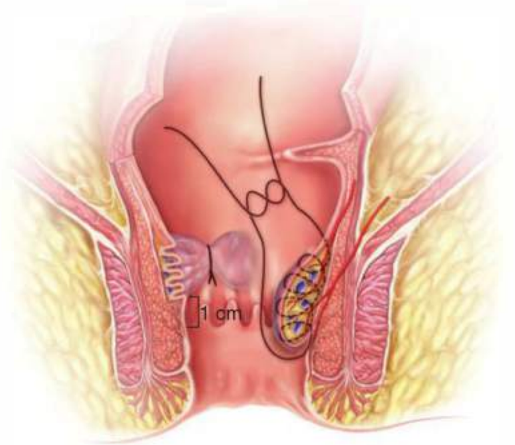

FIG 13 ● Mucosal proctopexy. Holding the THD proctoscope as a continued retractor and holding the long anchor tail against the scope, mucosal and submucosal bites can be taken to eliminate the prolapse of the hemorrhoid or mucosa. These bites are taken distal to the transfixion site at a step size of half a centimeter and can be tied back to the anchor stitch to create the mucopexy. This mucopexy terminates at least 5 mm proximally to the dentate line and is tied to the first anchor stitch for a substantial mucosal proctopexy and to avoid potential abscess formation.

TECHNIQUES

SCLEROSANT INJECTION OF HEMORRHOIDS

Delineation of Hemorrhoidal Cushions and Verification of Anatomy

- After performing a proper anoscopy using serial dilation of graded Hill-Ferguson retractors, a hemorrhoidal bundle can be readily exposed using a Hill-Ferguson retractor with countertraction provided by the opposite hand holding a gauze. At this point, it is essential to note that there should be no external component and that the internal hemorrhoids to be targeted are grades I and II.
- Using an angled spinal needle (18- to 22-gauge with a bend of 30 degrees an inch from the tip), the proximal aspect of the hemorrhoidal bundle is found and a submucosal injection of a sclerosant solution of the surgeon's choice, usually between 3 and 5 mL in volume, is performed (**FIG 14**).
- Accurate injection reveals swelling of the mucosa without blanching of the mucosa, with a "striation sign" indicative of bridging hemorrhoidal veins.

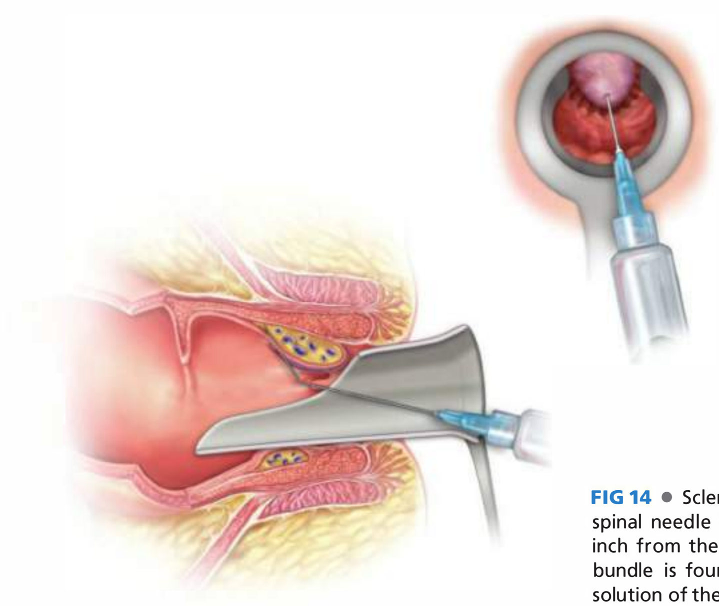

FIG 14 ● Sclerosant injection of hemorrhoids. Using an angled spinal needle (18- to 22-gauge with a bend of 30 degrees an inch from the tip), the proximal aspect of the hemorrhoidal bundle is found and a submucosal injection of a sclerosant solution of the surgeon's choice, usually between 3 and 5 mL in volume, is performed.

PEARLS AND PITFALLS

Indications	■ A thorough evaluation of the anorectum with classification of the hemorrhoidal cushions is essential in picking the optimal procedure. ■ Ruling out inflammation or prior radiation can help prevent wound complications. ■ Operative hemorrhoidal treatment requires a failure of conservative therapy. ■ Sclerotherapy has limited indications but is invaluable in the anticoagulated patients, as it creates no bleeding. ■ Doppler-guided techniques are for those with internal hemorrhoidal disease without external components.
Incisions	■ Sparing the anoderm reduces postoperative pain and anal stenosis. ■ In traditional hemorrhoidectomy, isolation of the hemorrhoidal pedicle can be done as soon as the hemorrhoidal bundle narrows. Never "chase the hemorrhoid" proximally into the rectum—it can be very difficult to ligate a lost "bleeder" appropriately if it retracts and such a proximal dissection will not improve the patient's symptoms of bleeding, irritation, or prolapse.

Dissection and suturing	■ Including fibers of the underlying sphincter during running closure of the mucosal gap may prevent a dissection-based hematoma. ■ When performing a mucosal proctopexy or a suture ligation, it is important that the stitch remains proximal to the dentate line to prevent cryptoglandular interface abscess formation. ■ Using a long initial anchor stitch for the hemorrhoidal pedicles can always provide a mucosal proctopexy by gathering the mucosa and tying back to the anchor while closing. ■ In order to reduce the risk of anal stenosis, minimize the amount of normal tissue resected/incorporated between hemorrhoidectomy sites. A small anodermal incision with submucosal dissection of the vascular tissue may also help.
Hemostasis	■ Surgical hemostasis is paramount. ■ Up to 5 to 8 postoperative days, the hemorrhoidal pedicle can slough or suffer from infection and cause pronounced bleeding. ■ Most postoperative bleeding occurs as a result of poor ligation and requires urgent suture ligation.
Proctopexy	■ Although the anchor stitch is often well affixed, the mobility of mucohemorrhoidal prolapse makes for an insufficient proctopexy if the knot that is made between the anchor and the running suture is not set proximally by the operating surgeon. The proctopexy is meant to gather the mucosal tissues and slide them cephalad; as such, the knot must lie near the anchoring suture, not toward the anal verge.
Rubber band ligation	■ It is imperative that the band is placed 1 to 2 cm proximal to the dentate line to minimize postbanding pain. ■ Many surgeons only band one hemorrhoid at each visit to minimize discomfort; multiple ligations are associated with greater pain, vasovagal syncope, and urinary retention. ■ Should vasovagal symptoms or substantial discomfort occur, injection of a local anesthetic with epinephrine can be performed to help alleviate symptoms; perhaps, the best treatment is to remove the band. ■ Although banding seems trivial, there are several reported cases of necrotizing pelvic infections leading to sepsis and even death after elective band ligation. It is also advised that the surgeon be mindful of treating the immunocompromised patient.
Sclerotherapy	■ Some surgeons are concerned about intravenous injection of sclerosant, so withdrawal with the injecting needle is helpful before injecting. ■ Intramucosal injection (induces mucosal blanching) must be avoided because it can lead sloughing and ulcerations. ■ No mucosal swelling, however, may mean the injection is too deep and can result in prostatic abscess, pyelophlebitis, and small soft tissue/rectal ulceration.

POSTOPERATIVE CARE

- These operations can all be safely performed in the outpatient setting.
- A bare minimum of intravenous fluids should be administered to reduce the risk of postoperative urinary retention. We limit our intraoperative fluid use to less than 200 mL.
- Routine use of diluted liposomal bupivacaine (Exparel) has dramatically reduced postoperative pain, shortened recovery, and reduced postoperative narcotic use.
- Postoperatively, warm water tub soaks are used to relax the levators, reduce levator spasm, and alleviate urinary retention.
- Postoperatively, we prescribe a low-dose narcotic (hydrocodone-acetaminophen), an oral nonsteroidal antiinflammatory drug (NSAID) (ketorolac 10 mg three times a day for 5 days), and a low-dose muscle relaxant (diazepam 2 mg orally three times a day to assist with pelvic floor spasm). Prescription narcotic medications are unnecessary after in-office rubber band ligation.
- The patient is given instructions to consume a high-fiber diet (25 g per day), slowly increase water intake to match fiber intake, refrain from straining, and consume a daily or twice-daily dose of a stool softener such as polyethylene glycol.
- Signs and symptoms of vasovagal episodes or pelvic sepsis are explained to the patient.

OUTCOMES

- Operative excisional hemorrhoidectomy has, by far, the lowest recurrence rate but results in increased patient pain postoperatively. Recurrence rates are quoted at 1.4%.
- Doppler-guided ligation is a newer modality of treating hemorrhoids that still has yet to attain long-term follow-up data to accurately assess recurrence rates. In a study of 170 patients with a majority having grade III disease (82.7%), control of bleeding was obtained in 159 patients (93.5%) and control of prolapse in 152 (89.5%), with mean follow-up 11.5 ± 12 (range, 1 to 41) months.
- Eighty percent of patients with grade I or II hemorrhoids will note improvement in symptoms after rubber band ligation and up to 70% will remain completely symptom free. The recurrence rate, though, is higher with banding than with surgical excision.
- The results of sclerotherapy in resolving internal hemorrhoids have been evaluated in small trials and retrospective reviews. Many researchers have found the benefits of

injection therapy to be short-lived and somewhat comparable to diet control. However, in the actively bleeding/oozing anticoagulated patient, a modality that does not promote further bleeding may be invaluable. Khoury et al. prospectively randomized 120 patients with grades I and II disease to single versus multiple injections, with nearly 90% reporting resolution or improvement in symptoms 1 year after injection and no difference with regard to the number of treatment sessions required.

COMPLICATIONS

- Bleeding with severe hemorrhage (occurring less than 5% of all cases)
- Urinary retention
- Infection of closed hemorrhoidectomy sites
- Fecal impaction
- Anal stenosis
- Skin necrosis
- Intramucosal or suture abscess from ligation techniques
- Cryptoglandular abscess
- Tenesmus
- Persistent or excessive levator spasm
- Pelvic sepsis, necrotizing soft tissue infections, anorectal necrosis
- Systemic absorption of sclerosant solution leading to acute respiratory distress syndrome (ARDS)

SUGGESTED READINGS

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Chapter 45 Surgical Management of Anal Fissures

Daniel Albo

DEFINITION

- An anal fissure is an acute longitudinal tear or a chronic ovoid ulcer in the squamous epithelium of the anal canal.
- They are also often referred to as fissure in ano.
- The exact etiology of anal fissures is debated. Risk factors that increase the likelihood of developing an anal fissure include the following:
  - Increased sphincter tone
  - Chronic constipation
  - Straining to have a bowel movement, especially if the stool is large, hard, and/or dry
  - Sedentary lifestyle
  - Sexual practices: anal intercourse, insertion of anal/rectal foreign bodies
  - Overly tight or spastic anal sphincter muscles: failure of relaxation of the anal sphincter during bowel movements
  - Decreased blood flow to the perianal skin
  - Scarring in the anorectal area
  - Inflammatory bowel disease, such as Crohn's disease and ulcerative colitis
  - Anal cancer, especially after radiation therapy
  - Tuberculosis
  - Sexually transmitted diseases (such as syphilis, gonorrhea, chlamydia, chancroid, HIV)
  - Leukemic infiltrates
  - Decreased blood flow to the anorectal area
  - Anal fissures are also common in women after childbirth and in young infants.
  - Women are more commonly affected than men (58% vs. 42%).

DIFFERENTIAL DIAGNOSIS

- Hemorrhoids (specially thrombosed hemorrhoids)
- Anal canal cancer
- Anal trauma

PATIENT HISTORY AND PHYSICAL FINDINGS

- Patients typically present with intense anal pain during and especially after defecation. The pain can last for several minutes to a few hours after having a bowel movement.
- Although patients are often asymptomatic between bowel movements, they often develop a "fear of defecation" and may try to avoid defecation secondary to the pain.
- Chronic constipation is common.
- Some bright red anal bleeding, especially on the toilet paper, is common.
- On physical exam, the anus appears tight and spastic. The pain is usually severe enough that the patient will not tolerate a digital rectal exam in the office.
- On anoscopy, which oftentimes is done under conscious sedation due to severe anal pain, the fissure is usually linear, although ovoid-shaped fissures are oftentimes seen as well.
- Anal fissures are almost universally present along the posterior midline in men and they are often associated with a sentinel skin tag at the squamous-columnar epithelial junction (anal verge). In women, they can also be seen on an anterior location (**FIG 1**).
- Anal fissures seen in Crohn's disease and tuberculosis are frequently painless.

IMAGING AND OTHER DIAGNOSTIC STUDIES

- Diagnosis is made by visual inspection. Unless findings suggest a specific cause or the appearance and/or location is unusual, further studies are not required.
- In selected cases, flexible sigmoidoscopy or colonoscopy may be indicated.

SURGICAL MANAGEMENT

- The majority of anal fissures will resolve with medical management and will not require surgery.
- Medical management includes the following:
  - Aggressive prevention of constipation
    - Increase fiber and decrease fat in the diet
    - Fiber supplementation
  - Increase water intake

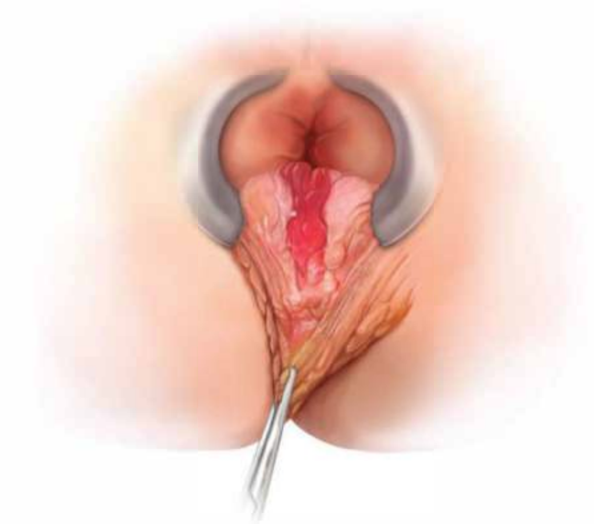

FIG 1 • Anal fissure. With an anoscope inserted in the anal canal, an anal fissure can be seen in the posterior midline of the squamous epithelium of the anal canal. A sentinel skin tag can be seen on the distal end of the fissure on the anal verge.

- Use of moist pads (flushable baby wipes) for wiping and anal hygiene
- Avoiding straining or prolonged sitting on the toilet
- Soaking in a warm bath (also called a sitz bath), 10 to 20 minutes several times a day, to promote the relaxation of the anal muscles

- These conservative measures lead to healing of the anal fissure in a few weeks to a few months in 80% to 90% of patients. However, when these conservative measures alone are not successful, pharmacologic intervention can also be instituted. This includes the following:
  - Topical nitrates ointment: Examples include nitroglycerin ointment 0.4% (Rectiv) and glyceryl trinitrate ointment (Rectogesic). Although effective, they are dose dependent. Disabling headaches are common at higher doses, making patient compliance with the treatment unreliable.
  - Topical calcium channel blockers, including nifedipine or diltiazem ointment, are as effective as nitrate ointments but with significantly less side effects. Examples include topical nifedipine 0.3% with lidocaine 1.5% ointment and diltiazem 2% ointment.
- Combination of medical therapies may offer up to 98% cure rates.
- A combined surgical and pharmacologic treatment, administered by colorectal surgeons, is periodic direct injection of botulinum toxin (Botox) into the anal sphincter to relax it. Oftentimes, these injections prove less and less potent with each application. With patients spending thousands of dollars and not achieving a permanent cure, they oftentimes elect to have surgery.
- When conservative medical therapy fails, surgery is considered.

Preoperative Planning

- Mechanical bowel preparation is not necessary.
- Fleet enemas are prescribed for the night before and the morning of surgery to clear the rectal vault.
- Intravenous cefoxitin is administered within 1 hour of skin incision.
- A preoperative time-out and briefing is conducted with the entire surgical team in attendance.
- An anal block with bupivacaine extended-release liposome injection is associated with both pain relief for 72 hours and a 45% reduction in total opioid consumption at 72 hours.

Positioning

- The patient is placed supine on a modified lithotomy position with the legs on padded stirrups to prevent neurovascular injuries to the calves (**FIG 2**).
- Alternatively, the patient can be placed in a prone jackknife position on a split-leg table, with the surgeon positioned between the legs (**FIG 3**). The buttocks are spread apart with tape.
- The author prefers to perform these procedures under general anesthesia.
- Using headlights is critical for good visualization.

FIG 2 ● Modified lithotomy position. The legs are placed on stirrups with padding to help prevent neurovascular injuries.

FIG 3 ● Prone jackknife position. The lower extremities are placed on a split-leg table position to allow the surgeon to operate from in between the patient's legs.

CLOSED LATERAL INTERNAL SPHINCTEROTOMY (TRANSCUTANEOUS)

- Using lubrication, perform a gentle anal dilation with two fingers.
- An anoscope is used to confirm the presence of the anal fissure.
- With the patient on a modified lithotomy position and palpating with the tip of your right index finger, identify the anal intersphincteric groove (**FIG 4**). The intersphincteric groove is a distinct groove in the anal canal, forming the lower border of the pecten analis, marking the change between the subcutaneous part of the external anal sphincter and the border of the internal anal sphincter.
- For the closed internal lateral sphincterotomy, the author prefers to use a cataract scalpel due to the vertical plane of the cutting edge of the blade (**FIG 5**), as opposed to the oblique plane of the cutting edge of a no. 11 blade. This makes it easier to cut the internal sphincter more evenly as the scalpel is withdrawn from the intersphincteric groove.
- Place your left index finger in the anal canal. In cases of HIV or hepatitis B/C infection, insert an anal speculum instead of inserting your own finger as a precaution to avoid potential transmission of communicable disease in case of inadvertent injury to your index finger during the sphincterotomy.
- Using a no. 11 blade scalpel on your right hand, create a small opening on the skin overlying the intersphincteric groove on the patient's left lateral side. Performing the closed lateral internal sphincterotomy on the anal canal's left lateral side is easier for a right-handed surgeon to perform (scalpel in your dominant hand).

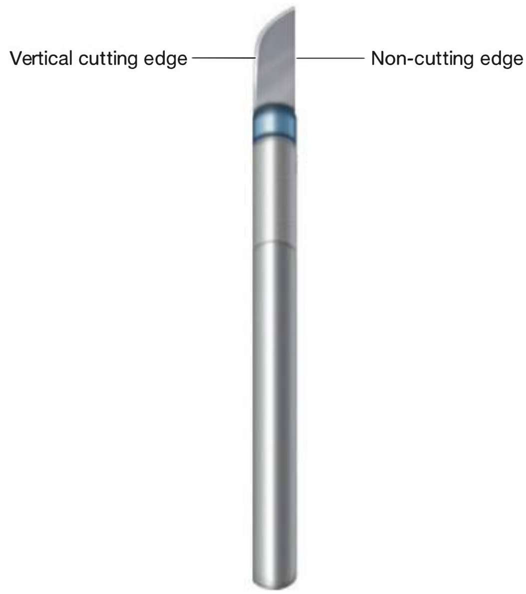

FIG 5 ● A cataract scalpel. This scalpel's blade has a vertical cutting edge and a blunt edge on the opposite side, making its shape and size ideal to insert in the intersphincteric groove.

- Introduce a cataract blade scalpel through this skin opening and into the intersphincteric groove, with the blade of the knife in between the internal and external anal sphincter muscles and until the tip of the blade is located just distal to the level of the dentate line (**FIG 6**). The blade should be inserted parallel to the sphincter

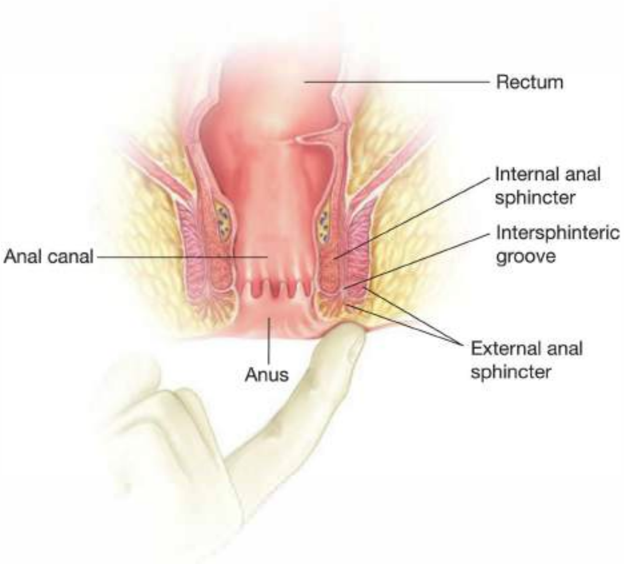

FIG 4 ● The intersphincteric groove. The intersphincteric groove can be easily palpated by the surgeon's right index finger between the external and internal anal sphincters.

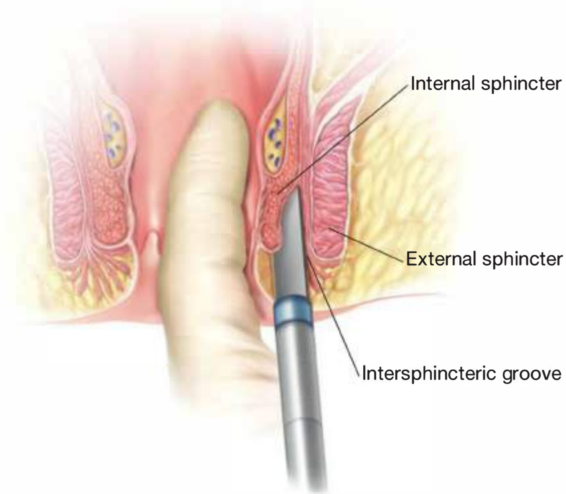

FIG 6 ● Closed internal lateral sphincterotomy: insertion of the cataract scalpel into the intersphincteric groove. The blade of the cataract scalpel is inserted into the groove, parallel to the plane of the sphincters, in order to avoid inadvertent injury to the external sphincter upon insertion.

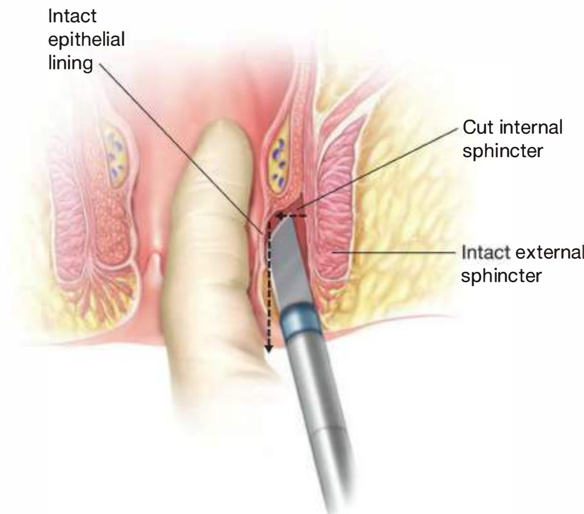

FIG 7 ● Closed internal lateral sphincterotomy. The cataract scalpel blade is first pushed internally toward the anal canal and is then withdrawn *(dotted arrows)*, cutting the internal sphincter in the process. The index finger inside the anal canal allows the surgeon to gauge the proper depth of transection through the sphincter without violating the epithelial lining of the anal canal.

muscles, so that it is oriented on an anterior/posterior direction, therefore preventing accidental cutting of the external sphincter on the way in.

- Alternatively, you can use a no. 11 blade scalpel if a cataract scalpel is not available.
- Now, turn the blade of the cataract scalpel 90 degrees so that the left lateral cutting edge is facing inward, toward the internal anal sphincter.
- Press the cutting edge of the blade toward your index finger (placed in the anal canal), cutting the internal sphincter in the process (**FIG 7**). As you withdraw the scalpel outward, finish cutting the internal sphincter evenly in one sweeping motion. Repeat this maneuver if necessary.
- If you transected the internal sphincter appropriately, you should feel the anus relax immediately.
- Avoid cutting the mucosa of the anal canal because this could lead to troublesome anal fistulae postoperatively. In the event that the anal canal mucosa is cut, reapproximate it with running fast-absorbable 3-0 suture. The presence of your index finger in the anal canal allows you to feel the blade as it cuts through the internal sphincter and helps prevent cutting the mucosa of the anal canal.
- Minor bleeding from the skin opening at the end of the procedure is not uncommon; holding pressure from inside and outside the anal canal is usually all that it is necessary to achieve hemostasis. If more troublesome bleeding occurs from the transected internal sphincter muscle bed, you can inject thrombin glue into the area and hold pressure. In the rare cases where the bleeding does not stop, you may have to open the overlaying mucosa of the anal canal to expose the bleeder and control it surgically.
- Place a tampon in the anal canal at the completion of the procedure for hemostasis; the patient can remove it postoperatively.
- In patients with large left lateral hemorrhoids, the closed lateral internal sphincterotomy can be performed on the patient's right lateral side, in between the right anterior and right posterior hemorrhoidal pedicles. This helps reduce the risk of bleeding from a transected hemorrhoidal pedicle. The technique used is the same as the one described here, but using your right index finger in the anal canal and cutting with the scalpel in your left hand.

OPEN LATERAL INTERNAL SPHINCTEROTOMY

- Using lubrication, perform a gentle anal dilation with two fingers.
- An anal speculum is inserted to confirm the presence of the anal fissure and to expose the anal canal.
- With the patient on a modified lithotomy position and palpating with the tip of your right index finger, identify the anal intersphincteric groove (**FIG 4**). The intersphincteric groove is a distinct groove in the anal canal, forming the lower border of the pecten analis, marking the change between the subcutaneous part of the external anal sphincter and the border of the internal anal sphincter.
- Make a radial incision with a no. 15 blade scalpel over the intersphincteric groove on the patient's left lateral side and extend it toward the anal canal for a distance of 1 to 1.5 cm (**FIG 8A**).
- Performing the open lateral internal sphincterotomy on the anal canal's left lateral side is easier for a right-handed surgeon to perform. In patients with large left lateral hemorrhoids, the closed lateral internal sphincterotomy can be performed on the patient's right lateral side, in between the right anterior and right posterior hemorrhoidal pedicles. This helps reduce the risk of bleeding from a transected hemorrhoidal pedicle.
- Using Metzenbaum scissors to develop a submucosal plane, separate the anal mucosa from the underlying internal sphincter (**FIG 8B**).
- The distal aspect of the internal anal sphincter and the medial aspect of the external anal sphincter are exposed.
- The intersphincteric groove is dissected gently with Metzenbaum scissors, completely separating the internal sphincter from the external sphincter.
- The internal sphincter is then transected full thickness (**FIG 8C**) under direct visualization with Metzenbaum

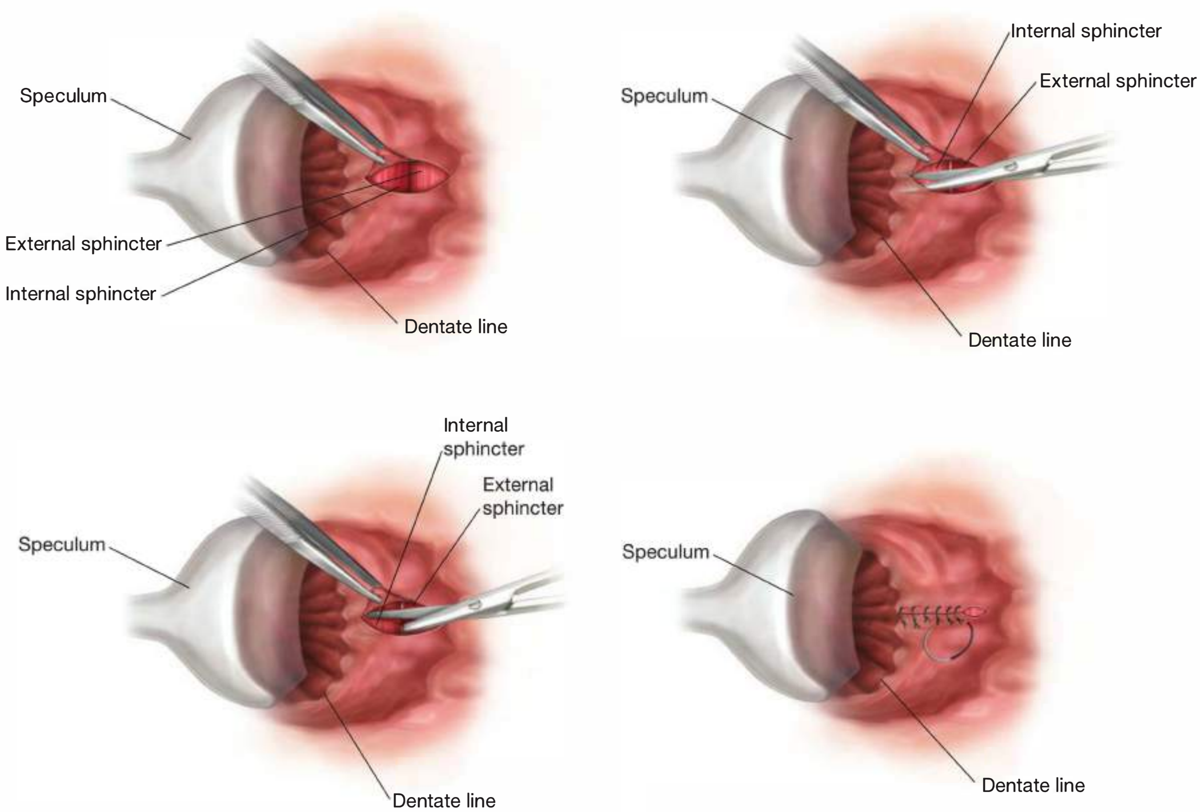

FIG 8 ● Open internal lateral sphincterotomy. **A.** A radial skin incision is made. **B.** A submucosal dissection is performed exposing the internal and external anal sphincters. **C.** The internal sphincter is cut to the level of the dentate line. **D.** The skin incision is closed with running absorbable suture.

scissors to the level of the dentate line (typically about 2 cm in length).

- If you transected the internal sphincter appropriately, you should feel the anus relax immediately.
- Hemostasis is carefully achieved with electrocautery.
- The incision is closed with a running, rapidly absorbable 3-0 suture (**FIG 8D**).
- Place a tampon in the anal canal at the completion of the procedure for hemostasis.

Other Procedures

- The Lord procedure: Dilation of the anus is performed initially with two fingers and then slowly stretching the anal canal (over 2 to 3 minutes) until it accommodates four fingers. The dilation, performed by moving the two fingers around in a circular fashion, accomplishes what was originally described as a "controlled" disruption of the internal sphincter. The problem is that there is really no way of controlling the disruption of the sphincter in this way and it is easy to disrupt the external sphincter as well. This procedure has largely been abandoned due to an unacceptably high incidence of anal incontinence associated with it.
- Excision of the fissure with posterior open sphincterotomy: This procedure has also been largely abandoned due to the deformity that it produces in the anal canal and unacceptably high incidence of anal incontinence associated with it.

PEARLS AND PITFALLS

Patient positioning	■ The author prefers the modified lithotomy position with the legs elevated.
Visualization	■ Using headlights is critical for good visualization.
Intersphincteric groove	■ It is critically important to properly identify the intersphincteric groove. ■ Gentle palpation with the tip of the right index finger allows for easier localization of this groove.
Closed internal lateral sphincterotomy	■ A left lateral internal sphincterotomy is easier to perform for a right-handed surgeon. ■ A right lateral internal sphincterotomy may be preferred in patients with large left lateral hemorrhoids. ■ Using a cataract blade greatly facilitates a more uniform transection of the internal sphincter. ■ Cut the internal sphincter as you withdraw the blade out. ■ Having your left index finger inside the anal canal helps prevent accidentally cutting the anal mucosa.
Open internal lateral sphincterotomy	■ Separate the internal and external sphincters. ■ Cut the internal sphincter to the level of the dentate line. ■ This results in higher incidence of anal sphincter dysfunction postoperatively when compared to the closed technique.
Postoperative care	■ Aggressive prevention of constipation with a bowel regimen is mandatory.

POSTOPERATIVE CARE

- This procedure is typically performed on an outpatient basis.
- The patient removes the anal tampon the day after surgery or during the first bowel movement.
- Aggressive prevention of constipation with a bowel regimen is mandatory.
- The patient is placed on a high-fiber, low-fat diet.
- The author recommends over-the-counter fiber supplementation (totaling 25 to 35 g of fiber per day). Stool softeners and increasing water intake are also necessary to promote soft bowel movements and to aid in the healing process.
- Judicious use of laxatives.
- Nonsteroidal antiinflammatory agents are prescribed. Narcotic use is used sparingly due to their tendency to induce constipation.
- Warm sitz baths for comfort purposes are used.
- Wiping after bowel movements is only allowed with flushable baby wipes (no toilet paper) to prevent irritation.
- Use of zinc oxide ointments may help accelerate the healing of deep anal fissures.

OUTCOMES AND POSTOPERATIVE COMPLICATIONS

- Garcia-Aguilar and colleagues have published perhaps the most comprehensive analysis of outcomes after open internal sphincterotomy (OIS) and closed internal sphincterotomy (CIS).
- Overall, both techniques accomplish excellent results in terms of resolution of pain and healing of the fissure.
- Differences in persistence of symptoms (3.4% OIS vs. 5.3% CIS), recurrence of the fissure (10.9% vs. 11.7% CIS), and need for reoperation (3.4% OIS vs. 4% CIS) were statistically not significant.

- However, statistically significant differences were seen in the percentage of patients with permanent postoperative difficulty controlling gas (30.3% vs. 23.6%; $P < .062$), soiling underclothing (26.7% vs. 16.1%; $P < .001$), and accidental bowel movements (11.8% vs. 3.1%; $P < .001$) between those who underwent OIS and those who had CIS.
- Although 90% of patients reported general overall satisfaction, more patients undergoing CIS (64.4%) than OIS (49.7%) were very satisfied with the results of the procedure.
- The author concluded that lateral internal sphincterotomy is highly effective in treatment of chronic anal fissure but is associated with significant permanent alterations in continence. CIS is preferable to OIS because it effects a similar rate of cure with less impairment of control.

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Chapter 46

Operative Treatment of Rectal Prolapse: Perineal Approach (Altemeier and Modified Delorme Procedures)

Valerie Bauer

DEFINITION

- Rectal prolapse is a "falling down" of the rectum caused by weakness in surrounding supportive tissues. Straining during constipation secondary to functional disorders of elimination (anismus) and anatomic causes of outlet obstruction such as middle and anterior pelvic organ prolapse (enterocele, sigmoidocele, rectocele, hysterocele, and cystocele) are major risks factors. Other risk factors include low anterior cul-de-sac, multiparity, anal sphincter muscle weakness, levator diastasis, redundant rectosigmoid, and neurologic disease.[1] Recognition of the type of prolapse determines operative approach. Internal intussusception includes all layers of the rectum and rectosigmoid through the rectum and into the anal canal but not beyond. Partial thickness prolapse involves protrusion of the redundant **mucosal** layer of the rectum for a distance of 1 to 3 cm from the anal margin (**FIG 1A**). True prolapse consists of a full-thickness protrusion of all layers of the rectum through a sliding hernia of the cul-de-sac so that the rectum is out of the body (**FIG 1B**).[2]

FIG 1 ● Presentation of full-thickness rectal prolapse. **A.** Mucosal prolapse showing concentric circles of mucosal folds in association with hysterocele. **B.** Large prolapse in recurrent disease after a failed Altemeier procedure showing engorged mucosa and loss of concentric folds.

DIFFERENTIAL DIAGNOSIS

- Prolapsed and incarcerated internal hemorrhoids may appear similar to rectal prolapse. The appearance of concentric folds differentiate rectal prolapse from hemorrhoidal prolapse, which appears as radial invaginations relative to anatomic location of the internal hemorrhoidal cushions.
- Enterocele and sigmoidocele is the combined prolapse of posterior vaginal wall and herniation of the respective segments of bowel through the anterior cul-de-sac, which may cause anterior rectal prolapse and bleeding.
- Hysterocele and cystocele involve vaginal prolapse, which can also contribute to the "pulling down" of the fascial support of the rectum.
- Rectal cancer or polyps may act as a lead point from which colorectal prolapse occurs, hence underscoring the importance of diagnostic colonoscopy to rule out proximal mucosal pathology as a cause of intussusception.
- Inflammatory colitides should be considered for findings of isolated rectal ulceration, seen in the anterior rectum at the point of retroperitoneal fixation, where repeated internal prolapse forms. A discrete anterior solitary rectal ulcer is approximately 4 to 10 cm from the anal verge.

PATIENT HISTORY AND PHYSICAL FINDINGS

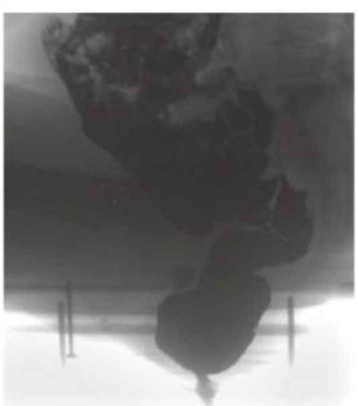
- Successful perineal proctosigmoidectomy for full-thickness prolapse (Altemeier) and mucosectomy for partial mucosal prolapse (modified Delorme) depends on proper determination of type of prolapse. Therefore, accurate history and recognition of physical examination findings is of paramount importance.
- Surgery for isolated internal prolapse is currently not performed in lieu of conservative management to include dietary and behavioral modifications, such as pelvic muscle rehabilitation for treatment of functional elimination disorders. However, future understanding of the relationship between posterior internal pelvic organ prolapse and middle/anterior pelvic organ prolapse may redefine guidelines for surgical indication using a multidisciplinary approach to multiorgan repair to include colorectal, urogynecology, and urology subspecialists.
- A thorough history must identify causes of constipation (and excessive straining) such as dietary and social behaviors (inadequate fiber intake, sedentary lifestyle), medications, and medical conditions (hypothyroidism, electrolyte disturbances, interstitial cystitis, pelvic organ prolapse, anxiety, or psychiatric disturbances).
- Past surgical history of multiple prior pelvic operations (hysterectomy, sacrocolpopexy, coloproctostomy) increases operative risk for complication. Prior abdominal repair of rectal prolapse with rectosigmoid resection is a contraindication to

perineal proctectomy due to altered mesenteric blood flow and risk for distal ischemia.

- Risk factors for colorectal cancer and polyps is determined through family history and personal history of changes in bowel habits, bleeding, and results of most recent colonoscopy.
- Obstetric and urogynecologic history aims to determine risk factors for anal muscle weakness and pelvic organ prolapse, such as number of intrauterine pregnancies, term vaginal deliveries, large-birth-weight baby, prolonged labor, use of forceps, high-grade vaginal tear, absence of controlled episiotomy, and urinary incontinence. Additionally, nulliparity has been associated with higher incidence of rectal prolapse as well.[3,4]
- Initial presentation is commonly described as "something falling out that has to be pushed back in." Other possible initial complaints include a feeling of fullness in the pelvis, severe pain (levator muscle spasm), bleeding, incomplete evacuation with splinting or positional maneuvers to eliminate, excessive straining, mucus or fecal staining, perineal discomfort and burning (due to chronic moisture), improved pain on lying down, and fecal urgency with "nothing there."
- Initial anorectal examination is done in prone jackknife or lateral Sims position. It begins with inspection of the perianal skin. In the absence of grossly visible prolapse at the anal margin, a patulous anus, fecal smearing, and thickening (lichenification) of anoderm due to chronic perineal moisture suggests rectal or mucosal prolapse. The appearance of the anus may be flat due to loss of compliance and function of the pelvic floor musculature (perineal descent syndrome). Visible scars due to episiotomy or prior anorectal surgery should be noted.
- Vaginal examination may reveal anterior vaginal prolapse (cystocele) or posterior vaginal wall prolapse (rectocele, enterocele).
- Digital rectal examination determines anal sphincter tone and function. Patients with full-thickness prolapse often have little to no resting or squeeze tone due to levator muscle separation and pudendal nerve damage. Patients are asked to squeeze to give some indication of sphincter strength (diagnostic of fecal incontinence). Digital palpation of the perineal body may also reveal anterior thinning and sphincteric defect due to prior obstetric injury or other mechanisms of levator separation.
- Digital compression in the anterior rectum may reveal rectocele. The patient should be asked to strain during digital palpation to evaluate for paradoxical contraction or lack of anal sphincter relaxation (indicative of functional elimination disorder, anismus). Similarly, exaggerated strain may reproduce internal prolapse and/or rectocele, which is appreciated by luminal protrusion into the posterior wall of the vagina.
- Anorectal examination uses a side-viewing anoscope (Hirschman) to evaluate the anal canal. Internal hemorrhoids may or may not prolapse with rectal prolapse. However, they may be inflamed, bleeding, or thrombosed due to excessive straining from outlet obstruction caused by the prolapse. Patients with rectal prolapse complain more of hemorrhoidal disease due to a lack of awareness of rectal prolapse. Rigid proctosigmoidoscopy allows for evaluation of the rectum and sigmoid up to 25 cm from the anal verge for evidence of prolapse or other mucosal disease. Anterior solitary rectal ulcer is classically seen between the first and second valve of Houston and represents the point of recurrent internal prolapse. Release of air insufflation and having the patient bear down as the scope is withdrawn will prolapse redundant tissue into the aperture of the proctosigmoidoscope, which is diagnostic of rectal prolapse in the office.

IMAGING AND OTHER DIAGNOSTIC STUDIES

- Having the patient squat or strain, especially after administration of fleet enema, will help protrude the prolapsed rectum. This test is performed in the clinic and is diagnostic of rectal prolapse (toilet test).
- Defecography uses fluoroscopic imaging to evaluate the structure and function of posterior, middle, and anterior pelvic floor during the three phases of elimination—rest, squeeze, and strain. It may be used to diagnose rectal prolapse if it is not clinically evident. Pelvic floor structures are visualized using thick barium paste instilled into the rectum, a barium-impregnated tampon in the vagina, oral contrast for small bowel, and intravenous contrast for visualization of the bladder. Internal rectal prolapse is demonstrated during strain in image (**FIG 2A,B**).
- Pelvic floor physiology testing determines preoperative functional baseline of the anal sphincter, especially when there is associated fecal incontinence. These tests include anal manometry, rectal sensation, and anal electromyography (EMG).
- Pudendal nerve terminal motor latency (PNTML) determines neurogenic impediment to anal sphincter muscle function.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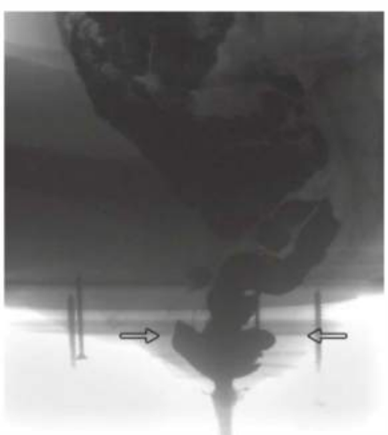
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FIG 2 • **A.** Cine defacography during the initial strain phase of elimination shows foreshortening of rectum with early internal intussusception. **B.** The prolapse progresses with strain, but not beyond the anal canal, illustrating internal recto-rectal intussusception (*arrows*) without mucosal or full thickness prolaspe.

Although pudendal neuropathy is not a contraindication for repair of rectal prolapse, its presence may predict poor outcome in improvement of fecal incontinence associated with rectal prolapse after surgery and should be discussed with the patient preoperatively.[5]

SURGICAL MANAGEMENT

Preoperative Planning

- Perineal repair of rectal prolapse is favored for patients with high-risk surgical comorbidites. Therefore, medical and cardiac risk stratification should be obtained prior to surgery and discussed with every patient, including the possibility of complication due to comorbid condition.
- Surgery is done under general anesthesia; however, in the high-risk population, the procedure can be performed under spinal or even local anesthesia.
- Patients undergo preoperative bowel preparation and fleet enemas before the procedure.
- Previous intraabdominal resection for repair of rectal prolapse increases ischemic complications from subsequent perineal resections, and it is considered a relative contraindication to perineal repair.

Positioning

- The patient may be placed in lithotomy position using candy cane or Allen stirrups or in prone jackknife position.

TECHNIQUES

PERINEAL PROCTECTOMY (ALTEMEIER PROCEDURE)

Preparation after Anesthesia Induction

- Rigid proctosigmoidoscopy is performed to ensure there is clean preparation. Residual stool may be suctioned and the rectum irrigated with saline or diluted Betadine solution until clean.
- A full perineal and vaginal preparation is performed using Betadine solution.
- A Foley catheter is inserted.
- Local anesthesia, using a total of 30 mL 0.25% Marcaine with 1:200,000 epinephrine, is infiltrated through a 22-gauge spinal needle in the intersphincteric groove circumferentially.
- A Lone Star retractor system (CooperSurgical Inc, Trumbull, CT) is positioned using small hooked retractors placed at the dentate line circumferentially (**FIG 3**).

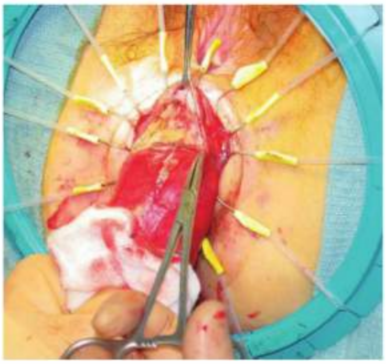


FIG 4 ● A full-thickness incision is placed 1 to 1.5 cm from the anal verge using electrocautery around the rectum.

Incision

- The prolapsed segment is grasped with Babcock clamps.
- Electrocautery is used to score a circumferential incision 1 to 1 ½ cm proximal to the dentate line. This is deepened through all the layers of rectal wall circumferentially (**FIG 4**).
- Clamps are applied to the distal edge of the rectum.

FIG 3 ● Placement of the Lone Star retractor using hooked elastic bands attached to the dentate line in a circumferential fashion.

Anterior Dissection of the Hernia Sac

- A deep pouch of Douglas is often encountered and dissected free from the anterior segment of the rectum (**FIG 5**).
- The hernia sac is resected, allowing access to the intraabdominal cavity and delivery of excess redundant bowel.
- The peritoneal edges are reapproximated using absorbable suture, thus excluding the abdominal cavity.

Posterior Dissection

- An energy device, such as Enseal (Ethicon Endo-Surgery Inc, Cincinnati, OH), may be used to seal and divide the mesorectum (**FIG 6**).
- Redundant bowel is freely delivered (**FIG 7A**). The extent of delivery may vary according to the degree of prolapse and extent of surgical dissection (**FIG 7B**).

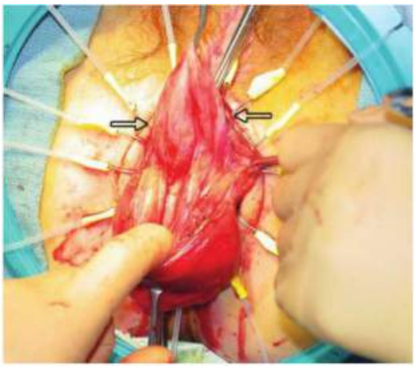


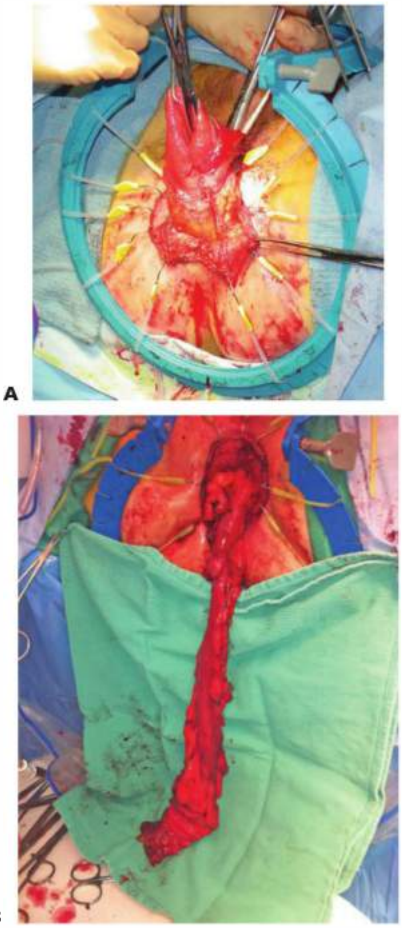
FIG 5 ● Sharp dissection frees the anterior hernia sac (as noted by the *arrows*) from the prolapsed rectal tissue.

Posterior Levatorplasty

- A modification of the Altemeier's operation involves the addition of a levatorplasty, which is the plication of either the anterior or the posterior levator ani muscles with long-term absorbable sutures such as polydioxanone (PDS). Placation of either the anterior or posterior levator muscles decreases pelvic outlet aperture and decreases recurrence while improving continence.[6] Anterior levatorplasty is associated with a higher incidence of dyspareunia than posterior levatorplasty.
- The levator ani muscle is grasped on each side with a Babcock clamp and reapproximated using two to three interrupted sutures (**FIG 8**). Care should be taken to ensure that two fingerbreadths pass through the remaining aperture to avoid excessive compression of the rectum and subsequent constipation.

FIG 6 ● An energy device that enables sealing of mesorectal vasculature may be used to safely and rapidly divide the mesorectum in the process of mobilizing the redundant rectal prolapse.

A



B

FIG 7 ● **A,B.** Variable degrees of redundant prolapse may be observed in the mobilization and delivery of bowel.

- If the peritoneal cavity is entered, the peritoneum is closed with absorbable sutures. The bowel is fastened to the peritoneum and anterior tissue using interrupted absorbable sutures.

Resection of Redundant Rectosigmoid

- The level of transection is determined by the viability of the bowel and approximation to the proximal free edge of the distal resected cuff. Division begins anteriorly. In order to prevent retraction of the rectum into the pelvis, four corner sutures are placed and left tagged prior to completely transecting the rectum.
- Absorbable 2-0 Vicryl sutures are placed full thickness in interrupted fashion, reapproximating the bowel.
- Upon completion, rigid proctoscopy is performed to ensure the viability of the bowel proximal to the anastomosis and also to assess the integrity of the bowel, ruling out a possible perforation that might have been incurred during the dissection.
- The Lone Star retractor is removed and the anastomosis is interiorized.

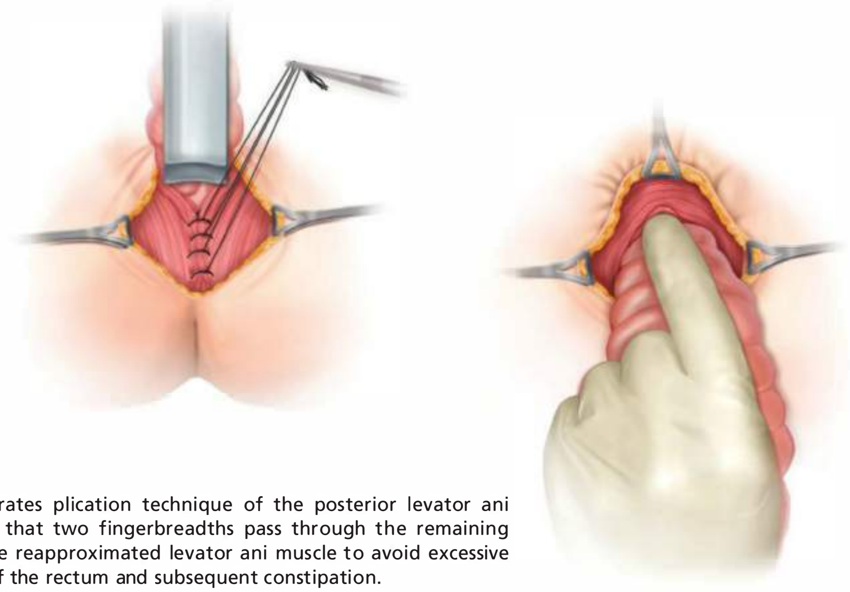


FIG 8 ● Illustrates plication technique of the posterior levator ani muscles. Note that two fingerbreadths pass through the remaining aperture in the reapproximated levator ani muscle to avoid excessive compression of the rectum and subsequent constipation.

DELORME PROCEDURE

- This procedure was described by Delorme in 1900, for repair of mucosal prolapse, and involves stripping of the mucosa from the prolapsed bowel, placating the denuded muscular wall, and reanastomosing the mucosal rings.[7]

Preparation after Anesthesia Induction

- The patient is positioned and prepared in similar fashion than that of an Altemeier procedure.
- The submucosa is infiltrated using a local anesthetic such as 0.25% bupivacaine with 1:200,000 epinephrine in order to reduce bleeding and facilitate the plane of dissection.

Incision

- A circular incision is made through the mucosa approximately 1 cm proximal to the dentate line (**FIG 9A**).
- A sleeve of mucosa and submucosa is sharply dissected from the underlying muscle to the apex of protruding bowel and the point at which there is some tension (**FIG 9B**).

Plication of muscularis propria

- The denuded muscle (muscularis propria) is prepared for longitudinal plication by placing serial Allis clamps in each quadrant. Vicryl sutures are placed in all four quadrants,

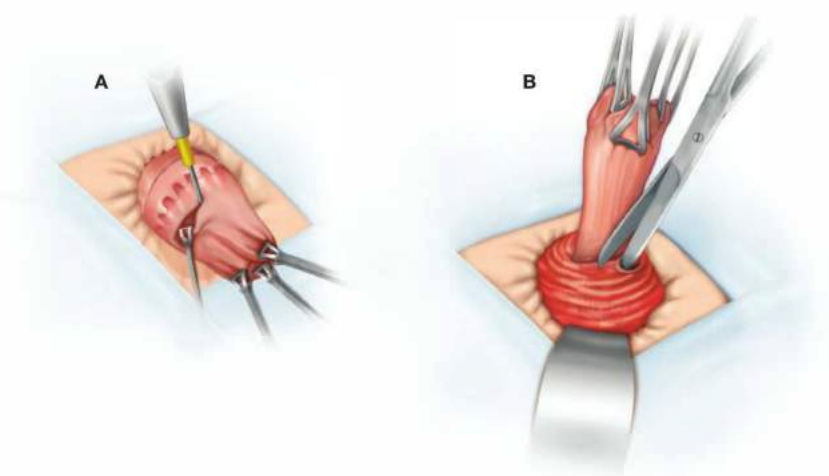


FIG 9 ● **A.** The mucosa is dissected 1.0 to 1.5 cm proximal to the dentate line, and **(B)** it is then stripped off of the muscularis propria.

beginning from proximal to the incised mucosa and ending at the level to where the mucosa is dissected (**FIG 10**).

- The placating sutures are tied after confirmation of absolute hemostasis.

Resection and anastomosis

- The stripped mucosa is then excised and anastomosed to the distal mucosa with interrupted absorbable sutures.

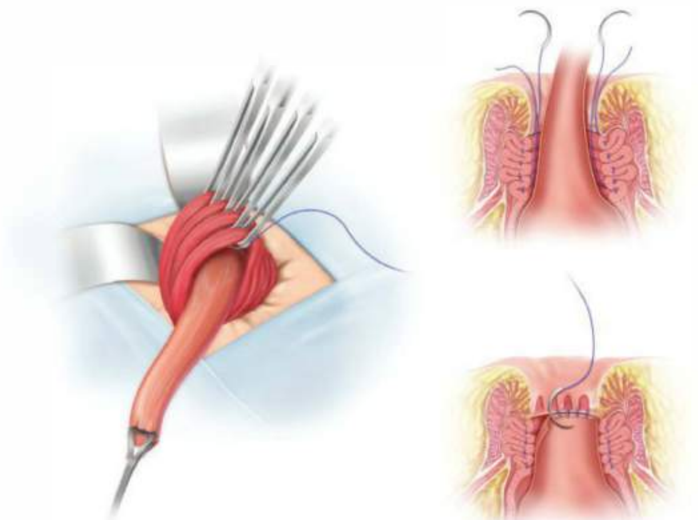


FIG 10 ● The muscularis propria is plicated in all four quadrants.

PEARLS AND PITFALLS

Indications	■ A thorough history and physical examination should be obtained, including in-office administration of enema to reproduce and confirm full-thickness or partial rectal prolapse. ■ Clinical suspicion for internal prolapse may be diagnosed with symptoms of incomplete defecation and defecogram showing rectorectal intussusception with or without obstruction. ■ Prior history of rectal prolapse repair increases risk for ischemia on subsequent perineal repair if the initial procedure involved division of mesenteric blood flow. ■ Complete colonoscopic evaluation should be performed to rule out proximal cause of obstructed defecation or prolapse.
Dissection	■ Identification, resection, and closure of the anterior hernia are important for obliterating the hernia sac contributing to the anterior prolapse. ■ Care should be taken to prevent division of the mesentery proximal to the bowel edge in order to minimize anastomotic ischemia and tension.
Levatorplasty	■ Placation of either the anterior or posterior levator muscles decreases pelvic outlet aperture and decreases recurrence while improving continence. ■ Anterior levatorplasty is associated with higher incidence of dyspareunia. ■ Posterior levatorplasty should allow two fingerbreadths between the bowel and muscle approximation to minimize constipation postoperatively.
Rigid proctosigmoidoscopy	■ Evaluates for potential unrecognized rectal perforation that may have been undetected during the dissection

POSTOPERATIVE CARE

- Regular diet is usually resumed on postoperative day 1.
- The Foley catheter is removed the day after surgery. The patient can be discharged on postoperative day 1.
- A bowel regimen should be implemented to minimize constipation and excessive straining postoperatively. The patient should be educated to take adequate fiber intake and gentle cathartics, such as milk of magnesia, each day for 2 weeks until the anastomosis has healed. Avoidance of excess straining should be stressed, along with orders for nothing per rectum.

OUTCOMES

- Perineal proctosigmoidectomy has variable reported recurrence rates ranging from 10% to 25% in large clinical studies. The addition of posterior levatorplasty improves recurrence rates down to 7.7% and also increases time to recurrence from 13.3 months to 45.5 months.[6]
- The Delorme procedure has similarly high recurrence rates but has been favored to perineal proctosigmoidectomy in cases of extreme comorbid conditions or failed surgery for prolapse.[8]

COMPLICATIONS

- Anastomotic dehiscence (intrapelvic leakage is uncommon) is usually due to tension and/or poor blood supply. Therefore, extreme care must be taken to mobilize the bowel adequately and to avoid transecting the mesentery too far proximally.
- Bleeding occurs in 5% of patients, with resulting pelvic hematoma.
- Anastomotic stricture: Most patients will develop some degree of stricture, but it rarely requires dilatation.

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Chapter 47

Operative Treatment of Rectal Prolapse: Transabdominal Approach

Karin M. Hardiman

DEFINITION

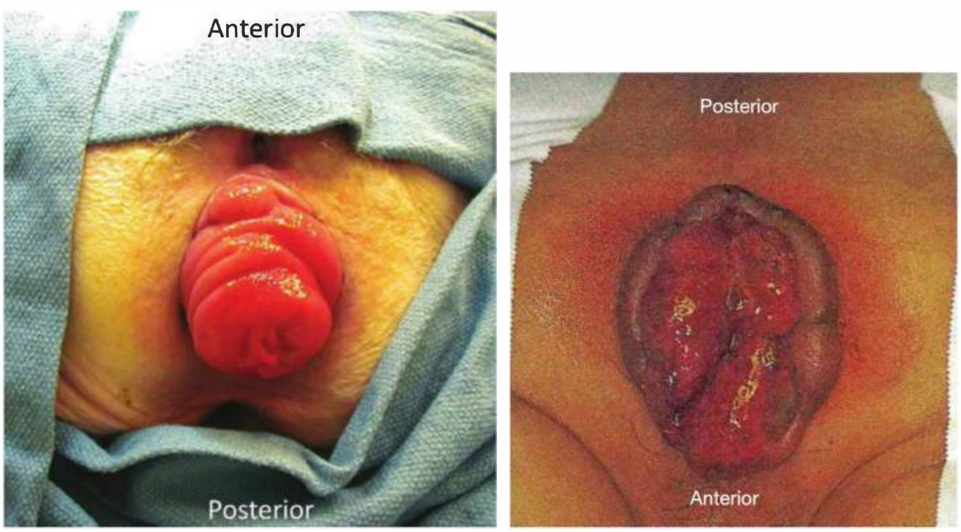
- Rectal prolapse is the full-thickness protrusion of the rectum through the anus. The rectum intussuscepts and then progresses onward to come out of the anus.

DIFFERENTIAL DIAGNOSIS

- It is important to differentiate rectal prolapse from prolapsing hemorrhoids (**FIG 1**), as the treatment paradigms are completely different.

PATIENT HISTORY AND PHYSICAL FINDINGS

- Rectal prolapse is most common in multiparous elderly women with long-standing constipation. A small percentage is also seen in young male patients. Scleroderma and psychiatric disorders are also more common in patients with rectal prolapse.
- Patients describe having tissue extrude from their anus that usually retracts on its own or with manual pressure. Prolapse is most often associated with episodes of straining but it can occur even with ambulation, especially in elderly female patients. It is important to elicit how much they are prolapsing, how often, and how much it is bothering them in order to decide whether to operate. Prolapse is often associated with mild bleeding and mucus.
- It is important to elicit any bowel habits dysfunction that has to be addressed. Recurrence rates of prolapse are higher after surgery when severe constipation or obstructed defecation due to pelvic floor dysfunction are not addressed.
- The patient should be asked about their continence as the surgeries for prolapse described here do not immediately improve continence. After prolapse surgery, about half of patients have some improvement in continence over time, but if their incontinence is severe and they cannot squeeze on exam, they may be better served with an ostomy. Intense counseling is critical.
- Associated gynecologic and/or urologic pelvic floor dysfunction issues (including difficulty with urination and uterine prolapse) commonly seen in rectal prolapse patients should be addressed in a multidisciplinary fashion together with a urogynecologist.
- Patients often come with digital photographs of their prolapse that allow for confirmation of the diagnosis. Otherwise, it is important to elicit the prolapse in the clinic to be able to differentiate it from prolapsing hemorrhoids.
- The best way to confirm the rectal prolapse is to give the patient 5 minutes on the toilet to elicit the prolapse and then examine them. Rectal prolapse looks like a single long tube sticking out with concentric ring; prolapsing hemorrhoids look like multiple individual quadrants of tissue (**FIG 1**).
- Physical exam should include digital rectal exam to assess for masses. Having the patient push during the exam allows the examiner to feel for enterocele, rectocele, and cystocele. In addition, the patient should be asked to squeeze to assess the sphincter muscles.



A B

FIG 1 ● It is important to differentiate **(A)** rectal prolapse from **(B)** prolapsing internal hemorrhoids. Rectal prolapse is prolapsing tissue that has full concentric rings (patient is in supine position, in candy canes). Prolapsing internal hemorrhoids is a mucosal prolapse in three separate bundles (patient is in a prone jackknife position).

- Patients with an incarcerated rectal prolapse may on occasion present to the emergency room. In these cases, the treatment depends on the appearance of the bowel. If viable, gentle reduction with sedation, reassurance, and education are usually all that is needed and the patient can follow up electively; if not viable, a perineal proctectomy is needed.

IMAGING AND OTHER DIAGNOSTIC STUDIES

- Any patient being evaluated for rectal prolapse should have a colonoscopy to rule out either a malignancy acting as the lead point of the prolapse or a synchronous tumor.
- In patients that are unable to elicit prolapse or bring you a picture, a defecography can be very helpful. During this procedure, the patient's small bowel, rectum, and vagina are all filled with contrast and the patient is asked to have a barium bowel movement while the radiologist takes a video. This often demonstrates the prolapse along with other types of pelvic floor dysfunction. The prolapse may not be seen on defecography, as evacuation of barium requires less straining than evacuation of hard stool in constipated patients.

SURGICAL MANAGEMENT

Operative Planning and Strategy

- The choice of operation is dependent on many factors including patient health, prior surgeries, the operating surgeon's comfort with laparoscopy, and whether the patient has a history of constipation.
- If the patient is healthy enough, then an abdominal rather than a perineal approach should be offered due to the lower risk of recurrence. Otherwise, they may be better served with a lower risk perineal operation or no operation at all.
- Rectal prolapse is not dangerous unless incarcerated, so not all patients are offered operation.
- Abdominal surgery for rectal prolapse should include dissection posterior to the mesorectum with fixation of the mobilized rectum just below the sacral promontory, as this fixation decreases the risk of recurrence. The fixation can be performed with sutures or with mesh.
- In constipated patients, resection of the sigmoid colon is recommended. In these cases, although not proven beneficial by Cochrane review of available evidence, either a full bowel preparation or just enemas can be performed preoperatively at the surgeon's discretion.
- The surgery can be performed open or laparoscopically. Laparoscopic surgery is associated with significant short-term advantages over open surgery.
- Preoperative antibiotics are given within 1 hour of incision to decrease the risk of postoperative wound infection and are stopped within 24 hours of surgery.
- Heparin prophylaxis is given perioperatively to lower the risk of deep vein thrombosis.

Positioning

- Any rectal prolapse should be reduced manually prior to starting the operation.
- For laparoscopic operations, the patient is placed on a lithotomy position with the legs on Yellofin stirrups and with the thighs parallel to the ground to avoid conflict with the surgeon's arms (**FIG 2**). Avoid pressure on the calves and lateral peroneal nerves.
- Both arms are tucked and padded to avoid nerve injuries (for open cases, the arms are placed on arm boards laterally). All lines and cords are kept out of the tucking.
- Tape the patient across the chest over a towel to secure him/her to the operating room (OR) table.

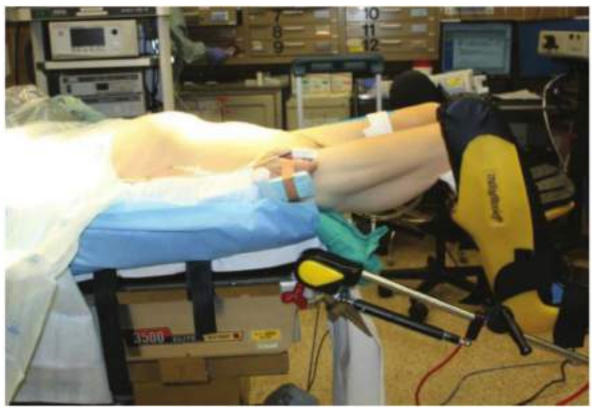


FIG 2 • Patient positioning for laparoscopic rectal prolapse repair. The patient is placed in a lithotomy position with the thighs parallel to the ground to avoid conflict with the surgeon's arms. The patient is placed on a beanbag with both arms tucked and taped to the table over a towel.

TECHNIQUES

LAPAROSCOPIC SUTURE RECTOPEXY

Insufflation, Port, and Team Setup

- The abdomen is accessed with either a Veress needle or a Hassan port at the inferior portion of the umbilicus and carbon dioxide (CO_2) pneumoperitoneum is established.
- Port placement (**FIG 3**): A 5-mm infraumbilical camera port is inserted for the 30-degree camera. Three 5-mm working ports are inserted in the right lower quadrant, the right upper quadrant, and the left lower quadrant.
- The surgeon stands on the patient's right side, with the scrub nurse next to him/her. The assistant stands on the left side of the table (**FIG 4**).

Posterior Dissection

- The patient is placed in a steep Trendelenburg position with the left side up. The bowel is placed in the upper abdomen. The sigmoid colon and rectum are often very redundant and can be hard to manipulate. At times, this may require additional port placement.
- The rectosigmoid is pulled toward the abdominal wall, tenting upward the base of its mesentery at the sacral promontory (**FIG 5**). The peritoneum is incised along the root of the mesocolon with cautery across the promontory and toward the right and left posterolateral aspect of the cul-de-sac.

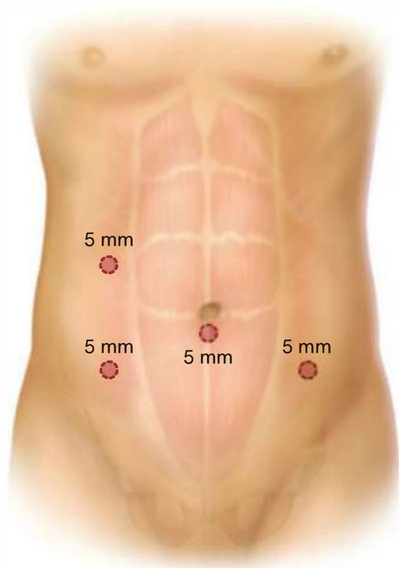


FIG 3 ● Laparoscopic rectopexy port placement. A 5-mm infraumbilical camera port is inserted for the 30-degree camera. Three 5-mm working ports are inserted in the right lower quadrant, the right upper quadrant, and the left lower quadrant.

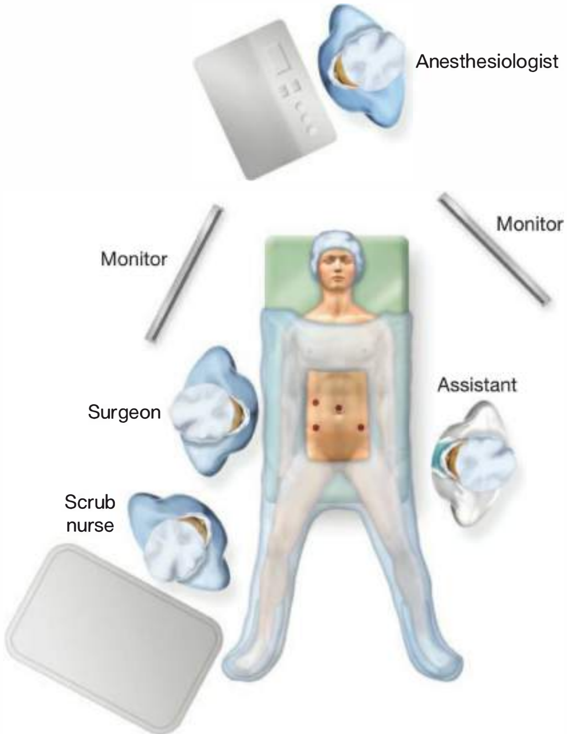


FIG 4 ● OR team setup. The surgeon stands on the patient's right side with the scrub nurse next to him/her. The assistant stands on the left side of the table.

- The rectum is then lifted anteriorly toward the abdominal wall in order to reveal the alveolar plane in the presacral space located between the mesorectum and the presacral fascia (**FIG 6**). Dissect the presacral space distally with an energy device until reaching just above the anal canal. Digital rectal examination may be needed to confirm the distal extent of dissection is appropriate (**FIG 7**).
- Avoid penetration into the endopelvic fascia along the lateral pelvic wall, because this can lead to serious bleeding from the hypogastric vein and its branches. Also, dissecting into the presacral fascia could result in catastrophic bleeding from the presacral venous plexus.
- The sympathetic nerves should be identified and preserved intact in the retroperitoneum.
- Minimize unnecessary dissection of the lateral rectal stalks.

Rectopexy

- Completely reduce the prolapse by retracting the rectosigmoid junction in a cephalad direction.

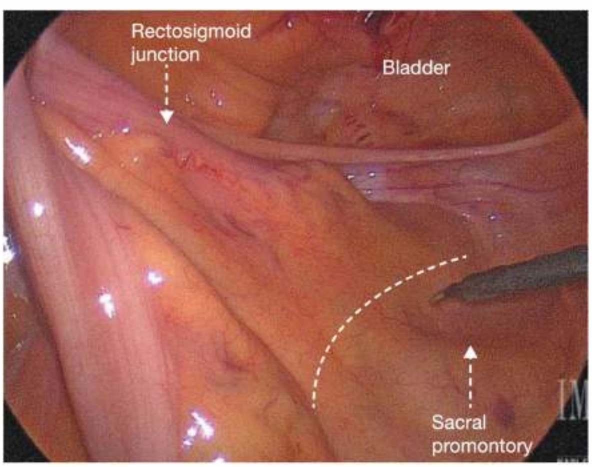


FIG 5 ● The rectosigmoid is pulled toward the abdominal wall, tenting out the base of its mesentery peritoneum at the sacral promontory. The peritoneum is incised along the root of the mesocolon *(dotted line)* across the promontory toward the right posterolateral cul-de-sac.

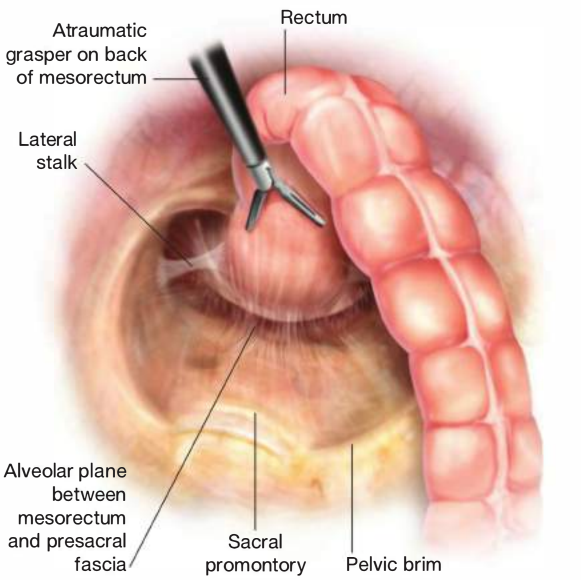


FIG 6 ● The rectum is lifted anteriorly toward the abdominal wall in order to reveal the alveolar plane between the mesorectum and the presacral fascia.

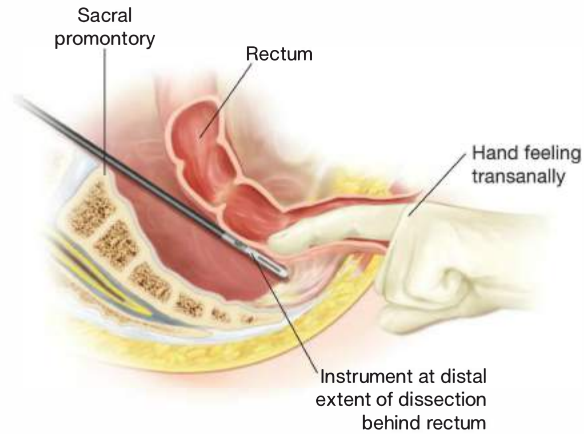


FIG 7 ● Digital rectal examination allows palpating an instrument placed at the distal end of dissection, confirming that the posterior dissection has reached the top of the anal canal.

- The rectopexy sutures (braided nonabsorbable or absorbable sutures) are placed starting just below the top of the promontory. While retracting the rectum anteriorly, three sutures are placed along the midline, from the presacral fascia to the back of the mesorectum, placing the most distal stitch first (**FIG 8**). SH needles will fit through 5-mm ports if the curve of the needle is slightly flattened.
- When placing these stitches, it is important to have the needle enter at a right angle to the bone and then turn the needle after the bone is felt so that a wide swath of presacral fascia is incorporated in the stitch (**FIG 8**). Pull up on the mesorectum and place the stitch through the back of the mesorectum to pull the rectum upward when tying the knots. It is helpful to use a knot pusher or an automatic tying device to tie the knots in the narrow confines of the presacral space.
- Another important tip is not to remove any misplaced stitches but instead to just tie them, as removal can result in significant bleeding from the presacral veins.

Closure

- Assess the abdomen for hemostasis; remove all ports and close skin incisions with absorbable suture.

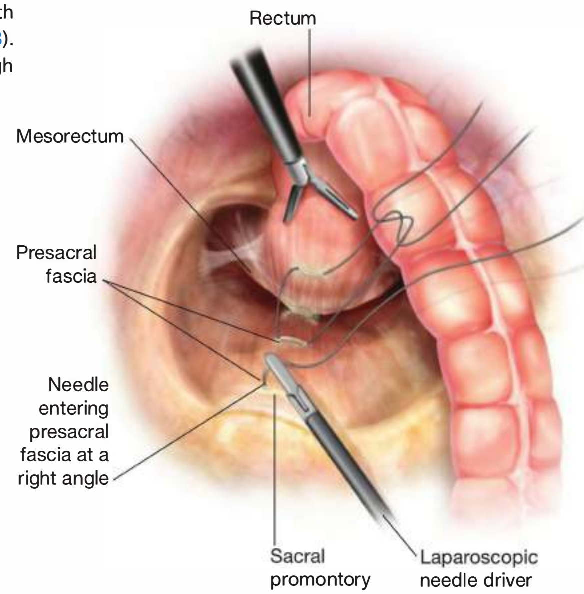


FIG 8 ● Stitch placement for rectopexy. The stitches are placed along the midline, starting with the first one a few centimeters distal to the promontory and moving upward. The needle should enter the presacral fascia at a right angle. When bone is felt, turn the needle to encircle a wide swath of presacral fascia. Pull up on the mesorectum and place the stitch through the back of the mesorectum to pull the rectum upward when tying the knots.

HAND-ASSISTED LAPAROSCOPIC SURGERY RESECTION RECTOPEXY

- Hand-assisted laparoscopic surgery (HALS) in colorectal surgery has the same short-term outcome advantages of conventional laparoscopic-assisted (LA) surgery over open surgery, including less pain, faster recovery, lower incidence of wound complications, and reduction of cardiopulmonary complications, especially in the obese and in the elderly.
- Advantages of HALS over conventional LA colorectal surgery include the following:
  - Reintroduces tactile feedback into the field
  - Shorter learning curves; easier to teach
  - Shorter operative times and lower conversion to open rates
  - Higher usage rates of minimally invasive surgery

Port Placement, Team, and Operating Room Setup

- Start by placing a hand access port through a 5- to 6-cm Pfannenstiel incision. Care is taken to avoid bladder injury (**FIGS 9**, **13**).
- Insufflate the CO_2 pneumoperitoneum; a 5-mm port is placed through the hand port.
- Insert a 5-mm supraumbilical camera port.
- Insert two 5-mm working ports in the right and left lower quadrants, respectively.
- The operating team and OR setup is otherwise identical as previously described (**FIG 4**).

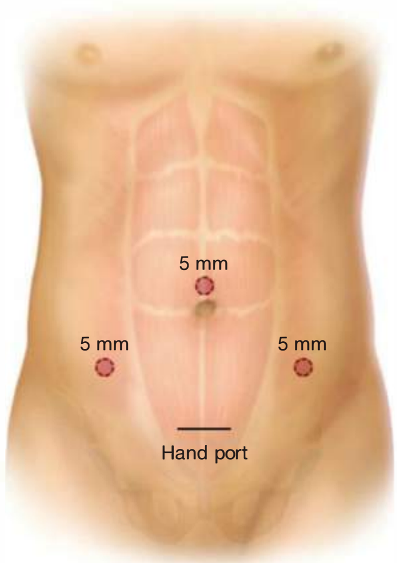


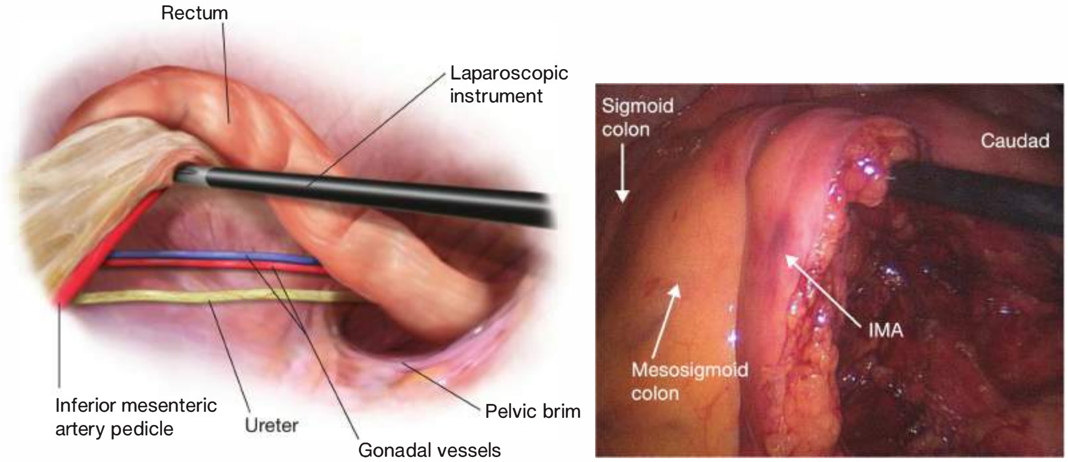
FIG 9 ● HALS rectopexy port placement. A 5-mm supraumbilical camera port is inserted for the 30-degree camera. Two 5-mm working ports are inserted in the right lower quadrant and the left lower quadrant. The hand port (GelPort) is inserted through a 5- to 6-cm Pfannenstiel incision.

POSTERIOR DISSECTION

- The patient is placed in a steep Trendelenburg position with the left side up. Using your right hand, gently pull the small bowel out of the pelvis and placed it in the upper abdomen. A laparotomy sponge, inserted via the hand port, can be used to hold the small bowel out of the pelvis and also to clean the camera tip intracorporeally.
- The sigmoid colon and rectum are often very redundant and can be hard to manipulate. HALS greatly facilitates this maneuver. If necessary, insert an additional port for this purpose.
- Using the hand, the rectosigmoid junction is pulled toward the anterior abdominal wall and pubis, tenting out the peritoneum at the sacral promontory. This peritoneum is incised with cautery across the promontory and toward the posterolateral cul-de-sac on the right and left sides.
- The rectum is then lifted anteriorly toward the abdominal wall in order to reveal the alveolar plane in the presacral space located between the mesorectum and the presacral fascia (**FIG 6**). Dissect the presacral space distally with an energy device until reaching just above the anal canal. Digital rectal examination may be needed to confirm the distal extent of dissection is appropriate.
- Avoid penetration into the endopelvic fascia along the lateral pelvic wall, because this can lead to serious bleeding from the hypogastric vein and its branches. Also, dissecting into the presacral fascia could result in catastrophic bleeding form the presacral venous plexus.
- The sympathetic nerves should be identified and preserved intact in the retroperitoneum.
- Minimal dissection of the lateral rectal stalks should be performed.

Sigmoid Resection

- This step should only be performed if the patient has a redundant colon and severe constipation.
- The mesentery of the sigmoid colon is separated from the retroperitoneum bluntly by medial to lateral dissection starting at the original opening made in the peritoneum at the sacral. The inferior mesenteric artery is lifted up and the left ureter and gonadal vessel are identified and left intact in the retroperitoneum (**FIG 10**).
- Once this dissection reaches the abdominal side wall, the attachments between the sigmoid colon and the lateral peritoneum are divided.
- The mesentery to the bowel to be resected is divided with the LigaSure or Harmonic, staying close to the bowel until the top of the rectum is reached distally and the point appropriate for anastomosis is reached proximally. This proximal point is where the proximal colon reaches the rectum in the position it will be in after the rectopexy.
- The bowel is divided distally at the top of the rectum as defined by the splaying of the teniae coli. This division can be done with a laparoscopic gastrointestinal anastomosis (GIA), Contour, or thoracoabdominal (TA) stapler



A B

FIG 10 ● Schematic (**A**) and operative (**B**) pictures. Medial to lateral mobilization of the mesosigmoid colon. The mesentery of the sigmoid colon is separated from the retroperitoneum bluntly by medial to lateral dissection starting at the original opening made in the peritoneum at the sacral promontory. The inferior mesenteric artery (IMA) is lifted up and the left ureter and gonadal vessel are identified and left intact in the retroperitoneum.

placed through the hand port. This position is estimated by pulling the top of the rectum up to the top of the sacral promontory. The proximal bowel is then pulled through the hand port and is divided extracorporeally. A 31-mm end-to-end anastomosis (EEA) anvil is then placed in the open end of the descending colon.

- The end-to-end colorectal anastomosis with a 31-mm EEA (**FIG 11**) is performed after the rectopexy sutures are placed but before they are tied.
- An underwater air test is performed to check for anastomotic leak (**FIG 12**). Perform after tying the rectopexy sutures. Perform this test with a colonoscope so that the anastomosis can be viewed at the same time. An air leak would indicate a disruption in the anastomotic line and may necessitate revision of the anastomosis.
- If there is undue tension on the anastomosis, the lateral and retroperitoneal attachments to the descending colon should be divided.

Rectopexy

- The lid of the hand port can be left on or off for placement of the rectopexy sutures depending on surgeon preference.
- The rectopexy sutures are to be placed starting just below the top of the promontory. Along, braided nonabsorbable suture on an SH needle is used to perform

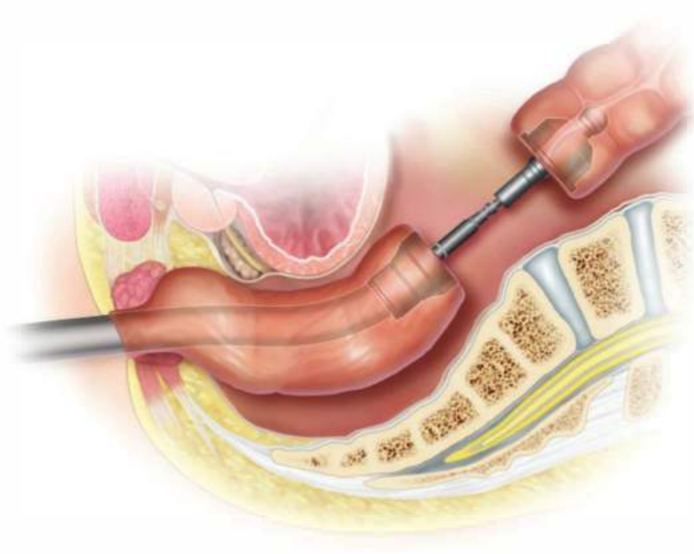


FIG 11 ● The end-to-end colorectal anastomosis is performed with a 31-mm EEA.

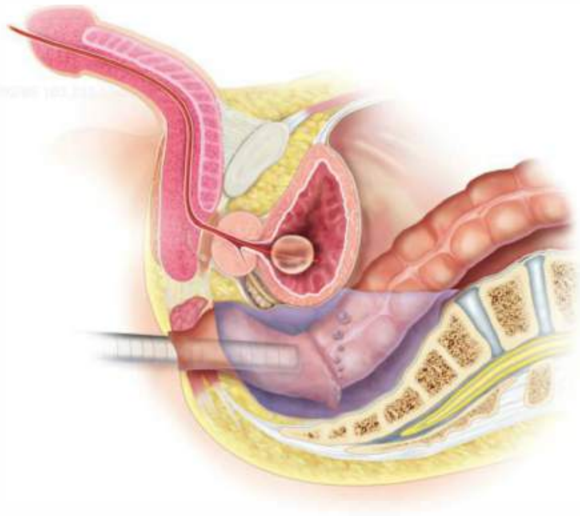


FIG 12 ● An underwater air test is performed to check for anastomotic leak. An air leak would indicate a disruption in the anastomotic line and may necessitate revision of the anastomosis.

suture rectopexy. Alternatively, absorbable suture or mesh can be used.

- The rectum is held out of the way with a retractor, and three sutures are placed in the midline from the presacral fascia to the back of the mesorectum, placing the most distal stitch first (**FIG 8**).
- When placing these stitches, it is important to have the needle enter the tissue at a right angle to the bone and then turn the needle after the bone is felt so that a wide swath of presacral fascia is encircled. Another tip is not to remove any misplaced stitches but instead to just tie them, as removal can result in significant bleeding from the presacral veins.
- The rectum should be pulled up (with any prolapse reduced) and the stitch should then be placed through the back of the mesorectum such that the rectum is hitched up higher on the sacrum than it was previously. This should be repeated for each of the three stitches.
- If a resection is being performed, place the sutures, tag them, and then tie them after performing the anastomosis.

Closure

- The rectus muscles and peritoneum can be approximated with absorbable suture or not.
- The anterior fascia is closed with running polydioxanone (PDS) sutures.
- The wound is irrigated and the skin is closed with running absorbable subcuticular sutures.
- The 5-mm port sites are closed with absorbable subcuticular sutures.

OPEN RECTOPEXY WITH OR WITHOUT SIGMOID RESECTION

Pfannenstiel Incision

- Make a 10-cm Pfannenstiel incision two fingerbreadths above the pubis. Divide the anterior fascia with cautery, taking care to leave the rectus muscles intact. This division should curve superiorly at the lateral edges so as not to divide the oblique muscles.
- Create a plane between the anterior fascia and the anterior surface of the rectus muscle using cautery and finger dissection while lifting up on the fascia with Kocher clamps (**FIG 13**). This plane should extend down to the pubis inferiorly and superiorly up about 6 cm.
- Find the midline between the rectus muscles and sharply enter the abdomen several centimeters from the pubis in order to avoid entering the bladder.
- With the bladder retracted medially, the posterior rectus sheet/peritoneum is incised inferolaterally in order

FIG 13 ● Pfannenstiel incision. The plane between the anterior fascia and the anterior surface of the rectus muscle has been created while lifting up on the rectus fascia with Kocher clamps. This plane should extend down to the pubis inferiorly and superiorly up about 6 cm.

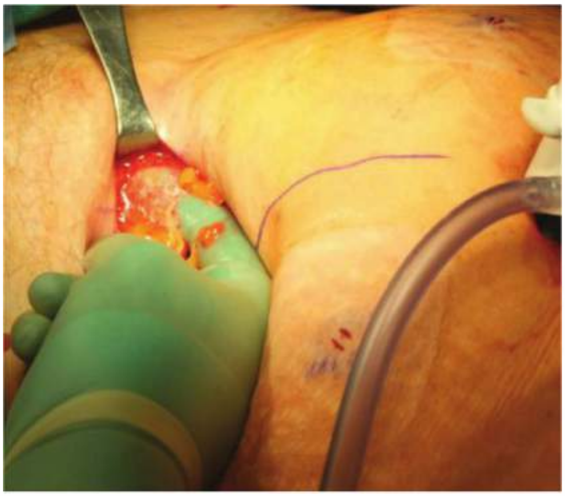


FIG 14 ● Pfannenstiel incision. The posterior rectus sheet/peritoneum is incised inferolaterally with the bladder retracted medially to avoid injuring the bladder.

to avoid injuring the bladder (**FIG 14**). This can be done bilaterally or on one side or the other.

- Place a wound protector (**FIG 15**).

Posterior Dissection

- Place the patient in Trendelenburg position. Place a Bookwalter (or similar) retractor for exposure.
- Pull the rectosigmoid forward and incise the peritoneum at the sacral promontory. At the top of the promontory, the sympathetic hypogastric nerves should be identified and preserved. They form a wishbone here and extend forward around the rectum (**FIG 16**).

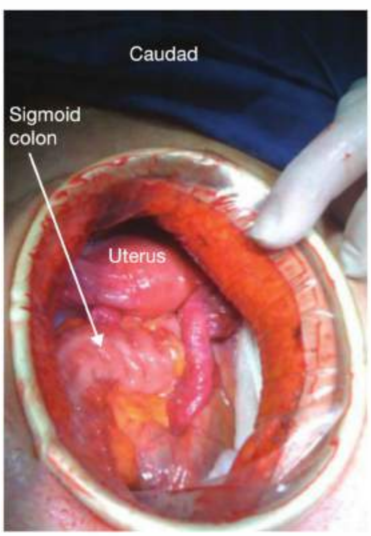


FIG 15 ● Placement of the wound protector.

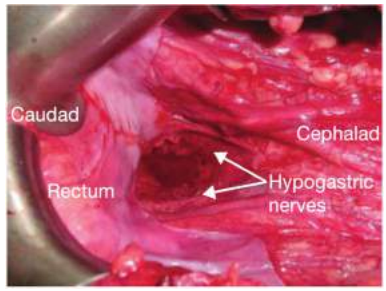


FIG 16 ● Identification of the hypogastric nerves. At the top of the promontory, the sympathetic hypogastric nerves should be identified and preserved. They form a wishbone here and extend forward around the rectum.

If these are divided in a male patient, the consequence is retrograde ejaculation.

- Place a St. Mark's retractor in this peritoneal opening, pull forward and superiorly on the rectum, and divide the alveolar plane between the mesorectum and the presacral fascia with the Bovie cautery, taking care to stay out of the presacral venous plexus (**FIG 17**).
- As the dissection proceeds, the St. Mark's retractor should be placed more distally so that appropriate tension is always maintained. This dissection should be carried out posterior to the rectum down to the level of the pelvic floor.
- The lateral stalks should be left intact as much as possible during this dissection. Useful tools for this dissection include the long tip for the Bovie as well as the extender that can be placed between the long tip and the handpiece and bariatric St. Mark's retractors.

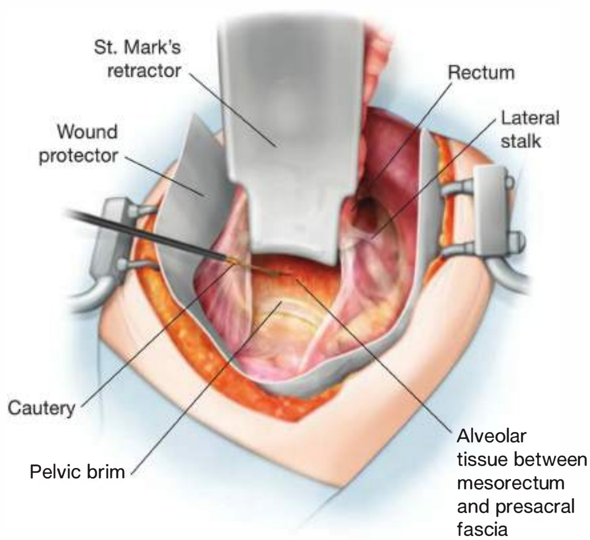


FIG 17 ● Exposure of the presacral space using the St. Mark's retractor. Place the retractor behind the mesorectum and pull forward and upward to reveal the alveolar plane of the presacral space. The dissection is carried down to the level of the pelvic floor; reposition the retractor frequently to maintain the proper tension to reveal the correct tissue plane.

- Check the extent of the distal dissection by placing one hand or surgical instrument in the abdomen at the most distal extent of the dissection and then reach under the drapes to place a finger in the anus to feel the other hand through the posterior rectal wall. The dissection should extend to the top of the anal canal.
- Any prolapse should again be reduced at this time.

Sigmoid Resection

- This step should only be performed if the patient has a very redundant sigmoid colon and severe constipation. The technique for open sigmoidectomy has been described elsewhere in this book.
- The bowel is divided distally at the top of the rectum as defined by the splaying of the teniae.
- The proximal point of transection is where the proximal colon reaches the proximal rectum in the position it will be in after the rectopexy. This position is estimated by pulling the top of the rectum up to the top of the sacral promontory.
- The colorectal anastomosis with 31-mm EEA stapler is performed after the rectopexy sutures are placed but before they are tied.

Rectopexy

- The rectopexy sutures are to be placed starting just below the top of the sacral promontory. Use a long, braided nonabsorbable suture on an SH needle to perform the suture rectopexy, or absorbable suture or even mesh that is attached to the promontory and then sutured to the rectum or mesorectum can also be used.
- The rectum is held out of the way with a retractor and three sutures are placed in the midline from the presacral fascia to the back of the mesorectum, placing the most distal stitch first.
- When placing these stitches, it is important to have the needle enter the presacral tissue at a right angle to the bone and then turn the needle after the bone is felt so that a wide swath of presacral fascia is encircled (**FIG 8**). Another tip is not to remove any misplaced stitches but instead to just tie them as removal can result in significant bleeding from the presacral veins.
- The rectum should be pulled up (with any prolapse reduced) and the stitch should then be placed through the back of the mesorectum such that the rectum is hitched up higher on the sacrum than it was previously. This should be repeated for each of the three stitches.
- Alternatively, the stitches can be attached to the lateral stalk on one side or the other.
- If a resection is being performed, place the sutures, tag them with hemostats, and then tie them after performing the anastomosis with a 31-mm EEA stapler.

Closure

- The rectus muscles and peritoneum can be approximated with absorbable suture or not.
- The anterior fascia is then closed with running PDS sutures.
- The wound is irrigated and the skin closed with running absorbable subcuticular sutures.

PEARLS AND PITFALLS

Diagnosis	■ Must differentiate rectal prolapse from prolapsing internal hemorrhoids
Posterior dissection	■ Must stay in the correct plane and in the midline; otherwise, severe bleeding may occur.
Sigmoid resection	■ Perform resection only in patient's very redundant sigmoids and with severe underlying constipation. ■ The anastomosis should be tension-free without redundancy.
Rectopexy	■ Always check and be sure that the rectal prolapse is reduced before performing the rectopexy. ■ Place sutures through presacral fascia below top of promontory. ■ Tie, rather than remove, misplaced presacral stitches to avoid bleeding.

POSTOPERATIVE CARE

- The orogastric tube is removed at the completion of the case.
- Patients are offered liquids the day of surgery and their diets are advanced to a general diet as tolerated. Reasons not to advance the diet include nausea, vomiting, and abdominal distention. Flatus is not needed for diet advancement but is preferred prior to discharge home.
- Length of stay varies, with laparoscopic and HALS suture rectopexy often being as short as 2 days and open resection rectopexy as long as 7 days.
- Chemical and mechanical prophylaxis for deep vein thrombosis should be started in the operating room and should be continued postoperatively.
- Early ambulation is important.
- Pain is managed with a combination of narcotic and nonnarcotic medications, starting with mostly intravenous medications and quickly converting over to oral medications.
- The Foley catheter is left in place 2 days due to the low pelvic dissection. Upon removal, the patient should attempt to void frequently and intermittent straight catheterization should be performed as needed for retention. Some patients will continue to need this at home.
- Patients should be placed on fiber and/or an osmotic laxative such as MiraLAX as soon as they are able to tolerate oral intake. The goal is one or two soft bowel movements a day such that straining is avoided. The medication can be titrated at home to reach this goal as not all patients have a bowel movement prior to discharge.

OUTCOMES

- Recurrence rates are very low, with most series reporting less than 5% recurrence.
- If recurrence occurs in the case of rectopexy alone, rectopexy can be performed again with or without resection.
- If recurrence occurs after resection and rectopexy, further attempts at repair must be chosen carefully so as not to devascularize any bowel.

COMPLICATIONS

- Pelvic bleeding in the postoperative period is avoided by meticulous technique and hemostasis. If it occurs and is not profuse, it will usually stop by withholding all anticoagulants.
- Wound infection is the most common complication and should be treated by opening the skin and packing the wound until healing occurs.
- The risk of anastomotic leak is 2% to 5%.

SUGGESTED READINGS

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Chapter 48

Cytoreductive Surgery and Hyperthermic Intraperitoneal Chemotherapy for Peritoneal Surface Dissemination of Colorectal Cancer

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DEFINITION

- The term peritoneal surface disease (PSD) describes the intraabdominal dissemination of neoplasms to peritoneal surfaces and is a term complementary to peritoneal carcinomatosis.
- Cytoreductive surgery (CRS) and hyperthermic intraperitoneal chemotherapy (HIPEC) have been shown to be effective treatment options for a variety of epithelial primaries. The scope of this chapter is to analyze the role of CRS/HIPEC in the management of selected colon cancer patients with peritoneal dissemination.
- The operation is a two-step process:
  - Surgical resection (CRS) of involved organs and peritoneal surfaces, followed by
  - Delivery of heated chemotherapy (HIPEC) to the peritoneal cavity
- During HIPEC, a heated chemotherapy solution is circulated in the abdominal cavity to treat any cancer cells that may remain after CRS. Delivering chemotherapy at the time of cytoreduction allows a more complete distribution in the peritoneal cavity and exposes tumor-to-drug concentrations higher than that achieved with systemic chemotherapy.
- Thus, the theoretical advantage of CRS/HIPEC, which is now routinely performed in specialized centers, is that it treats macroscopic diseases surgically and microscopic diseases pharmacologically. The results of a prospective randomized trial testing this hypothesis are expected to be released soon.
- The goal for CRS/HIPEC applied to PSD from colon cancer is the complete cytoreduction of all macroscopic disease prior to perfusion with HIPEC. Therefore, appropriate candidates are identified based not only on their ability to tolerate aggressive CRS but also on the likelihood of obtaining a complete cytoreduction.
- Careful selection of patients can help ensure that only those who can expect to have the greatest benefits are subjected to the inherent risks of this treatment paradigm.

PATIENT SELECTION

- Patient selection is based predominantly on the extent of disease and the functional reserves of the patient.
- Preoperative evaluation includes complete history and physical, review of previously obtained pathology, and infused computed tomography (CT) of the chest abdomen and pelvis or dedicated abdominal magnetic resonance imaging (MRI). Preoperative lab work includes blood counts, electrolytes, liver function panel, and carcinoembryonic antigen (CEA) levels.
- Our selection criteria include the following:
  - The patient is medically fit to undergo CRS/HIPEC without signs of kidney, liver, or bone marrow dysfunction preoperatively.
  - The patient's Eastern Cooperative Oncology Group (ECOG) functional status is less than or equal to 2.
  - There is no extraabdominal disease or retroperitoneal disease.
  - There is low-volume peritoneal disease (preferably a peritoneal carcinomatosis index less than 14) that is potentially completely resectable.
  - Any parenchymal hepatic metastasis should be limited and should not require anatomic liver resection.
- Malignant ascites and bowel obstructions are predictors of incomplete resection and worse overall survival.

IMAGING AND OTHER DIAGNOSTIC STUDIES

- Infused CT of the chest, abdomen, and pelvis is the standard preoperative imaging study and helps to rule out extraabdominal disease, extensive hepatic metastases, and insurmountable small bowel involvement. Sites of impending obstruction may also be identified.
- Although the sensitivity of CT scan for detecting PSD is low, it is useful in determining overall operability. Solid disease components may be hidden in patients with large volumes of malignant ascites (**FIG 1**).
- MRI may detect PSD with up to 100% sensitivity, yet has a significantly high false-positive rate, especially after prior operations. This is because MRI is incapable of recognizing a difference between scar tissue and recurrent PSD.
- Positron emission tomography (PET) is rarely used given that sensitivity and specificity are prohibitively low, especially in patients with limited disease.
- Endoscopy can allow clinicians to tattoo second colonic primaries in less than 5% of the patients. Endoscopic ultrasonography is unlikely to change the management of these patients.
- Diagnostic laparoscopy can assist in determining the extent and stage of PSD prior to CRS/HIPEC.
- The peritoneal carcinomatosis index (PCI) is the most commonly used staging system for PSD. It provides a way to

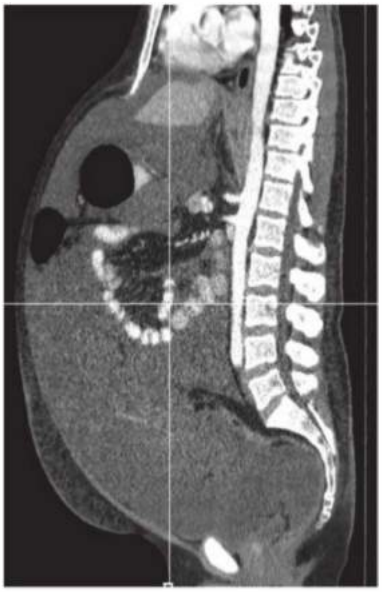

FIG 1 ● Infused CT of a patient with large volume of malignant ascites. The PCI is calculated based on the size of solid disease components but it is not possible to distinguish solid components from ascitic fluid in patients with a large volume of malignant ascites. In these cases, we use the ascites score to evaluate patients for the operation.

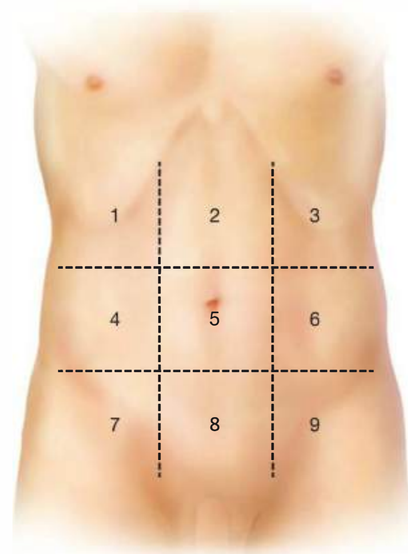

FIG 2 ● Schematic for calculating the ascites score. One point is assigned for the presence of malignant ascites in each of nine abdominal regions on supine CT. The nine regions correlate with those used to calculate the PCI.

standardize the extent of disease. It has been shown to have prognostic value and certain scores have been used as a cutoff in deciding when CRS/HIPEC is appropriate. Calculating the PCI involves dividing the abdomen into nine regions and the small bowel into four regions. For each region, a score of 0 (no tumor), 1 (tumor up to 0.5 cm), 2 (tumor up to 5 cm), or 3 (tumor >5 cm) is applied to assist in understanding tumor burden. Scores for each of the 12 regions are tabulated to derive the PCI score.

- We calculate ascites score in patients with voluminous ascites (**FIG 2**) based on preoperative imaging. Patient with colorectal primaries and ascites score greater than 3 (or three out of nine abdominal areas with ascitic fluid while on supine position on the CT table) have minimal chances to achieve a complete CRS. In these patients, we start the operation with diagnostic laparoscopy to establish resectability.

SURGICAL MANAGEMENT

Preoperative Planning

- Preoperative assessment includes a history and physical, laboratory evaluation consisting of blood counts, comprehensive metabolic panel, CEA, and a blood type with crossmatch of four units of packed red blood cells.
- Splenectomy vaccines are routinely administered at least 2 weeks prior to the operation when splenectomy is anticipated.
- At the surgeon's discretion, ureteral stents may be placed prior to incision. This is generally appropriate for patients with a good possibility of ureteral involvement, prior retroperitoneal surgical exploration, or large volume of disease.
- A bowel preparation is routine. Patients with a bowel obstruction may benefit from the use of enemas.
- Prophylactic antibiotics are administered prior to induction of anesthesia.
- Both mechanical and pharmacologic deep vein thrombosis (DVT) prophylaxis is instituted as appropriate.

Positioning and Team Setup

- The majority of patients are placed supine. In cases of rectal cancer, induced PSD at modified lithotomy position is preferred (**FIG 3**).
- In the modified lithotomy position, the legs are placed in Allen or Yellofin stirrups. All pressure points are padded to prevent neurovascular injuries and/or calf myonecrosis.
- The thighs are positioned level with the abdomen, as this allows placement of a self-retaining retractor without creating excessive pressure between the retractor and the patient's thighs.
- The perineum is positioned flush with the edge of the operating room table.
- The arms are placed in a neutral position and supported with suitable armrests.
- The surgeon starts at the patient's right side, with the assistant standing to the patient's left side and with the scrub nurse standing to the surgeon's right side (**FIG 4**). If the patient is in a modified lithotomy position, a second assistant would be standing in between the patient's legs.

FIG 3 ● Patient positioning. If a large bowel resection is anticipated, the patient is placed on a modified lithotomy position, with the legs on Yellofin stirrups. The thighs are positioned level with the abdomen, as this allows placement of a self-retaining retractor without creating excessive pressure between the retractor and the patient's thighs. The arms are tucked. All pressure points are padded to prevent neurovascular injuries and/or calf myonecrosis.

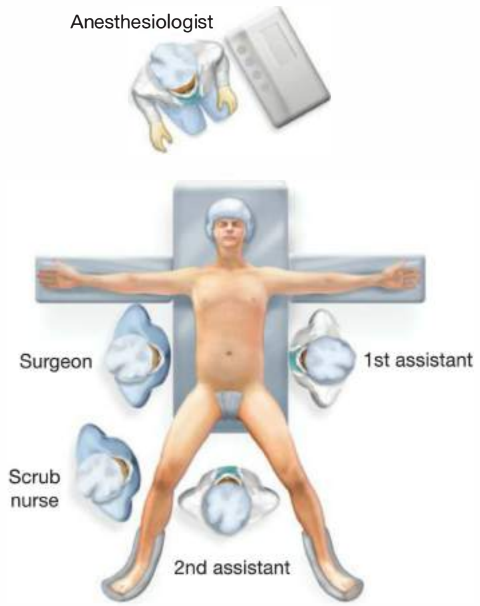

FIG 4 ● Team setup. The surgeon starts at the patient's right side, with the assistant standing to the patient's left side and with the scrub nurse standing to the surgeon's right side. A second assistant, if available, stands in between the patient's legs.

CYTOREDUCTIVE SURGERY

- After prepping and draping the abdomen, an incision is made from the xiphoid to the pubis to facilitate complete exposure of the peritoneal cavity.
- If the falciform ligament is present, it is resected in continuity with the round ligament prior to placing a fixed retractor (Bookwalter or bilateral Thompson).
- All adhesions from previous operations are lysed to allow all areas of the peritoneal cavity to be exposed to HIPEC.
- It is important at this point to proceed with a detailed mapping of the distribution of disease prior to commencing with any organ resection. Invasion of major vascular retroperitoneal structure or disease at the porta hepatis should not be undertaken for colon cancer–induced PSD.
- CRS is then undertaken to remove all visible tumor deposits if possible. Only peritoneal surfaces involved by tumor deposits are stripped from the abdominal wall using electrocautery.
- The greater omentum is routinely removed as it is nearly always a site of tumor deposits in patients with carcinomatosis (FIG 5). Any other involved tissue or organ not vital to the patient is also removed. During resection of the lesser omentum (if there is no gross involvement), we

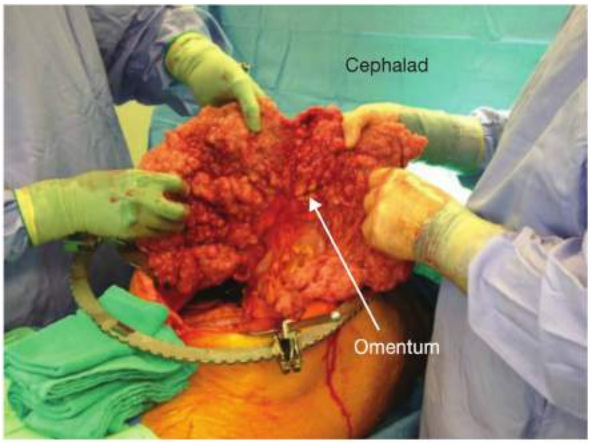

FIG 5 ● Intraoperative photograph of a patient with peritoneal carcinomatosis. Thickening of the omentum from tumor implants is referred to as "omental cake."

attempt to preserve the vagal branches going to the stomach. This will spare the patient a long-lasting gastroparesis and will significantly improve postoperative quality of life.

- Splenectomy is performed in case of direct involvement or any identified involvement of the left hemidiaphragm in order to facilitate a complete diaphragmatic stripping. Attention should be taken to avoid injury to the tail of the pancreas. In case of a distal pancreatectomy, a drain should be left in place. Even though the incidence of pancreatic leak is not higher with CRS/HIPEC, the associated mortality is significantly higher and should be taken into consideration.
- If during the procedure the surgeon feels complete cytoreduction is not possible or carries undue risk for the patient, the operation is aborted or tailored to delay bowel obstruction, as incomplete CRS offers no survival advantage in colon cancer–induced PSD.
- If a bowel resection is required, no data exist regarding the timing of creating an anastomosis; thus, any anastomosis required could be made prior to or following HIPEC. Required ostomies are created following HIPEC.
- We encourage the use of diverting loop ileostomies in cases where a low anterior resection (LAR) with primary anastomosis is performed.

GRADING THE RESECTION

- The degree of resection is judged by the surgeon at the conclusion of the cytoreduction.
- Residual disease is evaluated by measuring the diameter of the largest remaining tumor deposits.
- The two classification systems in use are the R status of resection and the completeness of cytoreduction (CC) score (Table 1). Complete cytoreduction of all gross disease is designated R0 or R1 or CC-0.
- We define complete CRS as no macroscopic evidence of disease at completion of CRS and we group R0/R1 resections together. We very rarely claim R0 resection in peritoneal carcinomatosis, maybe only in oligometastatic peritoneal disease. In addition, the pathologist cannot practically evaluate the margins, of the plethora of specimens, that CRS produces.

Table 1: Grade of Resection

R Status	Diameter of Largest Remaining Tumor Deposits	Completeness of Cytoreduction Score
—	0 mm	CC-0N—no visible disease following neoadjuvant chemotherapy
R0—clear margins R1—involved margins		CC-0S—no visible disease remains
R2a	2.5 mm	CC-1
	5 mm	CC-2
R2b	>5 mm–20 mm	
R2c	>20 mm–25 mm	
	>25 mm	CC-3

The two classification systems in use are the R status of resection and the completeness of cytoreduction (CC) score. Complete cytoreduction of all gross disease is designated R0 or R1 or CC-0.

HYPERTHERMIC INTRAPERITONEAL CHEMOTHERAPY

- Deciding whether or not to proceed with HIPEC is based on the degree of resection achieved but is also influenced by institutional protocols. Although HIPEC has a role in patients following a complete cytoreduction, it is unlikely to prolong survival following incomplete cytoreduction. We do, however, perfuse patients with massive malignant ascites identified at exploration even if a complete cytoreduction is not achieved. This helps prevent the return of the ascites and is of palliative benefit for the patient.
- Several factors that influence the efficacy of the chemotherapy include dose, timing, distribution, temperature, tumor responsiveness, tumor size, systemic chemotherapy, and prior surgery.
- The ratios of peritoneal drug concentrations to plasma drug concentrations are dependent both on the molecular weight and water solubility of the particular chemotherapy (Table 2). The most commonly used chemotherapeutic agents for colon cancer are mitomycin C (MMC) and oxaliplatin.
- Heating the chemotherapy increases the penetration of agents into tumor deposits and enhances their cytotoxic effects. The desired temperature of the perfusate in the abdomen ranges from 40°C to 42°C. During HIPEC, the patient is cooled to prevent systemic hyperthermia. Lowering the room temperature and using room temperature intravenous fluids accomplish this passive cooling.
- Perfusion for colon primaries at our institution is generally maintained for 120 minutes with MMC or oxaliplatin. Perfusion times may be decreased to avoid systemic absorption in patients deemed to be particularly susceptible. Factors that may make a patient more

Table 2: Chemotherapeutic Agents Used in Hyperthermic Intraperitoneal Chemotherapy for Colorectal Cancer

Agent	Molecular Weight	Peritoneal Fluid Concentration to Plasma Concentration
Floxuridine	246 Da	2000:1
Mitomycin C	334 Da	75:1
Oxaliplatin	397 Da	25:1

susceptible to drug toxicity include extensive peritonectomy, poor performance status, or old age.

- The perfusate is drained following the designated time period for perfusion. The abdomen is explored once again and anastomoses or ostomies are created. We do not routinely place drains, with the exception of patients undergoing distal pancreatectomy. The abdomen is closed and the procedure is concluded.
- Several techniques for perfusing with HIPEC have evolved. All consist of a closed circuit to maintain consistent hyperthermia and temperature monitoring (FIG 6A,B). There is insufficient evidence to support one technique over another.

Hyperthermic Intraperitoneal Chemotherapy Delivery Modalities: The Closed Abdominal Technique

- The closed technique is one of the two most commonly used HIPEC techniques.
- This technique involves the placement of inflow and outflow catheters through the skin prior to suturing the skin closed in a temporary yet watertight manner (FIG 7).
- Temporarily closing at the level of the skin while leaving the fascia open allows contact of the perfusate to the likely contaminated subcutaneous tissue on either side of the incision.

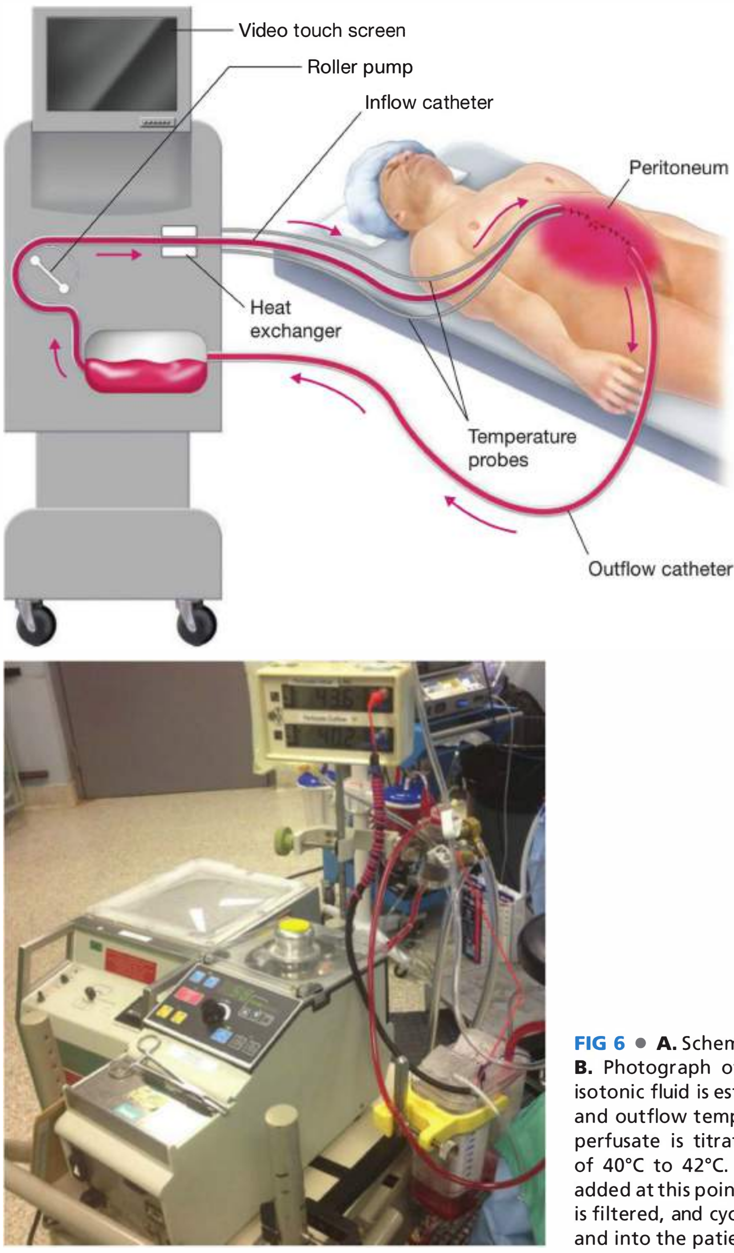

FIG 6 ● **A.** Schematic of a HIPEC perfusion circuit. **B.** Photograph of the perfusion circuit. Flow of isotonic fluid is established into the patient. Inflow and outflow temperatures are monitored and the perfusate is titrated to an outflow temperature of 40°C to 42°C. The chemotherapeutic agent is added at this point. The perfusate exits the patient, is filtered, and cycled back through the heat pump and into the patient for the set period of time.

FIG 7 ● A photograph depicting the closed abdominal technique. There are two inflow and two outflow cannulas that allow the abdomen to be in continuity with the perfusion circuit. The abdomen has been closed temporarily with a running suture at the skin level.

- The operating room personnel massage the abdomen (gently shaking it in a back-and-forth rocking fashion) to help distribute the perfusate throughout the abdomen (**FIG 8**).
- The increased pressure in the closed technique theoretically provides deeper penetration of the chemotherapy into tissues.
- For these reasons, the closed technique is our preferred approach to delivering HIPEC.

Hyperthermic Intraperitoneal Chemotherapy Delivery Modalities: The Open, or Coliseum Technique

- The open technique is also a commonly used HIPEC technique.
- This HIPEC technique involves suturing plastic sheeting circumferentially around the patient's skin incision and securing it to the fixed retractor (**FIG 9**). This expands the potential space with a "coliseum-like" device, which allows the bowel to float freely in a larger volume of perfusate.
- This technique theoretically increases exposure of all surfaces to the chemotherapy.
- The open technique allows the surgeon to manipulate the intraabdominal contents and may facilitate a more even distribution of heat and agent throughout the abdomen.
- Due to concern regarding exposure of operating room personnel to the chemotherapeutic agent with the open technique, specialized education and training of involved personnel is mandatory. Other safety efforts include restriction of operating room traffic, smoke evacuators, filtration masks, and waterproof gowns.

Hyperthermic Intraperitoneal Chemotherapy Delivery Modalities: Other Techniques

- Other modalities of perfusion have been developed in an attempt to combine the advantages of both the open and closed techniques but are not widely used.
- These techniques may provide more even drug and temperature distribution; however, they are generally complex and do not eliminate all safety risks to operating room personnel.

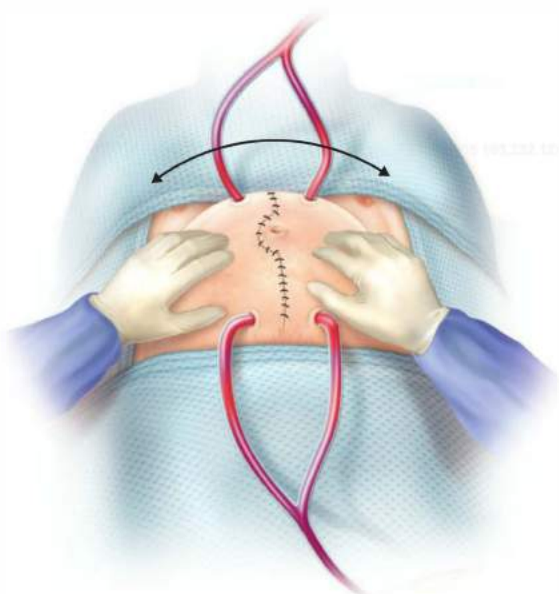

FIG 8 ● Distribution of the perfusate. The operating room personnel massage the abdomen (gently shaking it in a back and forth rocking fashion) to help distribute the perfusate throughout the abdomen.

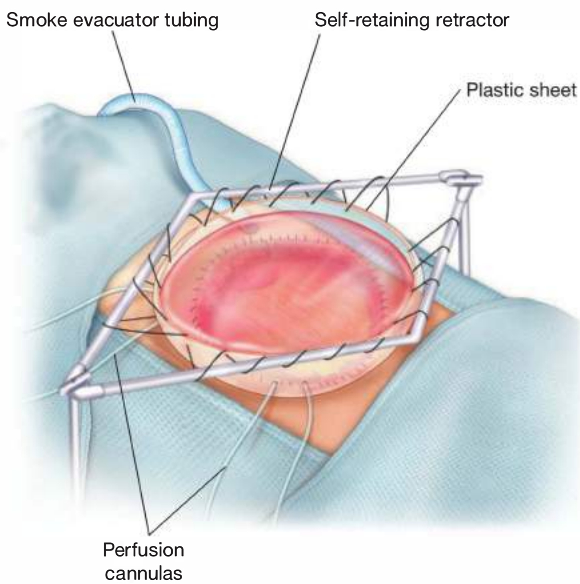

FIG 9 ● The open or "coliseum" HIPEC technique involves suturing plastic sheeting circumferentially around the patient's skin incision and securing it to the fixed retractor. This expands the potential space with a "coliseum-like" device, which allows the bowel to float freely in a larger volume of perfusate.

PEARLS AND PITFALLS

CRS/HIPEC goal	■ Complete cytoreduction prior to HIPEC infusion
Patient selection	■ It is critical to select appropriate candidates. Important elements to assess include the following: ■ Patient's performance status ■ Extent and distribution of disease ■ Consider use of laparoscopy.
CRS	■ Remove everything with tumor deposits: (nonvital) organs and peritoneum. ■ If a bowel resection is required, an anastomosis may be created prior to or following HIPEC. ■ Required ostomies are created following HIPEC. ■ The two predominating classification systems are used: R status of resection and the CC score.
HIPEC	■ Perfuse for 120 minutes at 40°C to 42°C. ■ Temperature >42°C greatly increases morbidity/mortality. ■ The closed abdomen and open (coliseum) techniques are most frequently used.
Postoperative care	■ Close ICU monitoring is required. ■ Postoperative complication rates are high: A high index of clinical suspicion is required.

POSTOPERATIVE CARE

- The goal is for extubation in the operating room, followed by hemodynamic support and close fluid monitoring in the intensive care unit (ICU).
- Seventy-five percent of our patients require close monitoring in ICU postoperatively for a median stay of 1 day, whereas 25% are admitted directly to the floor.
- Total parenteral nutrition is not routinely initiated postoperatively. A nasojejunal feeding tube is often but not always placed in the operating room for early initiation of trophic feeds.
- Broad-spectrum intravenous antibiotics are not continued postoperatively.
- Patients are kept NPO until exhibiting return of bowel function. Nasogastric tubes are used as necessary.
- The Foley catheter is removed within 48 hours; however, it is kept for 5 days in cases where an LAR was performed and for 10 days in cases of a cystectomy or bladder repair.
- Patient-controlled analgesia (PCA) or thoracic epidural analgesia is used postoperatively at the discretion of the surgeon.
- Mechanical and pharmacologic DVT prophylaxis is started on the day of the operation.
- Aggressive chest physical therapy is instituted. Early ambulation is encouraged.
- The median hospital stay for our first 1,000 CRS/HIPEC patients is 8 days.
- Postdischarge follow-up: Patients are discharged home with 2 weeks of prophylactic enoxaparin and are initially seen for a postoperative checkup 2 weeks following discharge from the hospital. Follow-up thereafter includes an examination, tumor markers, and CT imaging every 3 months.

COMPLICATIONS

- Given the extent of the surgical resection required to achieve adequate cytoreduction, morbidity is significant. Major morbidity over the last 5 years for our institution is 27% with 3.8% mortality.
- Complications are frequently divided into two groups: secondary to the operation itself or toxicity from the chemotherapeutic agent.
- The complications of CRS essentially depend on the combination of organs resected and are similar with that described in the general surgery literature. The gravity of the complication may be significantly worse and depends on the physiologic reserves of the patient (which are commonly depleted), the extent of CRS, ECOG, and impact of chemotherapy.
- Twenty-three percent of patients are likely to require a blood transfusion at some point during their operation or hospitalization.
- Predictors of morbidity include older age, higher PCI, greater number of visceral resections, poorer performance status, and higher drug dose.
- Morbidity rates are related to the experience of the center performing CRS/HIPEC.
- Common causes of death are bowel perforation, respiratory failure, bone marrow suppression, thromboembolic events, and sepsis.
- Preoperatively, diabetes, the presence of ascites, bowel obstruction, and poor performance status are predictors of increased mortality rates.
- Despite the significant rates of morbidity and mortality, CRS/HIPEC remains the only hope many of these patients have for long-term survival. Therefore, any legitimate evaluation of the complications following CRS/HIPEC must be compared to the inherent complications of PSD and its natural history without such treatment.

OUTCOMES

- The CC has been shown to be an important independent predictor of survival. The average rate of complete cytoreduction among high-volume centers is about 60% to 75%.
- Predictors of incomplete cytoreduction include poor performance status, disease outside of the peritoneal cavity, more than three hepatic metastases, biliary or ureteral obstruction, multifocal bowel obstructions, the presence of malignant ascites, and extensive disease in the gastrohepatic ligament.

- A consensus statement on the locoregional treatment of colorectal PSD recommends CRS/HIPEC as the treatment of choice for patients without distant metastatic disease and in whom complete cytoreduction is deemed feasible.
- CRS/HIPEC in our institution has a median survival of 33.6 months in colorectal cancer patients who achieved a complete CRS and 21.2 months if CRS/HIPEC is performed with synchronous hepatic resection of limited liver disease. This has to be compared with the 10 to 14 months median survival obtained with second-line chemotherapy and the 3 months median survival obtained with third-line chemotherapy for stage IV colorectal cancer patients.
- It is important to mention that systemic chemotherapy and CRS/HIPEC are complementary treatment and not in lieu of each other.
- These patients should be treated in a multidisciplinary fashion. Multiple lines of chemotherapy result in decrease in ECOG functional status, which is a well-documented predictor of increased postoperative morbidity and mortality. Conversely, upfront CRS/HIPEC resulting in major morbidity will deprive the patient from timely administration of systemic chemotherapy.
- Despite these results, HIPEC for this cohort has not been universally accepted in the oncology community and controversy remains.
- Patient quality of life is another key outcome following CRS/HIPEC. Our quality-of-life data indicate that patients return to their baseline between 3 and 6 months postoperatively. The expected decrease in quality of life immediately following such therapy and its duration should be communicated to patients considering CRS/HIPEC.

MAIN POINTS OF CYTOREDUCTIVE SURGERY/HYPERTHERMIC INTRAPERITONEAL CHEMOTHERAPY FOR PATIENTS WITH PERITONEAL SURFACE DISEASE FROM COLON CANCER

- CRS/HIPEC involves surgical resection of all seeded organs and peritoneal surfaces followed by heated chemotherapy within the abdomen.
- When planning CRS/HIPEC for patients with PSD from colonic primary lesions, appropriate patient selection hinges on the feasibility of obtaining a complete cytoreduction and the patient's ability to undergo the procedure.
- The sensitivity of preoperative CT in determining distribution of disease is small.
- The goal of CRS/HIPEC is the removal of all visible disease prior to perfusion with HIPEC. Incomplete cytoreduction offers no survival benefit in patients with PSD from colonic primary lesions.
- Many factors influence the efficacy of HIPEC. There are also many ways to perform HIPEC, each with their own advantages and disadvantages.
- Close monitoring is required postoperatively, as complication rates are high. Clinicians should maintain a high index of suspicion for complications.
- CRS/HIPEC may offer a survival benefit in low-volume patients with colon cancer–induced PSD when a complete cytoreduction is obtained. This treatment modality should be offered in addition to systemic chemotherapy.

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Part 5

Operative Techniques in Breast, Endocrine, and Oncologic Surgery

Chapter 1

Fine Needle Aspiration of a Breast Mass

Judy C. Pang   Claire W. Michael

DEFINITION

- Fine needle aspiration (FNA) biopsy is a percutaneous procedure that uses a fine gauge needle with or without a syringe to sample fluid from a cyst or extract cells from a solid palpable mass for cytologic analysis.

PATIENT HISTORY AND PHYSICAL FINDINGS

- A focused history should be obtained from the patient including duration of the mass, changes in size, associated pain, or fluctuations of the mass with menstrual cycle. Prior history of trauma or malignancies should also be ascertained. On physical examination, localizing the mass as within the breast parenchyma, lower axilla, or subcutaneous/cutaneous tissue of the chest wall is important. The differential diagnoses may be different. In addition, noting any skin changes such as redness, warmth, or edema is also helpful. Determining the size and quality of the mass as well as depth and relation to other structures is essential for an adequate sample while minimizing complications. There are no absolute contraindications to FNA.

IMAGING AND OTHER DIAGNOSTIC STUDIES

- Mammographic and ultrasound findings can be helpful in arriving at an accurate diagnosis. Knowing whether a lesion is solid or cystic can help select the appropriate needle and syringe. For lesions that are nonpalpable or difficult to palpate, image-guided (i.e., ultrasound) FNA is recommended to ensure proper sampling of the mass.

DIFFERENTIAL DIAGNOSIS

- Benign (i.e., fibroadenoma, cyst)
- Malignant (i.e., carcinoma, lymphoma)
- Atypical (core biopsy or surgical excision required for definitive diagnosis)

NONOPERATIVE MANAGEMENT

- For patients who opt not to undergo a biopsy, short-term follow-up (4 to 6 months) with repeat imaging and clinical examination to document stability or changes is recommended.

SURGICAL MANAGEMENT

- Alternative procedures to FNA biopsy are core needle biopsy and surgical excision of mass.
- For solid masses, FNA biopsy provides cells for cytology, whereas core needle biopsy obtains tissue. In situations where an experienced cytopathologist is not available or tissue architecture is necessary to make a diagnosis (e.g., differentiating between in situ and invasive disease), core needle biopsy is preferred.
- Surgical excision should be reserved for cases where FNA or core needle biopsy was inconclusive. It may be considered for small breast masses where the patient is strongly desirous of excision.

Preoperative Planning

- Prior to the FNA, the location of the palpable mass should be confirmed with the patient. The mass should be examined in the upright and supine position to determine the ideal position for the biopsy.

Positioning

- The patient may be upright or supine depending on the location of the mass. The patient should be positioned to optimize palpation and sampling of the mass.

Approach

- FNA can be performed using (1) a needle, syringe, and syringe holder; (2) a needle and syringe; or (3) a needle only.

EQUIPMENT

- Alcohol pads to cleanse the skin and gauze pads to apply pressure after completion of the procedure
- Local anesthetic is optional.
- Beveled hypodermic needles
  - A 23-gauge needle is preferred and typically the one to start with. If inadequate material is obtained, a 22-gauge needle can be used especially for lesions with minimal stroma (i.e., lymphoma, melanoma) or a 25-gauge needle for rubbery or fibrous masses (i.e., fibroadenoma).
  - The length of the needle is typically 5/8 in to 1½ in, which is just long enough to reach the target. Shorter needles are easier to manipulate because they will not bend.
- A slip-tip syringe is best as it is easy to handle and provides a good seal. A Luer lock syringe may also be used, but it can be difficult to remove the needle. A 10-mL syringe is preferred as it allows the hand to be closer to the target and only 2 to 4 mL of suction is needed for aspiration. For larger cystic lesions, a 20-mL syringe may be advantageous.
- A syringe holder allows for one-handed grip and application of suction leaving the other hand free to stabilize the target.
- Glass slides and cover slips
- Slide holder for air-dried slides

- Ninety-five percent ethanol (EtOH) in a jar for fixation of slides or spray fixative. If the jar is not slotted for separating slides, using paper clips on alternating slides can achieve the same goal.
- There are different rapid stains that can be used for adequacy checks including toluidine blue, rapid hematoxylin and eosin, rapid Papanicolaou for fixed slides, and Giemsa and Diff-Quik for air-dried slides.
- Needle rinses can be performed in RPMI (cell block or flow cytometry for lymphoma), 10% buffered formalin (cell block), or CytoLyt (thin prep).

FINE NEEDLE ASPIRATION USING NEEDLE, SYRINGE, AND SYRINGE HOLDER[1,2]

- Carefully palpate the mass to estimate the size and depth as well as assess the structures nearby to avoid (i.e., major blood vessels, bone, and lung especially with small breasts).
- Fix the mass firmly in place with the fingers.
  - For large lesions, use the thumb and opposing finger (**FIG 1**).
  - For smaller lesions, place the forefinger and middle finger on top of the mass and then spread them apart, stretching the skin (**FIG 2**).
- Plan the angle of the needle at the entrance point of the skin and determine the depth of penetration.
  - If the needle enters at 90 degrees to the mass, the needle should penetrate the skin on top of the mass (**FIG 3A,B**).
  - If the needle enters at a 30- to 45-degree angle, which is oftentimes more comfortable and practical, compensate for the acute angle by penetrating the skin adjacent to the mass and not on top of the mass (**FIG 4A,B**).
  - When entering at 90 degrees, penetrating too deep with the needle can potentially result in a pneumothorax. If this is a concern (e.g., mass near the chest wall), a 30- to 45-degree angle is preferred.
  - To stabilize the instrument, rest the barrel of the syringe on the forefinger of the palpating hand or use the thumb to stabilize the syringe as you enter the mass. Once the needle is in the mass, the thumb can be removed (**FIG 4A**).
- Extracting material
  - For cystic lesions, applying suction without back and forth movement is sufficient.
  - For solid masses, 15 to 20 excursions are made before suction is released and the needle is removed from the mass. If blood is seen at the hub, the number

FIG 1 ● Fixation of a large mass using the thumb and opposing finger.

FIG 2 ● Fixation of smaller mass using forefinger and middle finger.

FIG 3 ● **A,B.** Needle entering 90 degrees to the mass should penetrate the skin on top of the mass.

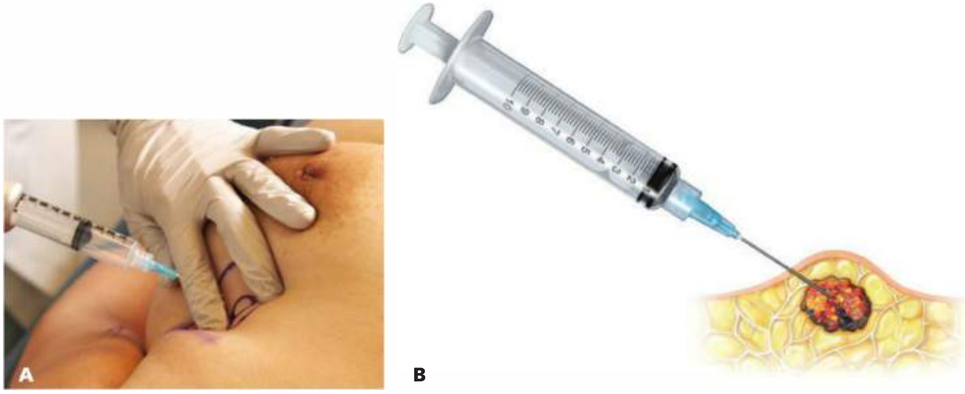

FIG 4 ● **A,B.** Needle entering 30 to 45 degrees to the mass should penetrate the skin adjacent to the mass and not on top of the mass.

of excursions should be limited and suction released before reaching 15 to 20. Always release the suction before pulling the needle out of the patient; otherwise, all the material will flow into the barrel of the syringe, which will be very difficult to extract (**FIG 5**).

- Adequate sampling
  - To sample different areas of a well-defined large lesion, it is preferable to make separate passes to sample different areas. This is also preferable in well-defined lesions. In ill-defined targets, especially fibrocystic changes of the breast, it is best to redirect while sampling in a fanlike fashion. To avoid tearing the tissue and causing bleeding, the needle should be retracted to the surface of the target (but still in the patient) before redirecting (**FIG 6**).
  - Typically, two to three passes are adequate. Additional passes are performed if the target is large or the sample is inadequate. However, typically more than three passes is not recommended as often times the yield of diagnostic material decreases with each subsequent pass due to blood. The first pass is traditionally the best.
- Zajdela's technique, which uses only the needle without a syringe or syringe holder (**FIG 7A**). This technique is ideal for small targets as it increases sensitivity to the difference in consistencies between normal breast tissue and the lesion that cannot be appreciated as well with a syringe and syringe holder. In addition, it is less bloody. However, this technique often yields less material than when suction is used, and there is a risk of overflow of material if the lesion is cystic. A syringe (without the plunger) can be used if needed (**FIG 7B**).

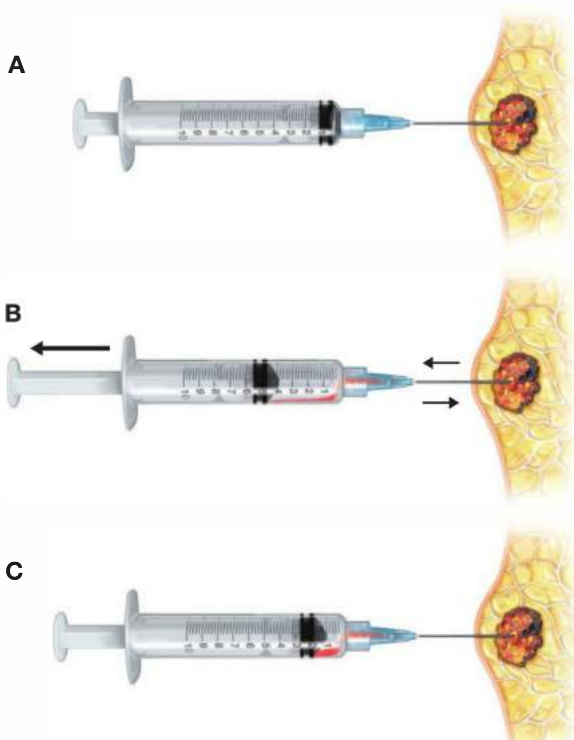

FIG 5 ● **A.** Needle placed in mass. **B.** Withdraw plunger creating 2 to 4 mL of vacuum/suction and perform 15 to 20 excursions. **C.** Release the plunger/suction before pulling needle out of the patient.

FIG 6 ● To sample different areas, redirect the needle in a fanlike fashion.

FIG 7 ● Zajdela's technique using only a needle **(A)** or a needle and a syringe without the plunger **(B)**.

PREPARING SLIDES[1,2]

- Expulsion of material
  - The needle is first disconnected from the syringe (**FIG 8**). The plunger is then pulled back all the way before reattaching the needle (**FIG 9A,B**). If using the Zajdela technique with the needle and syringe, disconnect the needle from the syringe before putting the plunger back into the syringe.
  - With the tip of the needle on the slide (bevel down), the plunger is forcefully pushed so that all the material is on one slide (**FIG 10A,B**). If there is abundant material, the plunger can be pushed slowly so that only a small amount of material is placed on each slide. The slides should be labeled with patient identifiers (i.e., name and birth date) with a pencil.
  - If there is remaining material in the hub, it can be rinsed for cytocentrifugation (in CytoLyt) or cell block (10% buffered formalin or RPMI) (**FIG 11**). If additional smears are desired, the flip technique can be used where the needle is secured in the rubber top of a Vacutainer tube. The hub is then flicked repeatedly onto a slide. Droplets of the material on the slides can then be smeared. (**FIG 12**).
- Smearing techniques
  - Rest the edge of a second slide on top of the slide that contains the aspirate material (**FIG 13**).

FIG 8 ● Disconnect needle from syringe.

FIG 9 ● **A,B.** The plunger is pulled back all the way **(A)** before reattaching the needle **(B)**.

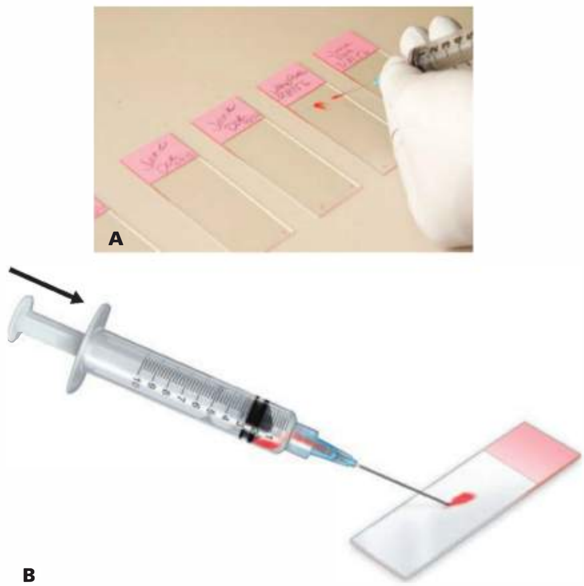

FIG 10 ● **A,B.** With the tip of the needle on the slide (bevel down), the plunger is forcefully pushed so that all the material is on one slide. If there is abundant material, the plunger can be pushed slowly so that only a small amount of material is placed on each slide.

FIG 11 ● The needle can be rinsed in RPMI, 10% buffered formalin, or CytoLyt.

FIG 12 ● Secure the needle in the rubber top of a Vacutainer tube. Flick the hub repeatedly onto a slide.

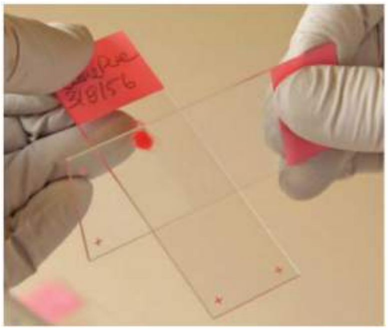

FIG 13 ● Rest a slide on top of the slide that contains the aspirate material.

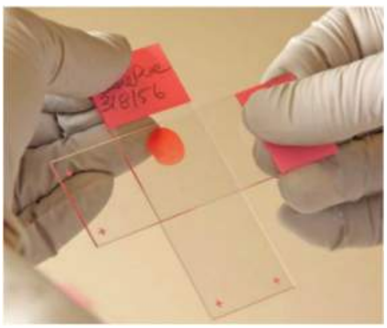

FIG 14 ● Rotate the top slide so that it is parallel to the bottom slide.

- Rotate the top slide so that it is level with the bottom slide (**FIG 14**).
- Keeping both slides level, apply light pressure and slide the top slide over the bottom slide (**FIG 15**).
- The end product should be a slide with material in an oval configuration of even thickness (**FIG 16**). Virtually, all the material should be on the bottom slides. Microscopically, the cells should be well preserved with intact cytoplasm. If too much pressure is applied, there will be crushed nuclei and few cells with preserved cytoplasm. If the slides are not maintained level to each other, the material will be scraped and lost and distortion will be present.

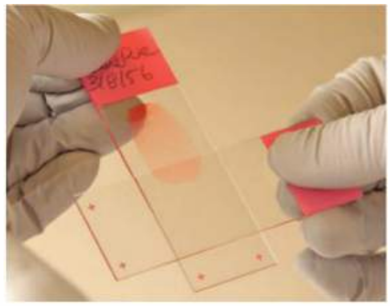

FIG 15 ● Apply light pressure and slide the top slide over the bottom slide.

FIG 16 ● End product with material in an oval configuration.

- Other techniques
  - Place a clean slide exactly parallel to the bottom slide containing the aspirate material and slide apart. The material will be present on both slides (also produces good smears) (**FIG 17A,B**).
  - For bloody aspirates, tilt the slide and allow the blood to drain into collecting media (**FIG 18A,B**). The particulates remaining on the slide is then scraped with the edge of another slide and then smeared onto a separate slide (**FIG 18C,D**). Alternatively, the particulates on the original slide can be smeared directly with a separate clean slide (**FIG 18E**).

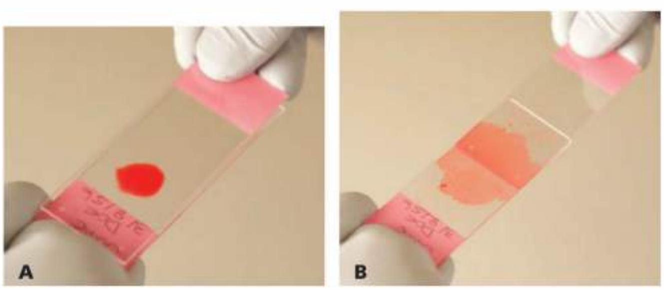

FIG 17 ● **A,B.** Place a clean slide exactly parallel to the bottom slide containing the aspirate material and slide apart.

FIG 18 ● **A.** Bloody aspirate. **B.** Tilt the slide and allow the blood to drain into collecting media. **C.** Scrape remaining particulates on the slide with the edge of another slide and then smear onto a separate slide **(D)** or smear the particulates on the original slide directly with a separate clean slide **(E)**.

FIX SLIDES

- The slides should be immersed in 95% EtOH or fixed by spray fixation (**FIG 19**). This should be done as quickly as possible after smearing the slides to prevent air-dry artifact. Alternatively, slides may be left to air dry without fixation. Ideally, both air dried and fixed slides should be made for cytologic evaluation.

FIG 19 ● Fix slides immediately in 95% liquid EtOH or spray fix.

PEARLS AND PITFALLS[3]

Indications	■ Palpable masses: A brief history and focused physical examination should be performed. ■ Diagnostic: primary neoplasms (benign vs. malignant), tumor recurrence, secondary or metastatic tumors, inflammatory diseases (uncommon), atypical epithelial lesions (require additional studies) ■ Therapeutic: evacuation of simple cysts
Major diagnostic pitfalls	■ False negative: small focus of carcinoma arising in a background of a predominantly benign lesion (i.e., fibrocystic change), carcinoma arising in a complex proliferative lesion (i.e., papilloma), well-differentiated carcinomas, rare tumor types, extensively necrotic or cystic carcinomas, sampling error, inadequate smears ■ False positive: fibroadenoma, papilloma/papillary lesions, atypical ductal hyperplasia, pregnancy-associated/lactational changes, fat necrosis, collagenous spherulosis, skin adnexal tumors
Major limitations	■ Inability to distinguish between invasive and in situ carcinoma ■ Accuracy is often dependent on the size of the lesion (less sensitive if $<$0.5 cm). ■ Low accuracy in tumors with a predominant necrotic/cystic component ■ Lack of specific diagnosis for majority of benign lesions ■ Need for biopsy (core or excisional) of all lesions with an "atypical" diagnosis ■ Ability to perform hormone receptor and *HER-2/neu* analysis can only be done with accuracy if an adequate sample is obtained.

POSTOPERATIVE CARE

- Pressure should be applied to the site for a few minutes to assure hemostasis, and then a sterile dressing is applied.

OUTCOMES

- 80% to 100% sensitivity, with a specificity of over 99%
- 3% to 5% false-negative and 0.5% to 2% false-positive rate
- Implementing the "triple test" is essential (correlation of clinical, radiologic, and cytologic findings)

COMPLICATIONS

- Low complication rate and most complications are minor
- Pain
- Bleeding/hematoma
- Infection
- Vasovagal reaction
- Pneumothorax
- Epithelial displacement/tumor seeding
- Artifacts occurring after aspiration may interfere with radiographic interpretation and histologic evaluation of surgical resection (epithelial displacement can mimic invasive carcinoma).

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Chapter 2 Wire Localized Breast Biopsy

Michael S. Sabel

DEFINITION

- The wire-localized excisional biopsy (or needle-localized biopsy) is used to obtain tissue for the diagnosis of a nonpalpable, image-detected abnormality. There are various methods for localizing breast lesions for excision, including wire localization, cutaneous markers, and radiocolloid occult lesion localization (ROLL). Wire localization is the most frequently used method and is described in this chapter.
- It is preferable to use image-guided biopsy as a first step (stereotactic biopsy or ultrasound or magnetic resonance imaging [MRI]-guided biopsy), as this avoids surgery in patients with benign disease and allows for a definitive oncologic operation in patients with malignant disease. Thus, the wire-localized excisional biopsy should be limited to patients who failed image-guided biopsy or are not suitable candidates. Wire-localized lumpectomy is a similar procedure for patients who have already been diagnosed with breast cancer, where the goal is a complete excision of the cancer with an adequate margin of surrounding normal tissue. For wire-localized lumpectomy, often, two wires are needed to "bracket" the cancer in order to assure complete removal.

PATIENT HISTORY AND PHYSICAL FINDINGS

- A bilateral breast exam should be performed in all patients for whom wire-localized breast biopsy is being contemplated for two reasons. First, to assess whether or not the lesion is truly nonpalpable. If the abnormality is palpable, then wire localization will not be necessary. If an abnormality is palpated, it is critical to review with the radiologist to be sure that the palpable abnormality corresponds to the imaging abnormality being recommended for biopsy. The second reason for bilateral breast examination is to make sure there are no other palpable occult abnormalities that may also require biopsy.
- For patients with biopsy-proven cancer who are to undergo wire-localized lumpectomy, a thorough history and physical examination is necessary to make sure they are suitable candidates for breast conservation therapy (BCT). Contraindications to BCT include prior radiation, collagen vascular disease, first or second trimester of pregnancy, multicentric cancer, or widespread calcifications (see Part 5, Chapter 5, Lumpectomy).

IMAGING AND OTHER DIAGNOSTIC STUDIES

- The preoperative imaging is essential to the procedure. Prior to the decision to perform a wire-localized breast biopsy, the breast imaging should be reviewed to determine whether the patient is a suitable candidate for an image-guided biopsy, as this is the preferable first step. The patient's allergies, medications (specifically aspirin or anticoagulants), or the presence of a bleeding diathesis should be reviewed. Contraindications to stereotactic core needle biopsy include an inability to adequately visualize the target lesion or an inability of the patient to remain in the position required for the procedure. Some patients may exceed the weight limit for the stereotactic table. Other factors that may preclude stereotactic core needle biopsy include higher breast density; lesions close to the skin, chest wall, or axilla; or the presence of breast implants.
- Prior to coming to the operating room (OR), the patient undergoes needle localization under image guidance. After local anesthesia, a rigid introducer needle with a hooked wire within it is directed toward the site of the abnormality using biplanar mammography (**FIG 1A**) or ultrasound (**FIG 1B**). The rigid needle is then removed, leaving the wire secured by the hook so it is not easily withdrawn or redirected (**FIG 2A,B**).
- In many cases, a wire-localized excision is recommended after an image-guided core needle biopsy–demonstrated atypia (lobular carcinoma in situ [LCIS], atypical ductal hyperplasia [ADH], atypical lobular hyperplasia [ALH], or flat epithelial atypia [FEA]). It is also often recommended after a needle biopsy of papilloma or radial scar. In these cases, a fraction may upstage to in situ or invasive cancer.[1–6] It is good to review the pathology and indications for the biopsy prior to the procedure.

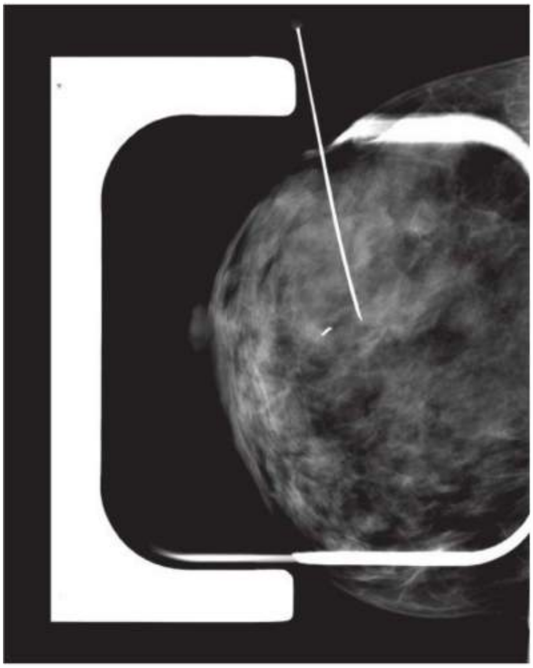
SURGICAL MANAGEMENT

Preoperative Planning

- Performing a breast exam after the localization will be difficult, as the wire will be secured by a variety of methods that will preclude physical exam. These should not be removed until the patient is positioned in the OR to minimize the chance of dislodging the wire during transport.
- Prior to taking the patient back to the OR, the localization films should be reviewed. Specifically, the surgeon should note the proximity of the abnormality to the wire, the direction of the wire from the point of skin entry, and how far the lesion is from the skin, as this may impact the degree of sedation (if any).
- Although the risk of infection after breast surgery is low, it tends to be higher than average for a clean surgical procedure, and several studies have shown that antibiotic prophylaxis significantly reduces the risk of postoperative infection.[7]

Positioning

- The patient should be positioned supine. Often, the localization wire is placed laterally, so the ipsilateral arm may need to be at 90 degrees.
- Once the patient is on the OR table and positioned, the tape and dressings securing the wire should be removed carefully as not to dislodge the wire. A gentle breast exam can be performed at this point to see if the lesion is palpable. In addition, light palpation while watching the external portion of the wire can give the surgeon an idea of what direction the wire is heading.



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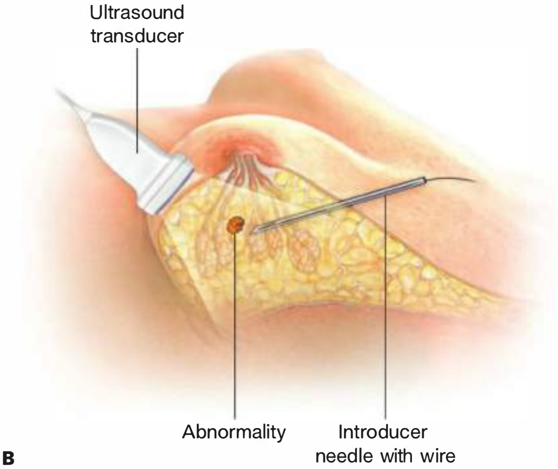

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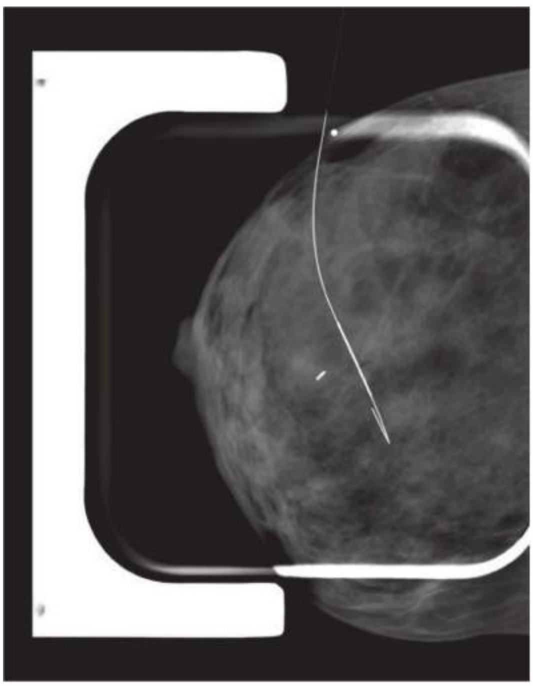
FIG 1 ● Placement of the rigid needle using biplanar mammography **(A)** or ultrasound **(B)**.



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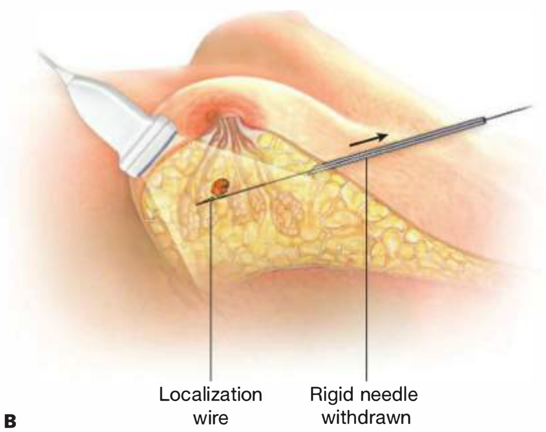


B

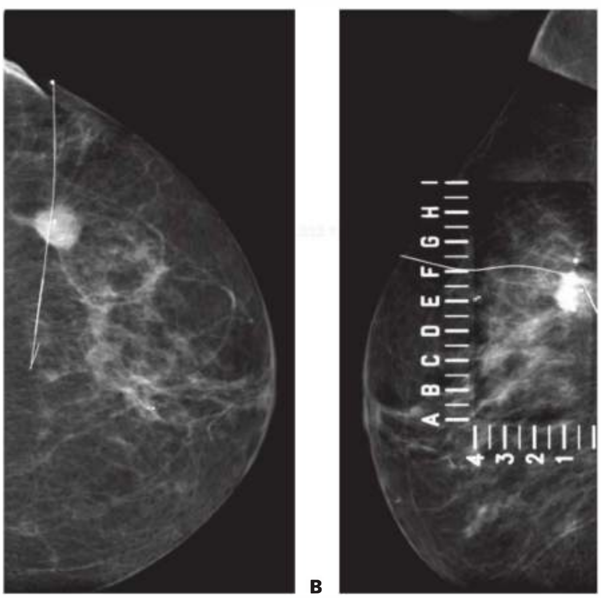
FIG 2 ● **A,B.** The rigid needle is withdrawn, leaving the wire in the location of the abnormality.

- The localization wire is often quite long and with a significant portion outside of the skin. The case will be facilitated by cutting the wire to a more workable length. Care must be taken not to advance the wire or pull the wire back (or out). It is also important not to cut the wire so close to the skin that it disappears. Secure the wire at the level of the skin prior to cutting with a wire cutter (**FIG 3**).

FIG 3 ● The wire is secured at the level of the skin while excess wire is cut. It is important not to dislodge the wire as well as to leave an adequate amount.

ANTICIPATING THE LOCATION OF THE ABNORMALITY

- After the dressings have been removed, the surgeon uses the site and direction of the wire along with the craniocaudal (CC) and lateral–medial (LM) views to determine the location of the abnormality in the breast. A small BB is usually placed at the site where the wire enters the skin, so it is possible to estimate how far through the breast tissue the wire extends. Remember, the breast is compressed during the mammography but not on the OR table, so the measurement on the film may not be exact. It is often helpful to identify the nipple on the mammogram as an additional landmark.
- The CC view (**FIG 4A**) demonstrates both the anterior–posterior and the lateral–medial location of the abnormality but gives no information regarding the superior–inferior location. With a laterally placed wire, the CC view can be used to estimate how deep the lesion is and how medial (especially when also using the nipple as an additional landmark).
- The LM view (**FIG 4B**) demonstrates the anterior–posterior orientation as well as the superior–inferior but gives no information regarding the lateral–medial location. Again, with a laterally placed wire, the deviation from the skin BB to the hook of the wire can be used to assess whether the wire is heading superiorly or inferiorly.
- Using both views, the surgeon should also note where the abnormality is in relation to the wire. Typically, the radiologist attempts to place the reinforced portion of the wire in close proximity to the lesion. It is crucial to know the relative proximity of the wire to the lesion and in what direction the wire sits relative to the lesion.



A B

FIG 4 ● The localization films show the relationship between the skin, the wire, and the abnormality. In the CC view **(A)**, the *dot* shows the entry point in the skin. The film shows the lesion to be posterior and lateral, but this film does not reveal the anterior–posterior position. The hook and reinforced portion of the wire are distal (medial) to the lesion. In the LM view **(B)**, you can again see the lesion is posterior, but now you can see that it sits superiorly. It may seem like the wire travels through the breast for some distance but most of that is external. The *white dot* shows where it enters the skin.

SKIN INCISION AND IDENTIFICATION OF THE WIRE

- Using both the preoperative imaging and examination of the breast, the surgeon can estimate the direction of the wire and the distance to the reinforced portion of the wire. Using a water-soluble marker, an incision should be marked out (**FIG 5**). For lesions close to where the wire enters the skin, the incision can be planned at the entry site. Otherwise, the incision should be placed directly over the predicted site of the mammographic abnormality.
- When marking the incision, it should be kept in mind that if this lesion is malignant, you may be returning for a reexcision lumpectomy or a mastectomy. Therefore, the incision should be placed in a way that does not compromise that. For lesions near the nipple–areolar complex, a circumareolar incision is cosmetically appealing, but excessive tunneling is discouraged as this will also complicate a reexcision lumpectomy if cancer is present.
- The incision should be kept small at first, as it can be lengthened later if need be (**FIG 6**). As these are typically performed with just local anesthesia or light sedation, the skin is anesthetized prior to any incision.

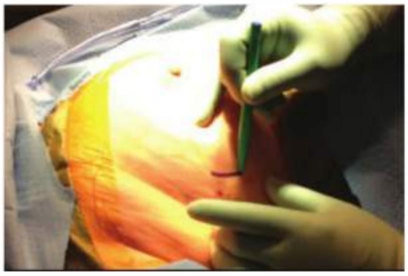


FIG 5 ● An incision is marked out over the anticipated site of the abnormality, keeping in mind a reexcision lumpectomy or mastectomy should the pathology return as malignant.

FIG 6 ● A small incision is made in the skin after infiltration of local anesthesia.

EXCISION

- The goal of the wire-localized excisional biopsy is to make the diagnosis while removing as little breast tissue as possible. If the CC and LM views suggest that the lesion is deep to the incision, the dissection is continued posteriorly so as to avoid removing excessive tissue anterior to the lesion and wire (**FIG 7A**). For more superficial lesions, flaps should be elevated shortly after incision but kept thick enough to avoid concavity at the site (**FIG 7B**).

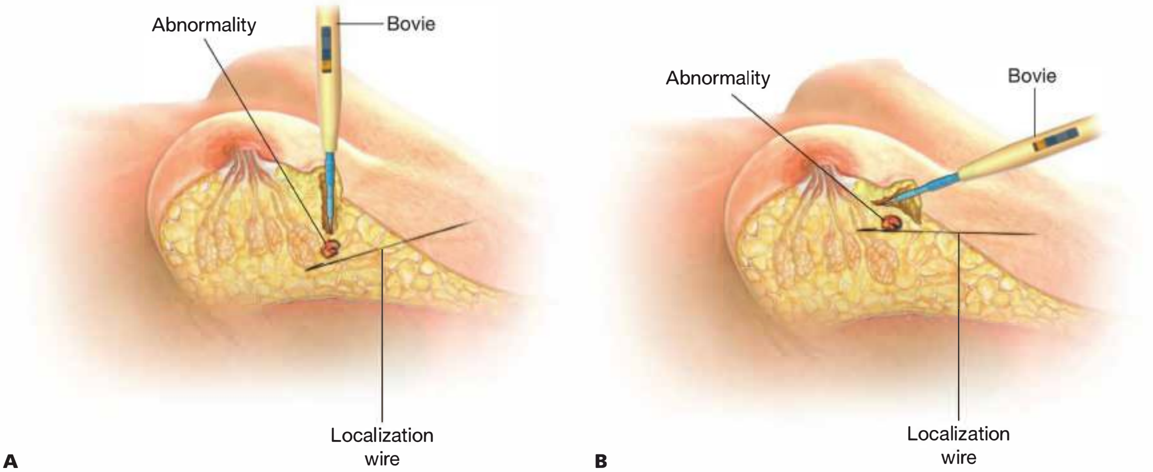


FIG 7 ● The subcutaneous fat and breast parenchyma are divided with cautery. For deep lesions **(A)**, dissect a fair distance to avoid taking excessive tissue anterior to the lesion (causing concavity). For superficial lesions **(B)**, thick flaps should be elevated shortly after incision.

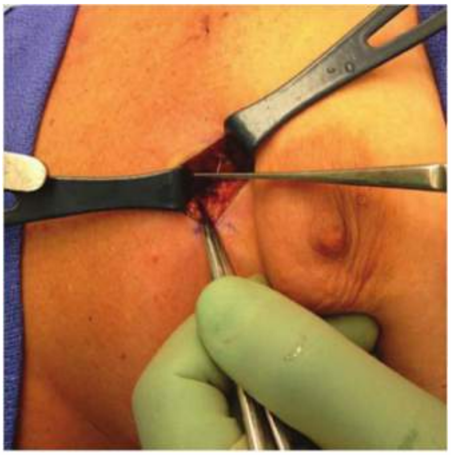
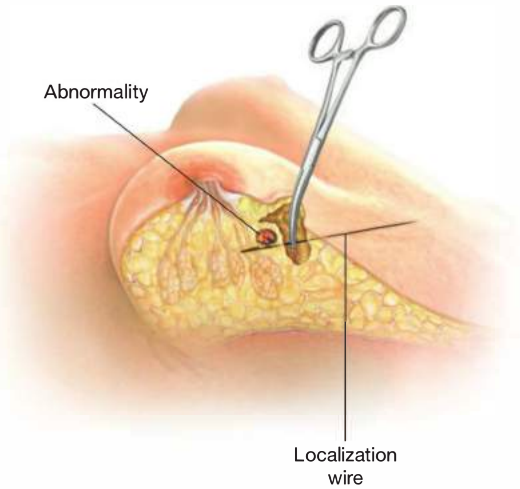


FIG 8 ● The wire is identified proximal to the anticipated site of the abnormality.

- If the incision does not pass through the entry site of the wire, the next step is to identify the shaft of the wire proximal to the lesion. Dissection is carried down to the wire, taking care not to land on top of the abnormality but rather on the wire proximal to the abnormality (FIG 8).
- Once the wire is identified, it is grasped with a hemostat on the specimen side, and the shaft of the wire is retracted into the wound. Take care to secure the wire adequately so it is not dislodged (FIG 9A,B).
- At the point where the wire enters the breast, grasp the tissue with an Allis clamp. Be careful to grasp above or below the wire and not the wire directly, as retraction on the clamp may dislodge the wire (FIG 10).
- Dissection then continues parallel to the wire, maintaining a circumference of approximately 1 cm of breast tissue around the wire. This is modified based on the size of the abnormality and the relationship between the wire and the lesion. For example, for a lesion sitting approximately 1 cm anterior to the wire, a larger margin is taken anteriorly, whereas a smaller margin can be taken deep to the wire.
- For mammographic masses, palpation along the wire will often allow the surgeon to identify the abnormality and proceed with excision, simplifying the procedure.
- Dissection continues until you are confident you are past the location of the abnormality and the specimen can be transected (FIG 11). Often, the wire will be encountered during this step, so take care not to divide the wire, potentially leaving the hooked end in the patient. If the wire is identified at this point, visualize where on the wire you are. If you are at the hook and the films show the hook is distal to the lesion, you should be fine. If you encountered the reinforced portion of the wire, grasp the remaining tissue in the direction of the wire and continue the dissection until you are past the hook.



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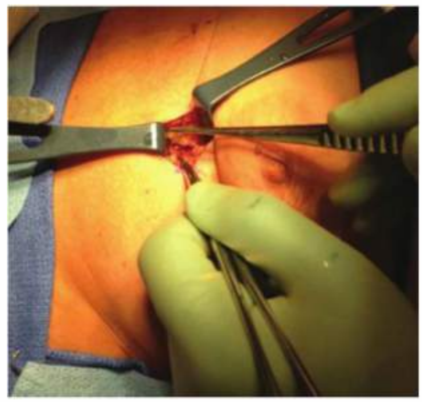

B

FIG 9 ● **A.** The wire is secured at the breast with a hemostat. **B.** Forceps are then used to pull the external portion of the wire through the skin and out of the wound.

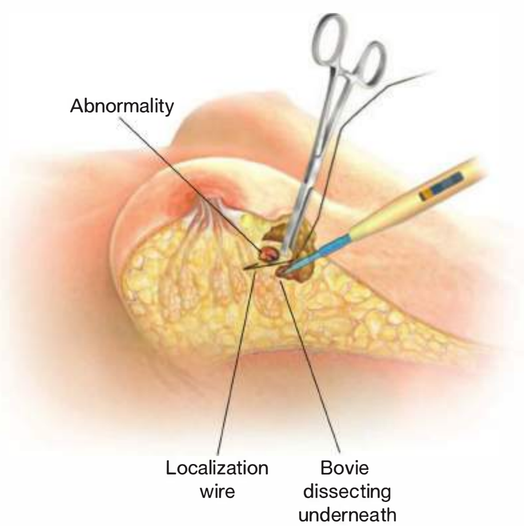

FIG 10 ● An Allis clamp is used to grasp the breast tissue (do not grab the wire) and dissection continues parallel to the wire in all directions.

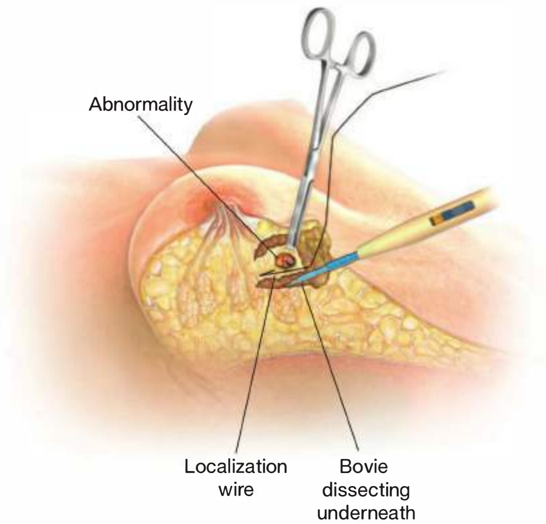

FIG 11 ● Once the circumferential dissection is past where you estimate the lesion to be, the specimen is transected, taking care not to divide the wire (and leave the hook).

ORIENTATION

- Immediately upon removing the lesion, maintain the orientation and place 2-0 silk sutures for the pathologist. If this returns as cancer, this allows for simple reexcision of any involved margin as opposed to a reexcision of the entire cavity. It is often preferable to place one or two orienting sutures before complete removal of the specimen.
- Three sutures are recommended to orient the mass correctly for the pathologist and avoid errors.[8] We recommend placing a short suture superiorly, a long suture laterally, and a double suture deep posteriorly (**FIG 12**).
- It is also often beneficial to place radiopaque clips on the specimen to allow for orientation of the lesion on the specimen mammograms. For example, if the wire enters laterally, placing a single clip superiorly and a double clip posteriorly allows you to orient the specimen on the films (**FIG 13A,B**). In the case of a wire-localized lumpectomy for cancer, this allows for reexcision of a potentially close margin. For a biopsy, if the abnormality is not within the specimen, this may help the surgeon identify in what direction additional tissue should be sampled.

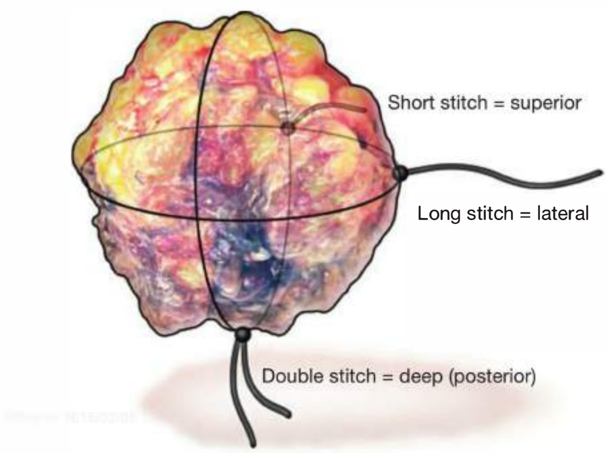

FIG 12 ● The lesion is oriented with three marking sutures prior to sending to radiology for specimen mammography.

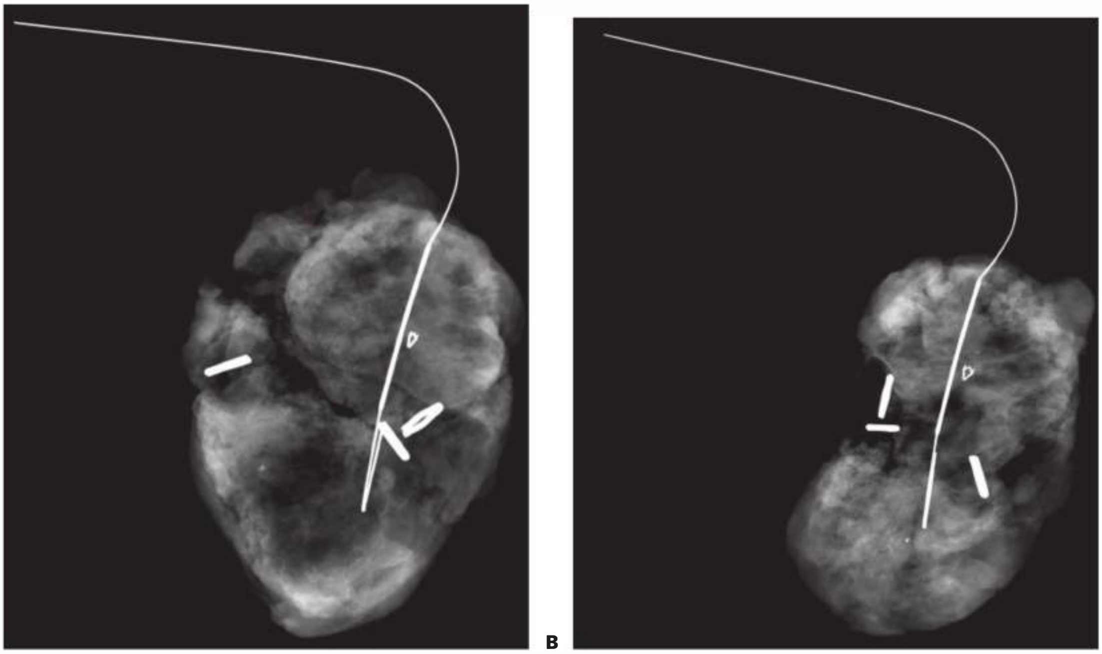

FIG 13 ● **A,B.** Specimen mammography shows the clip and wire to be completely removed.

SPECIMEN RADIOGRAPHY AND ADDITIONAL TISSUE

- Specimen radiography is performed to confirm that the area of concern has been removed (**FIG 13A,B**). The specimen mammogram should demonstrate the presence of the microcalcifications of concern or the presence of a clip placed within the specimen. It should also show that the entire wire has been removed. If the wire becomes separated from the specimen, send both to radiology to document its removal.
- If the lesion is identified on specimen radiography, the wound can be closed. If the lesion is not present, then additional tissue should be excised and sent to radiology. It may be clinically evident what area needs further excision based on exposure of the wire during the dissection. The use of radiopaque clips on the specimen, as well as other landmarks on the original mammograms, may also help identify where to excise additional tissue.
- If a second specimen fails to identify the lesion, it becomes a judgment call whether to continue or abandon the procedure. For ultrasound-visible lesions, intraoperative ultrasound may be able to identify the abnormality. In the case of a clip that should have been in the specimen, sometimes these can get dislodged and suctioned out. Filtering and x-raying the fluid in the suction canister can sometimes reveal a dislodged clip. Otherwise, it may be prudent not to continue and plan on reimaging and, if necessary, returning to the OR rather than taking an excessive amount of breast tissue.

CLOSURE

- Once the biopsy is complete, hemostasis is assured and the wound is irrigated with saline.
- For an excisional biopsy, the surgeon should *not* try to reapproximate the breast tissue. The cavity will fill with seroma and fibrin, and ultimately, fibrous tissue, which will maintain the normal contour.
- The incision is closed with absorbable deep dermal sutures, followed by either a subcuticular stitch or tissue adhesive. Drains should not be used.

PEARLS AND PITFALLS

Indications	■ Image-guided biopsy is the preferred approach to the nonpalpable abnormality. Review the case with the radiologist to confirm whether this is an option.
Placement of incision	■ Keep in mind that if malignant, the patient may need a reexcision lumpectomy or mastectomy. Orient your incision with this in mind.
Identifying the wire	■ Take care not to move or dislodge the wire during the positioning, prepping, and draping of the patient. ■ Identify the wire early and secure it while bringing it into the wound so that it does not become dislodged during the procedure.
Excision	■ Grasp the tissue, not the wire, while excising the lesion so as not to accidently pull the wire out. ■ During dissection, palpate the area to identify the mass or if you are too close to the wire.
Specimen mammography	■ Three orientation sutures are necessary to avoid error. ■ Clips can help orient the specimen on the mammography so as to guide a reexcision.
Closure	■ Do not try to reapproximate the breast tissue or place a drain.

POSTOPERATIVE CARE

- After a breast biopsy, the patient should be placed in a breast binder or supportive brassiere. This helps sustain hemostasis and relieves tension on the skin closure imposed by the weight of the breasts. The patient should be encouraged to wear the support bra day and night for 1 week after surgery.

OUTCOMES

- In experienced hands, the failure rate of wire-localized biopsy is low, although published reports suggest the wire localization failure rate can range from 0% to 20%. Factors associated with failure include lesion type and size, distance from the wire, breast shape and size, and volume of excised tissue.[9–11]

COMPLICATIONS

- Seroma
- Hematoma
- Infection (cellulitis or abscess)
- Pneumothoraces (rare)
- Retained wire fragments
- Failure to identify abnormality

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Chapter 3

Subareolar Duct Excision

Amy C. Degnim

DEFINITION

- Subareolar duct excision is defined as the surgical removal of lactiferous ducts in the immediate subareolar space. The terms "major duct excision" or "central duct excision" refer to excision of the entire bundle of ducts contained within the central nipple stalk; microdochectomy refers to selective excision of a single abnormal duct.

ANATOMY

- The lactiferous ducts drain converging ducts from lobes of the breast gland and serve as a conduit for milk egress via the nipple during lactation (**FIG 1**). Most women have approximately 7 to 20 ducts that are distinct and functional sources of milk during lactation. At the base of the nipple, the lactiferous ducts widen centrally in a spindle shape over a short distance. This region is called the lactiferous sinus and can expand in lactation to 8 mm as a reservoir for milk. Surrounding the lactiferous ducts is a system of smooth muscle fibers that contract in response to nipple stimulation and oxytocin release, facilitating milk flow through the nipple.[1]

PATIENT HISTORY AND PHYSICAL FINDINGS

- Subareolar duct excision is undertaken in cases of abnormal nipple discharge for two purposes:
  - To obtain diagnostic biopsy tissue and rule out malignancy
  - To provide resolution of the bothersome discharge
- Abnormal, or "pathologic," nipple discharge is characterized by the following features:
  - Discharge from a single duct
  - Spontaneous discharge
  - Clear or bloody discharge

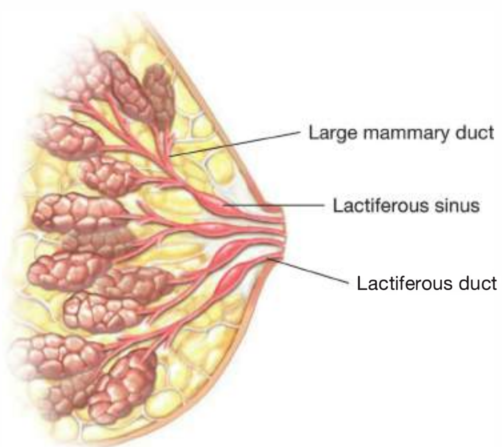

FIG 1 ● Normal anatomy of subareolar lactiferous ducts and sinuses.

- The history should be focused on questions to determine the laterality and quality of the discharge as well as whether it is spontaneous or only occurs with manual expression.
- Physical exam should include a thorough examination of both breasts and axillae.
- In addition, a detailed examination is necessary for both nipple–areolar complexes and the subareolar tissues.
- Inspect the nipples for crusting, bloodstained ducts, or any visible protuberances or nodules.
- The deep tissue of the areolae should be palpated carefully for any small nodules and to determine if subareolar pressure results in nipple discharge.
- The nipple itself should be palpated by rolling the nipple between the thumb and forefinger in order to best detect any small nodules located centrally within the nipple stalk. This should be performed first for the breast without discharge to set a normal comparison to the breast that is symptomatic.
- If no discharge has been identified up to this step of the examination, then attempt should be made to elicit discharge from both nipples, by applying pressure to the areola at the base of the nipple, then grasping the base of the nipple between the thumb and forefinger and drawing upward with gentle pressure.
- Throughout the examination, for any nipple discharge observed, its location (o'clock position) and quality of the fluid should be noted.

IMAGING AND OTHER DIAGNOSTIC STUDIES

- All women with abnormal nipple discharge should undergo diagnostic mammogram and ultrasound. Prior to the imaging studies, the imaging team should be informed about the symptom of nipple discharge and which breast is affected.
- Because nipple discharge can be associated with underlying malignancy, the primary purpose of diagnostic imaging is to look for possible signs of malignancy. Another goal of imaging is to evaluate the subareolar tissues for any findings that would explain the presence of nipple discharge.
- Generally, subareolar ducts are not visible with ultrasound unless they are abnormally dilated. A small nodule visualized within a dilated subareolar duct indicates a likely diagnosis of intraductal papilloma (**FIG 2**).

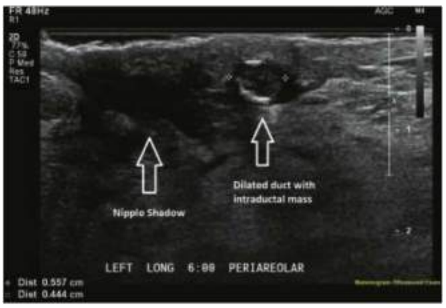

FIG 2 ● Ultrasound of a subareolar nodule.

- Evaluation with magnetic resonance imaging (MRI) is controversial. It detects more lesions than standard imaging for women with nipple discharge but is imperfect in ruling out malignancy associated with nipple discharge.[2]
- Ductography can be considered as a diagnostic test. This is a radiographic procedure that entails cannulation of the duct with abnormal discharge, then injection of contrast dye with immediate mammographic imaging. This procedure can identify and map out abnormal ducts and identify some intraductal filling defects, but it does not provide diagnostic tissue. For these reasons, it is not a required component of the evaluation and is intentionally avoided in some practices. Although it may help to localize the etiology of the discharge, it cannot reliably exclude malignancy or eliminate need for duct excision.[3]
- Another approach to diagnostic evaluation is via ductoscopy, a microendoscopic procedure to directly visualize the duct(s) with discharge. This requires special equipment and skill, with a learning curve for technical success. Ductoscopy can help to identify lesions and guide excision but has not been proven in large numbers of women to improve diagnosis to the point that duct excision can be avoided.[4,5]

DIFFERENTIAL DIAGNOSIS

- Intraductal papilloma
- Duct ectasia
- Carcinoma, either invasive or ductal carcinoma in situ
- Paget's disease

NONOPERATIVE MANAGEMENT

- Nonoperative management can be considered for cases of nipple discharge when
  - The discharge occurred on only one occasion and was not reproducible on examination
  - Both mammogram and ultrasound show no abnormalities.[6,7]
  - In this case, 3-month follow-up history and physical examination is recommended.
- Alternately, if imaging identifies a benign-appearing lesion and percutaneous core biopsy confirms a benign intraductal papilloma with complete or near complete removal by imaging, then observation is also appropriate with follow-up imaging in 3 months.

SURGICAL MANAGEMENT

- Subareolar duct excision removes the lactiferous ducts under the nipple, the primary connection between the nipple and the milk-producing lobules of the breast, so patients must be counseled that lactation from the operated breast should not be possible after surgery.
- Selective and focused excision of the single abnormal duct may be performed in an attempt to preserve other ducts for future lactation, but due to the very close proximity of the remaining ducts, scar tissue from the operation may still impair future lactation.
- In women who are past childbearing age, a plan to remove the entire bundle of subareolar ducts is preferred because future lactation is not needed, and this approach reduces the chance of recurrent discharge from another duct and need for repeat operation in a field of scar tissue.
- The patient should be informed of the possibility of a diagnosis of malignancy yet reassured that benign findings are most likely.

Preoperative Planning

- For subareolar mass lesions that are nonpalpable and identified only by imaging, preoperative localization with either a wire or a radioactive seed should be performed to ensure intraoperative guidance to the target.
- Before surgery, patients should be counseled that they may experience continued discharge in the first few weeks postoperatively, as postoperative fluid in the subareolar space may discharge via the nipple duct until healing is complete. This should resolve completely by 4 to 6 weeks.

Positioning

- The patient should be positioned supine.
- The ipsilateral arm is generally positioned at approximately 90 degrees, although the arm could also be tucked based on the patient's body habitus and preferences of the anesthesia team.

Approach

- The general approach is to dissect under the areola toward the nipple, isolate and excise the central duct bundle, and follow any abnormal ducts to complete removal, along with simultaneous excision of any nonpalpable lesions identified on preoperative imaging.

INCISION PLANNING

- In general, incisions are placed at the areolar edge.
- An incision at the inferior areolar edge is preferred if possible for better cosmesis, especially if the involved duct is located centrally on the nipple surface and the imaging does not demonstrate any abnormalities (FIG 3).
- Otherwise, incisions can be placed along the areolar border in the o'clock position of the abnormality, for either a peripherally located duct with discharge or if there is an imaging abnormality a few centimeters from the nipple.

FIG 3 • Incision at inferior areolar border.

- The length of the incision should be large enough that the surgeon has adequate visualization of the subareolar space without requiring excess retraction and ischemia of the areolar edge. Depending on the areolar size, the incision may go up to 50% of the circumference of the areola, but a shorter incision is preferred when possible to help preserve blood supply to the nipple and areolar dermis.
- Prior to incision, correct surgical site and plan should be confirmed with the operative team.

DUCT CANNULATION

- Once the field is prepped and draped, attempt should be made to cannulate the involved duct.
- A fine lacrimal duct probe (4-0) should be held ready in the dominant hand for cannulation prior to expressing the nipple discharge.
- The nipple should be grasped between the thumb and forefinger of the nondominant hand at the nipple base and drawn upward gradually (**FIG 4**). If no discharge is seen, increasing pressure can be applied to a reasonable degree. The goal is to elicit a single tiny drop of fluid at the skin surface; a smaller drop of fluid will be more helpful in identifying the location of the abnormal duct (**FIG 5**).
- The nipple should be pulled away from the breast gently in order to elongate the subareolar lactiferous sinus and improve the chance of cannulation (**FIG 6**).
- The lacrimal duct probe should be gently probed along the nipple skin surface at the site of the expressed fluid. The goal is to find the opening rather than make a false passage; the probe will slide easily into the duct once it is in the right location (**FIG 7**).

FIG 6 ● Cannulation technique.

FIG 4 ● Manual expression of nipple discharge.

FIG 7 ● Cannulated duct with probe advanced.

FIG 5 ● Visible tiny drop of fluid at nipple surface.

- The probe should be gently advanced as far as it will easily go. If it does not pass greater than 1 cm beyond the nipple skin surface, then the depth of the cannulation should be noted as a sign that there may be a very superficial obstructing mass lesion.
- If no discharge is identified or if the duct cannot be cannulated despite several attempts, the procedure should proceed to incision.

INCISION

- Prior to incision, local anesthetic can be used but should not be injected directly into the area of the subareolar ducts. If used, it should be injected intradermally directly at the planned incision site (no more than 1 mL) and additionally in a peripheral fashion into the four quadrants of the breast to create a local field block.
- The skin should be incised sharply with a scalpel, taking care to maintain a blade angle that is perpendicular to the skin.
- The incision should be deepened a few millimeters into the subcutaneous fatty tissue (**FIG 8**).

FIG 8 ● Incision into subcutaneous tissue.

ELEVATION OF THE AREOLAR SKIN FLAP

- The areolar skin edge is then retracted superiorly (skin hooks or sutures could be used), and dissection proceeds in the direction of the nipple toward the central duct bundle (**FIG 9**).
- Care should be taken to perform the dissection at a depth to preserve some subcutaneous fatty tissue under the areolar skin, as this will help to protect the viability of the areolar skin and nipple. Similarly, the lateral edges of the dissection field should narrow as the central duct bundle is approached (**FIG 10**).
- Attention should be paid to the location of dissection and its proximity to the nipple, looking closely for the ducts, which appear as narrow vertical tubular or strand-like structures. The ducts may be visibly discolored (**FIG 11**).

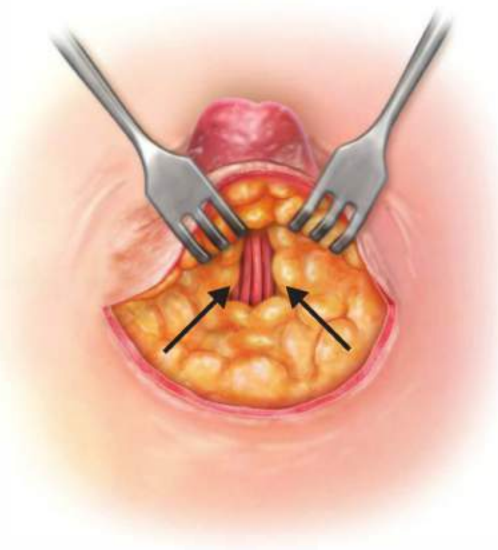

FIG 10 ● Narrowing the dissection field toward the nipple.

FIG 9 ● Retraction of the skin flap.

FIG 11 ● A visibly abnormal duct with discolored intraluminal fluid.

ISOLATION AND EXCISION OF THE CENTRAL DUCT BUNDLE

- Dissection then proceeds in vertical fashion on the lateral sides of the duct bundle under the nipple. This should proceed to the far side of the nipple (**FIG 12**).
- The duct bundle should be palpated between the thumb and finger to confirm the presence of the duct probe and any other small palpable nodules.
- The central duct bundle should then be transected at the deep aspect of the nipple dermis. If using electrocautery, the "cutting" mode should be chosen at a low energy setting to minimize thermal damage to the nipple dermis.
- As the duct bundle is transected, the cannulating probe will be identified. It may be withdrawn if it becomes difficult to maintain its position in the duct (**FIG 13**).
- The duct bundle should be retracted away from the breast, dissecting circumferentially around the duct bundle to a depth of approximately 4 to 5 cm or farther along a particular grossly abnormal duct (**FIG 14**).
- The tissue specimen should be transected at its base and oriented for the pathologist (**FIG 15**).
- The open wound should be palpated for any abnormalities, and the nipple dermis should be palpated between the thumb and finger to ensure that there are no any superficial nodules present that were not excised. In the event of a small nodule within the nipple dermis, a tiny skin incision in the nipple can be made to remove the lesion.

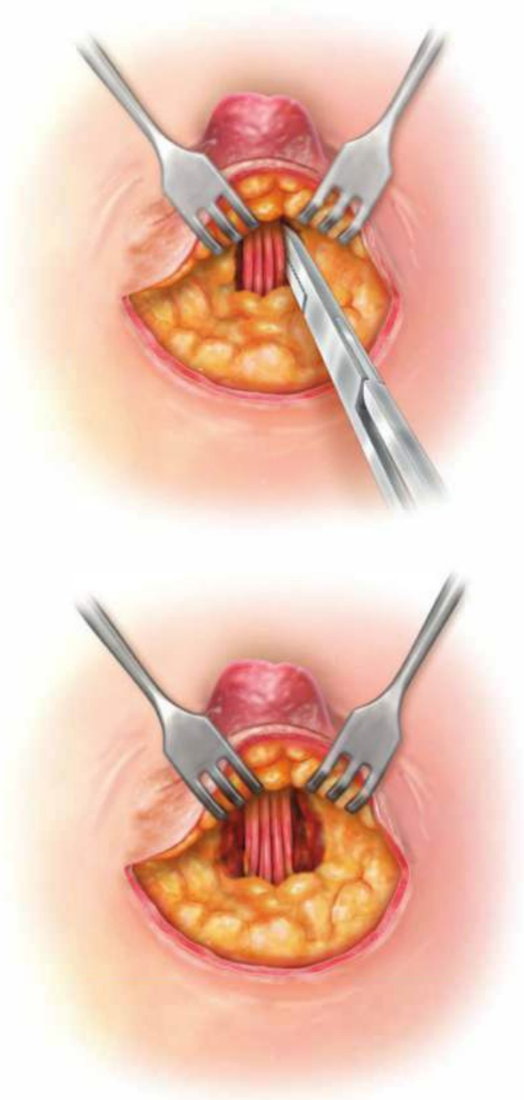

FIG 12 ● Vertical dissection along both sides of the duct bundle.

FIG 13 ● Transection of the ducts just deep to the nipple dermis.

FIG 14 ● Dissection of ducts deeper into the breast parenchyma.

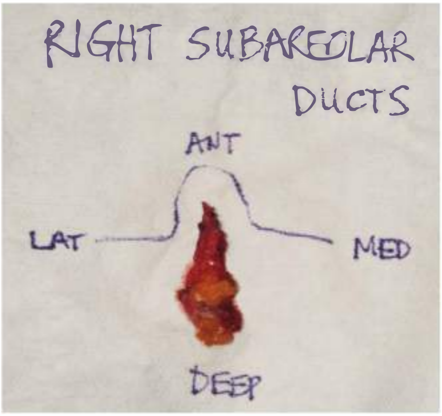

FIG 15 ● Orientation of the specimen.

CLOSURE

- After hemostasis, the parenchymal and subcutaneous tissue defect in the subareolar region must be closed in order to avoid nipple retraction in the healing phase. If there is a solid buttress of tissue underlying the nipple–areolar complex, the nipple will be less likely to retract.
- The parenchymal closure may be performed as a simple direct approximation of tissues, in whatever orientation results in least tension and absence of skin dimpling (FIG 16). If the defect is larger, it may require a small local tissue advancement flap or undermining of the breast gland from the skin. In that case, it is preferable to avoid further dissection under the areolar skin and obtain donor tissue from the other side of the cavity.
- If the nipple is effaced, it may be helpful to place a purse-string stitch in the deep dermis around the nipple base to recreate the normal nipple shape and prevent nipple retraction in the healing phase (FIG 17).
- The skin should be closed in two layers, with buried interrupted sutures in the deep dermis and subcutaneous tissue, followed by a running intradermal stitch in the skin edge. Care should be taken to place the deep dermal sutures so that the areolar skin edge is at or slightly above the breast skin edge (but not lower) (FIG 18), or the nipple–areolar complex will have a sunken-in appearance. If the areola is small, resulting in an incision with greater curvature, the final layer of skin closure should use multiple shorter bites (FIG 19).


A


B

FIG 16 ● Closure of the deep tissue. **A.** Medial-to-lateral closure, **(B)** superior-to-inferior closure.

FIG 17 ● Purse-string suture in the deep dermis of the nipple.

FIG 18 ● Appearance after closure of the deep dermal layer of incision, with the areolar edge at or above the breast skin.

FIG 19 ● Intradermal suture for final layer of closure.

- Adhesive dressings on the dermis of the nipple itself should be avoided. If an incision was required in the nipple dermis for an intradermal nodule, the nipple incision should be closed with fine interrupted nonabsorbable sutures.
- Dressings that create excess pressure on the nipple should also be avoided. If a pressure dressing is desired, it should have a "donut" opening for the nipple.

PEARLS AND PITFALLS

Preoperative counseling	■ Preoperative counseling should address ■ Focused duct excision versus excision of the entire duct bundle ■ Inability to lactate after surgery from the operated breast ■ Likely pathologic findings ■ Possible nipple discharge in the postoperative healing period
Incision planning	■ Inferior areolar edge is preferred.
Subareolar dissection	■ Be careful to preserve subcutaneous fat under the areolar skin and to limit dissection to as narrow a field as possible to reduce risk of skin necrosis.
Closure	■ Proper closure of the deep and superficial tissues under the nipple–areolar complex is critical to avoid nipple retraction with healing, and consider a purse-string stitch to reestablish normal nipple projection.

POSTOPERATIVE CARE

- The incision should be kept clean and dry.
- Clothing that creates excess pressure on the nipple should be avoided, and patients may choose to use a donut-type foam dressing to relieve any pressure on the nipple.
- Showering is permitted.
- If any nonabsorbable sutures were placed in the nipple skin, they are removed at 1 week.

OUTCOMES

- Subareolar duct excision for abnormal nipple discharge is highly successful, with resolution of discharge in the vast majority. Recurrent discharge is reported in the range of less than 5%.[8]
- Pathology findings are most often benign (papilloma or duct ectasia), but malignancy is found in the range of 0% to 20%.[8,9]
- The likelihood of successful lactation after duct excision is not well characterized.

COMPLICATIONS

- Bleeding and infection are possible complications after every surgical procedure but are rare with this procedure. Avoidance of antiplatelet therapies and anticoagulants per surgical routine will help to minimize risk of bleeding, and a single preoperative dose of intravenous antibiotics is recommended prophylactically.
- Skin necrosis is also rare but devastating if it occurs; for this reason, careful attention should be paid to preserving blood supply to the areolar tissue and limiting the extent of dissection under the areolar skin, with focused excision of the central ductal tissue.

ACKNOWLEDGMENTS

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Chapter 4

Cryoablation of Breast Fibroadenomas

Cary S. Kaufman

CRYOABLATION TREATMENT FOR BREAST FIBROADENOMAS—OVERVIEW

- Cryoablation is a minimally invasive, innovative treatment for breast fibroadenomas. The treatment is performed in an office setting rather than an operating room, resulting in a cost-effective and patient-friendly procedure with little to no scarring. Published reports demonstrate that cryoablation as primary treatment for breast fibroadenomas is safe and effective and at long-term follow-up, demonstrates progressive resolution of the treated area, with excellent patient and physician satisfaction (Table 1).
- About 80% of the approximately 1.3 million biopsies performed annually in the United States reveal benign conditions, primarily benign tumors or fibrocystic change. The most common benign breast tumor is a fibroadenoma.[1–3]
- Although not life threatening, benign breast tumors can cause fear, anxiety, and discomfort in the patient, and definitive treatment is often desired.[3–5]
- Fibroadenomas consist of a proliferation of epithelial and connective tissue elements within the lobular region of the breast. They are usually sharply demarcated from the adjacent breast tissue and give the clinical and imaged appearance of being encapsulated.[5]
- They often grow to a size of 2 to 3 cm and are multiple in 20% of women.[4,6–9]
- Approximately 10% of women will experience a fibroadenoma in their lifetime. Although most common in young women, fibroadenoma occurs in every age-group from adolescents to octogenarians.[1,2,7,10,11]

DIFFERENTIAL DIAGNOSIS

- These benign breast tumors have a classic physical examination: rubbery texture, smooth and well defined, circular to oval, and freely moveable within the breast.
- Other breast lesions that may have similar clinical presentations include phyllodes tumors, juvenile fibroadenomas, breast cancer (particularly medullary carcinomas), or breast cysts. Diagnosis is resolved by imaging and core needle biopsy.
- Cryoablation has only been proven effective for biopsy-proven fibroadenomas (Table 2).[12–16]

Table 1: Potential Advantages for Cryoablation in the Treatment of Fibroadenoma

Reasons to consider ablation techniques:
Small puncture incision
A procedure not surgery
Less scarring
Minimal discomfort
Less invasive
Less expensive

PATIENT HISTORY AND PHYSICAL FINDINGS

- Patients with small- to medium-sized single tumors that are not too close to the skin or nipple are appropriate candidates for cryoablation. Indications and contraindications are listed in Table 3.
- The target lesion must be clearly visible with ultrasound and not be within 1 cm of the skin or immediately deep to the nipple.
- A histologic diagnosis using a core biopsy should demonstrate a classic fibroadenoma without atypia. Other histologic lesions are not appropriate for cryoablation.
- Tumors should be measured in three dimensions and the longest dimension used to calculate freezing time (**FIG 1**).
- It is important to discuss with the patient the process of cryoablation and the progressive resorption of the residual necrotic debris over time (**FIG 2**).
- The candidate should not currently have breast cancer in the ipsilateral breast and be otherwise healthy. She should not be pregnant, breastfeeding, or have breast implants.

IMAGING AND OTHER DIAGNOSTIC STUDIES

- If the patient is in the mammography screening age-group, a pretreatment screening mammogram should be obtained and be normal except for the fibroadenoma (**FIG 3**).
- There are classic imaging findings of fibroadenoma on both ultrasound and mammography, but histology is needed for an accurate diagnosis[1,3,9,17] (**FIGS 3** and **4A,B**, ultrasound and mammogram of a fibroadenoma).
- The differential diagnosis includes the larger and faster growing juvenile fibroadenomas and phyllodes tumors.[1,7,9]
- Large-core needle biopsy is the diagnostic method of choice because of the need to differentiate between benign and malignant tumors in general and fibroadenoma from phyllodes tumor in particular.[1,9]

MANAGEMENT OPTIONS

- There are three treatment options for a confirmed fibroadenoma: (1) serial observation ("watchful waiting"), (2) surgical removal, and (3) cryoablation. Surgery for fibroadenoma provides definitive treatment while confirming the diagnosis and eliminating patient anxiety and future monitoring. Drawbacks to surgical excision include patient discomfort, anesthetic and surgical recovery, skin incision and potential scarring as well as operating room costs.[18]
- On the other hand, many women choose serial observation with the advantages of no surgical pain, avoidance of the operating room and anesthesia, less cost, and only a minimal scar from the large-core needle biopsy. Drawbacks to conservative management include ongoing patient anxiety regarding the presence and potential growth of a lump, the inconvenience of serial office visits, and the confusion of physical examination and mammography evaluations caused by the mass effect.[7,19]

Table 2: Published Reports of Cryoablation for Fibroadenomas

Author	Fibroadenomas (n)	Mean Size (cm)	Freeze Time (min)	Skin Injury	Any Growth @ 1 y	Still Palpable @ 1 y	Volume Decr (%) @ 1 y	Cosmesis by Patient @ 1 y	Satisfied Patient @ 1 y
Edwards[a]	310	1.8	N/A	0%	None	33%	97%	92%	100%
Nurko[b]	444	1.8	22	0%	None	35%	71%	82%	88%
Hahn[c]	23	<3.0	10	4%	None	22%	76%	96%	96%
Kaufman[d]	70	2.1	15	6%	None	25%	89%	100%	97%
Total/average	847	1.9	16	3%	None	29%	83%	93%	95%

[a]*From Edwards MJ, Broadwater R, Tafra L, et al. Progressive adoption of cryoablative therapy for breast fibroadenoma in community practice.* Am J Surg. *2004;188:221–224.*
[b]*From Nurko J, Mabry CD, Whitworth P, et al. Interim results from the FibroAdenoma Cryoablation Treatment Registry.* Am J Surg. *2005;190(4):647–651.*
[c]*From Hahn M, Pavlista D, Danes J, et al. Ultrasound guided cryoablation of fibroadenomas.* Ultraschall Med. *2013;34(1):64–68.*
[d]*From Kaufman CS, Littrup PJ, Freman-Gibb LA, et al. Office-based cryoablation of breast fibroadenomas: 12-month followup.* J Am Coll Surg. *2004;198:914–923.*

Table 3: Indications and Contraindications for Cryoablation for Fibroadenomas

Inclusion criteria for fibroadenoma cryoablation:
1. Lesion must be sonographically visible.
2. Diagnosis of fibroadenoma must have histologic confirmation.
3. Lesion size must be <3 cm in largest diameter.

Contraindications for cryoablation:
1. Pathology suggestive of phyllodes tumor or malignancy
2. Poor ultrasound visualization
3. Pathologic diagnosis of fibroadenoma nonconcordant with imaging or physical examination

Note: After cryoablation, patients should be followed with ultrasound assessment and physical examination at 6, 12, 18, and 24 months postprocedure.

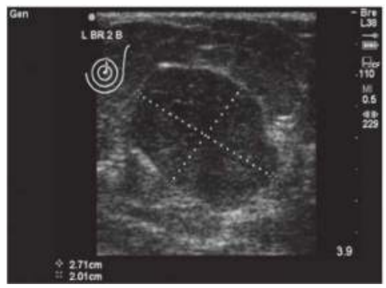

FIG 1 ● Ultrasound of fibroadenoma prior to treatment. Size, position, and two orthogonal views are taken.

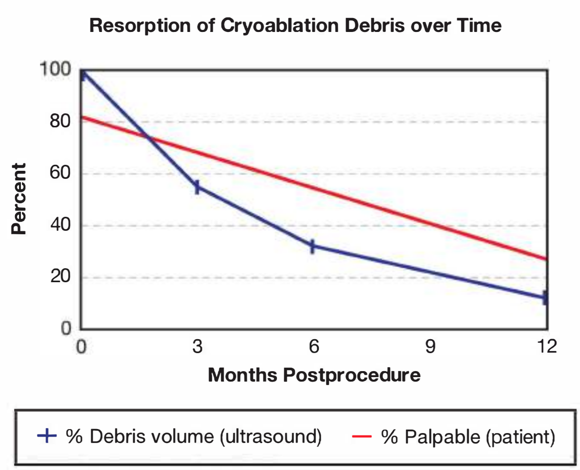

FIG 2 ● Postcryoablation resolution of palpable and ultrasound-visible cryolesion over the first year. Most cryolesions fully dissolve over the year, but tumors larger than 2 cm will take longer to resorb.

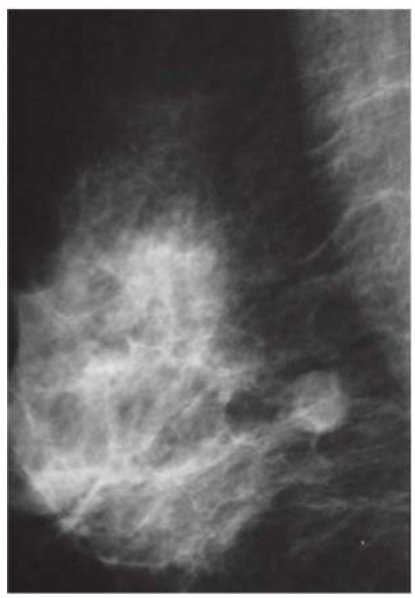

FIG 3 ● Mammogram demonstrating oval fibroadenoma.

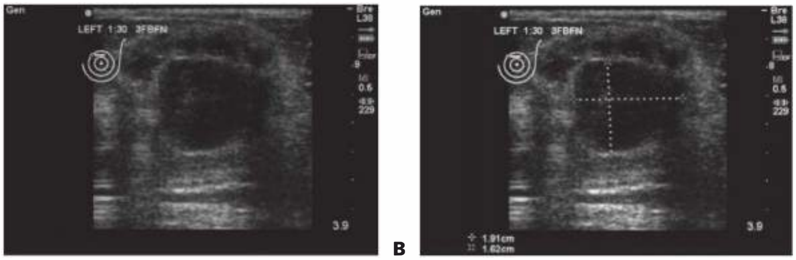

FIG 4 • **A,B.** Classic ultrasound image of fibroadenoma demonstrating well-defined borders and homogeneous solid mass with edge shadowing.

- Cryoablation for fibroadenoma has the advantage of being an office-based procedure with no need for systemic anesthesia, minimal discomfort, skin incision similar to the core biopsy site, and the expectation of lower overall costs of treatment compared with surgical excision. Drawbacks include slow progressive resorption of residual palpable debris.
- Multiple reports in the United States and Europe of favorable outcomes make cryoablation for fibroadenoma an attractive alternative for patients.[12–16,20] As a result of these reports, the American Society of Breast Surgeons has produced a statement in support of cryoablation as an acceptable alternative method of treatment of fibroadenoma.[21]

POSITIONING AND PROCEDURE DESCRIPTION

- Prior to the procedure, the cryoablation machine should be prepared, which typically includes filling the Dewars with liquid nitrogen.
- Cryoablation is an office-based sterile procedure with preparation similar to that of an ultrasound-guided core needle biopsy. Have a sterile cryoprobe available and a sterile field setup with equipment similar to that needed for core needle biopsy. In addition to the sterile instruments, multiple syringes of sterile saline should be available for injections to distance the skin away from the cryoprobe during the procedure.
- The cryoprobe should be tested just prior to use. A backup probe should be available in case the probe tests defective. During the test, no air bubbles should be discharged from the tip of the probe.
- Most cryoablation devices have an automated treatment program that is based on the longest tumor dimension to calculate treatment times. To initiate the automated treatment protocol on the cryoablation device, enter the fibroadenoma size measurement into the cryomachine.
- Note the distance beyond the fibroadenoma that the probe must extend for the symmetric distribution of the freezing.
- Identify the ideal skin entry site to create a cryoprobe pathway along the long axis of the fibroadenoma with adequate circumferential distance for the cryoprobe iceball to be entirely within the breast and away from the skin.
- Inject local anesthetic in the skin and along the path toward the fibroadenoma. Infiltrate some local anesthetic deep to and around the periphery of the target lesion. Some local is valuable beyond the target for the "past-pointing" of the cryoprobe beyond the tumor.
- Use a no. 11 scalpel blade to make a 3-mm entry site for the cryoprobe.
- Carefully place the tested cryoprobe along the desired track into and through the fibroadenoma (**FIG 5A**). This may take some time to be sure the cryoprobe lies within the center of the fibroadenoma. Before a final pathway is chosen, be sure that the cryoprobe lies in the mid-center

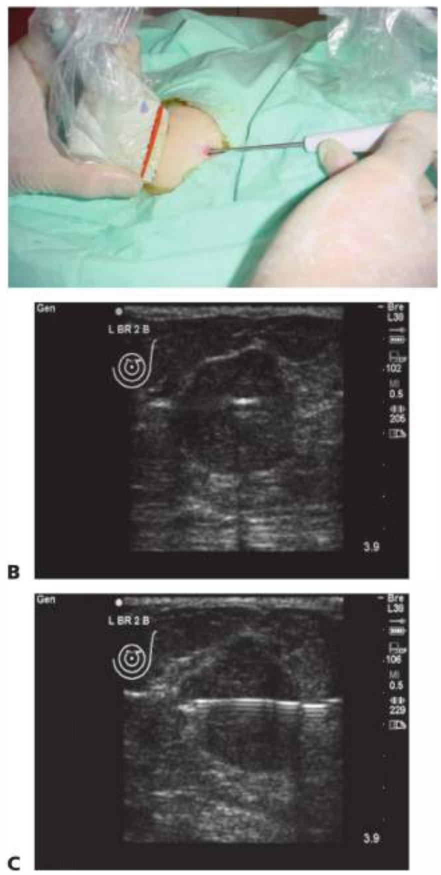

FIG 5 • **A.** Ultrasound examination of probe placement to confirm central location within fibroadenoma. **B.** Ultrasound view of probe in tumor via transverse image. **C.** Ultrasound view of probe in tumor via longitudinal image.

of the target lesion. Move your targeting ultrasound in all directions to confirm cryoprobe central placement both longitudinally and transversely (**FIG 5B,C**, two orthogonal ultrasound views of position of cryoprobe within fibroadenoma).

- Some fibroadenomas are very dense, causing the cryoprobe to deviate off the desired central pathway. It may take repeated efforts to place the probe in the center of a very rubbery tumor.
- One method to facilitate central probe position is to obtain a core needle biopsy just prior to placing the probe. If the core needle biopsy is obtained from the desired central pathway, it will be easier to place the treatment cryoprobe in the same path.
- Once the cryoprobe has adequately been placed and the distal "past-pointing" has been measured, you are ready to initiate the cryoablation sequence.
- Press the start button and use the ultrasound unit to document the development of the iceball. Obtain multiple measurements, especially iceball size, at the end of each of the three phases of treatment: first freeze, thaw, and second freeze (**FIG 6A,B**).


A
B

FIG 6 ● **A.** During procedure, surgeon holds both cryoprobe and ultrasound transducer. Continuous visualization of both cryoablation machine and ultrasound image is required. **B.** Ongoing ultrasound monitoring of skin bridge is necessary. Avoid pressing skin too close to iceball formation with ultrasound transducer.

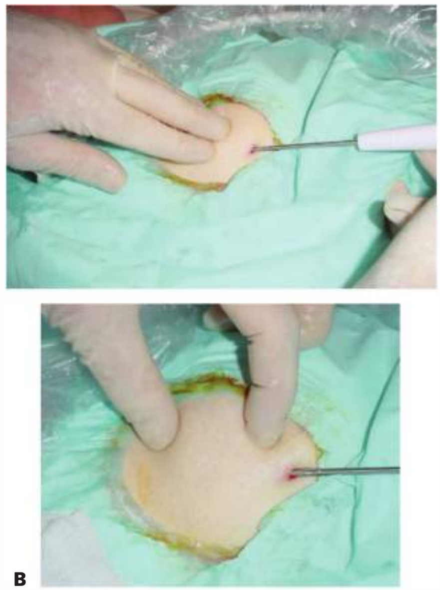
A
B

FIG 7 ● **A.** Use of palpation over iceball to confirm skin is moveable and not frozen to iceball, which can cause skin damage. **B.** Palpation of iceball during cryoablation confirming skin not attached to iceball.

- During the procedure, continuously monitor the skin bridge to be sure skin does not get frozen and attached to the iceball. Freely inject saline between the iceball and the skin to "lift" the skin away from the developing iceball. Skin that becomes attached to the iceball may be injured and result in scar.
- Tips to avoid skin injury during cryoablation include the following: (1) Touch and move the skin horizontally overlying the iceball formation to confirm there is a large subcutaneous portion of mobile fat separating the iceball from the skin. Repeated movement of the skin overlying the iceball confirms it is not becoming attached (**FIG 7A,B**). (2) Avoid continuous pressure of the monitoring ultrasound transducer pushing the skin down onto the developing iceball narrowing the distance between the iceball and the skin; (3) move the distal end of the cryoprobe toward the posterior (chest wall) direction so that the distance from the developing iceball to the skin is maximized. (4) If you wish more distance from the iceball to the skin, inject saline between the skin and iceball to lift the skin away from the iceball development. This can be done repeatedly as needed. Avoid adherence of the skin to the iceball at all times.
- The treatment consists of two high freeze cycles separated by a thaw cycle. Each cycle is usually the same length of time, for example or e.g., 8 minutes each for a total treatment time of 24 minutes.
- The cryoablation device will freeze high for the first and second freeze cycles. During the freezing, continuous ultrasound monitoring will visualize an iceball growing as it envelopes the target lesion. At the end of the first freeze, the iceball will be much larger than the targeted tumor (**FIG 8A–D**).

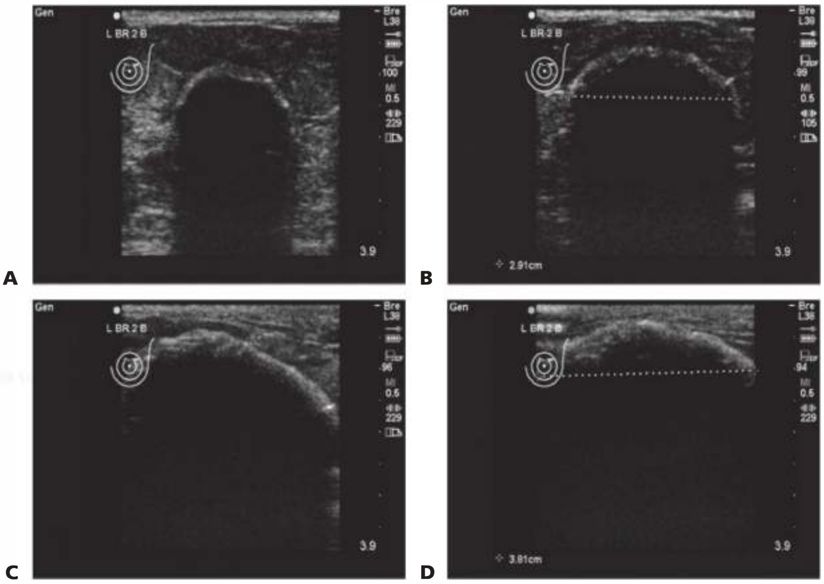

FIG 8 ● Serial Ultrasound Images of Cryoablation **A.** During initial iceball development. **B.** Transverse view of iceball at the end of first freeze cycle. **C.** Longitudinal view of iceball at end of second freeze cycle. **D.** Transverse view of iceball after cryoprobe removal.

- When the automated cryoablation machine reaches the end of the second freeze, it will automatically go into a warming mode. The cryoprobe cannot be removed while it is frozen. The tip of the probe will warm after about 30 seconds of warming so that the cryoprobe may be gently removed.
- At the end of the procedure, the patient will still be able to feel a firm frozen area, which is the iceball (**FIG 9**) that will thaw within an hour, but there will still remain a palpable mass, which is the residual necrotic debris. It will take several months for the debris to be resorbed.
- A Steri-Strip is placed on the entry wound similar to a core needle biopsy dressing. Careful not to place a tight adhesive bandage on the area because it will swell significantly over the next 2 days and blisters can develop. (see "Postoperative Care").

FIG 9 ● Immediate posttreatment palpation of iceball.

PEARLS AND PITFALLS

Lesion location	■ If the target lesion is close to the chest wall, then after placement of the probe during the initial icing phase, lift directly up off the chest wall with the probe in the tumor. This will allow the iceball to form without attachment to the pectoralis major. After the iceball is adequately formed, about 2 minutes into the freezing, you can release the traction away from the chest wall. ■ If the lesion is located close to the skin but away from the nipple, then after placing the probe into the tumor and confirming satisfactory position, inject lidocaine in the space between the skin and the tumor. Try to spread your fluid within the remaining space between the skin and the tumor. After you have over 1 cm of fluid in the ultrasound "window," proceed with freezing. Be ready to inject further saline/lidocaine during the freezing period for the first 4 minutes. Thereafter, the iceball will be unlikely to get too much bigger until the second freeze. ■ On concern during treatment is that there is a progressive iceball enlargement, and frequent skin reassessment must be made to avoid freeze injury. An easy way to tell if the iceball is getting too close to the skin is to examine the mobility of the skin over the iceball. If the skin has much movement, (similar to the skin of your hand over your knuckles) then the iceball is not too close. If there is limited horizontal movement of the skin, inject more fluid. If there is no skin movement, stop the procedure until you can inject more fluid and create a better bridge.

Patient selection	■ Avoid freezing lesions immediately deep to areola and close to the true nipple, especially if the patient is a young woman who wishes to breastfeed in the future. During the cryoablation, the immediate surrounding tissues may be injured or destroyed. This usually is not a problem within the body of the breast, because a small surrounding margin of normal breast tissue is often removed with fibroadenoma excision. But when the immediate surrounding tissue includes major milk ducts, one must be cautious in treating that patient. There is little experience of treating these patients and later determining the ability of these women to breastfeed. ■ There is anecdotal data on cryoablation of nonfibroadenomas. Although early in our experience, other lesions were treated with success, the current acceptable indications for cryoablation are for treatment of fibroadenomas. In the small series of nonfibroadenoma patients, they responded similar to the fibroadenoma cryoablated patients. However, a clinician would have little clinical support if there were complications on a nonfibroadenoma patient. We would refrain from treating those patients. ■ **Treating fibroadenomas during pregnancy.** There is little data on cryoablation during pregnancy. Rapidly growing or painful lesions should consider surgery during pregnancy, whereas others may wait.
Multiple tumors	■ For two tumors close together in the same quadrant, both less than 2 cm, it is possible to place the probe through both lesions at one time and treat both simultaneously. If they cannot be treated simultaneously, then using the same probe in the same quadrant would be reasonable if the entry site were unchanged. If there are two separate punctures to be made or if the lesions are in different quadrants of the same breast, then two separate probes would be optimal. When treating fibroadenomas of both breasts, two separate probes should be used.
Unable to place probe without undue force	■ Some fibroadenomas are very dense and seem to forbid entry of the cryoprobe. The best approach is to reevaluate your entry site and your options to "hold" the tumor in place while you advance the probe into it. One must be cautious to avoid past-pointing and pushing through the tumor once the probe enters it fully. One technique is to start the probe into the lesion, and then use your opposite hand to manually brace the tumor while you advance the probe slowly with your dominant hand. A slow twisting of the probe may allow the cryoprobe to enter the lesion. Use plenty of lidocaine. If it seems impossible to enter the lesion, consider temporarily removing the cryoprobe and using a spring-loaded core needle to take a few "bites" of the tumor at the planned site of cryoprobe entry. By creating a small-bore hole with the needle biopsy device, the cryoprobe may be able to enter the tumor more easily. Care to keep the cryoprobe sterile while you use the core biopsy tool.

POSTOPERATIVE CARE

- Bandage dressing over the entry site is very important to absorb some fluid that may drain out of the entry site. The treatment is essentially a burn of the interior of the breast. As with other burns, the area will swell over the next 2 to 3 days. A dressing over the area must accommodate the skin stretching and tissue swelling; otherwise, there will be blistering of the skin where tape or other adhesive dressings are placed.
- The entry site is closed with a Steri-Strip. Over the Steri-Strip can be placed a couple 2 × 2 gauze pads and then all covered with a Tegaderm-like adhesive waterproof dressing. Be careful not to stretch the adhesive dressing over the gauze because the tissue will swell. Stretch the skin and lay the unstretched dressing over the gauze so that the swelling of the skin over the next couple days will not create blistering at the corners of the dressing from a sheer effect that occurs with tissue swelling under a tight Tegaderm-like plastic. Do not stretch the Tegaderm-like plastic dressing on the skin but rather stretch the skin as you place the unstretched Tegaderm-like dressing over the gauze.
- Immediately after the procedure, patients have a cold firm spot on their breast, which is numb. They typically are able to drive themselves home after a few minutes of relaxation while getting dressed, since no sedation is necessary.
- Inform the patient that her tissue will swell significantly over the next few days, which may also be tender. Local treatments of ice packs and ibuprofen will aid in decreasing the swelling. Patients who are warned of the swelling and local tenderness will less likely be alarmed when it occurs.
- Sometimes, surrounding tissue is damaged and swells more than expected. If the lesion was on the chest wall, cryoablation of pectoralis muscle will be more painful than breast tissue ablation. Supportive pain medicine will allow this to resolve. In other patients, there is significant swelling in and around the cryoablated tissue. This is more likely with longer ablations or larger areas of normal breast tissue ablated. This occurs with cancer ablations due to longer treatment times. With tissue swelling, one must be cautious of skin taping or Steri-Strips during these first few days. Due to the swelling, there may be a sheering force on the skin by the tape, and skin blisters may occur. This is strictly due to tape applied too tight for the amount of tissue swelling that may occur. Avoid tape close to the cryoablation area. Pain may be due to blisters forming under the tape.
- Due to the complete destruction of all cells within the cryoablation target, all blood cells will lyse and exude their hemoglobin into the tissues. The entire treated area will turn a deep shade of red-purple merging to yellow green over the next week to 10 days. An informed patient will not be alarmed when these color changes occur. By 2 weeks, all the color is gone (**FIG 10A–C**).
- The patient is advised to call the office as needed for the first 5 days to let us know of the changes that have been described.

FIG 10 • **A–C.** Clinical images of patient postcryoablation at 1 week, 1 month, and 6 months. Note, the ecchymosis extends in a larger area than the fibroadenoma due to the lysis of blood cells in the area but resolves promptly.

It is not likely at all to have a significant posttreatment hemorrhage or infection. However, patients might think both of these events might be happening due to the typical changes postcryoablation.

- After these initial changes, the patient will be able to feel a firm oval mass at the site of the cryoablation zone. It will not be very tender but will be larger than the patient's original lesion or, if it was nonpalpable prior to cryoablation, it is now palpable to the patient. Knowing this change in physical exam will occur is helpful to prevent the patient's concern when they first palpate the area after the initial swelling is gone.

Long-Term Postprocedure Management

- After the initial healing period, the patient enters a long-term resolution phase. During this time, the patient will have very slow resolution of the residual mass left by the necrotic central cryoablative zone. Typically, there is little pain in the area. Properly informed patients express little concern when feeling the persistent cryonecrotic mass over several months as it resolves (**FIG 2**).
- Follow-up office visits. Some clinicians treat the patients and simply advise the patients of expected local changes in the breast and do not follow their patients in the office. This is not the advised method of follow-up, but some clinicians just wait for patients to call or return as needed. This method creates unnecessary anxiety in the patient and likely decreases patient satisfaction. We recommend regular follow-up exams for 1 year after cryoablation.
- As time goes on, patients are seen less frequently to confirm the residual mass is decreasing as well as to reassure the patient that all is well. The first posttreatment visit is about 2 to 4 weeks after the cryoablation. Next visit is 2 months later. Next visit is 3 to 4 months after that. Thereafter, every 3 to 6 months until the lesion has disappeared.
- With each visit, the area is examined with or without focal ultrasound measurements. With each exam, note the size of the residual cryonecrosis and reassure the patient of slow and progressive absorption.
- Most patients are younger than 40 years and not candidates for routine mammographic screening. If they are older than 40 years, preferably, their most recent mammogram was just prior to their cryoablation. Routine screening may follow. The first mammogram postcryoablation will have imaging changes from the procedure. If the imager is unaware of the treatment, they will note increased density and mass effect with indistinct margins in the area of the previously benign-appearing lesion. The unaware imager may consider the image BIRADS 4 and suggest a biopsy. However, clarifying the treatment events will modify the reading to either BIRADS 3 or 2, suggesting serial follow-up imaging.[22,23]
- The speed of resorption of the residual cryoablation debris relates to the original size of the target lesion. For tumors less than 2 cm, the area normally disappears within 1 year posttreatment. For those larger than 2 cm, it may take longer than a year. Almost all lesions over 2 cm are not palpable by 2 years. Ultrasound visualization of the residual cryoablated tissue remains visible for longer periods but that is similar to surgical scar seen by ultrasound. Ultrasound identification of the treated area is difficult to find by 3 years.
- Long-term (over 3 years) imaging changes vary from no evidence of treatment to residual scar similar to surgical biopsy changes. Mammograms may occasionally show focal calcifications in the area or radiating fibrosis, but the most common mammographic image is fatty replacement of the treatment area.[22] Ultrasound imaging most often demonstrates nonspecific breast tissue with some areas of hypoechoic scar over time. The iceball is usually at least 30% larger than the treated lesion then slowly resorbs. The tissue within the iceball becomes firm and much more noticeable than the prior tumor. Nonpalpable tumors become palpable immediately. Over the first 1 to 2 months, these areas will start to decrease in firmness. It will not be until about 6 months before they dissolve. Continue to reassure the patient that the firmness they feel is normal and expected. Anxiety of finding a new mass when none was present previously can readily undo the benefits of the procedure.
- Some patients may have a persistent firm mass for 6 to 9 months. If the cryoprobe was placed accurately and the treatment given properly, these patients will need to wait for the expected resolution of the palpable mass. For lesions over 2 cm, it will take over 6 months before their lesions start to noticeably decrease in size. Signs of a successful cryoablation include no growth in the palpable mass after the first month, and that after 6 months, there seems to be a slight softening of the mass, although it is difficult to notice. There should be no progressive measurable growth in the "mass." Reassurance is necessary for both the doctor and the patient during this time. By 9 months, it is clear that the cryolesion is getting smaller and the firmness is decreasing. By 12 months, there is noticeable change, even if the

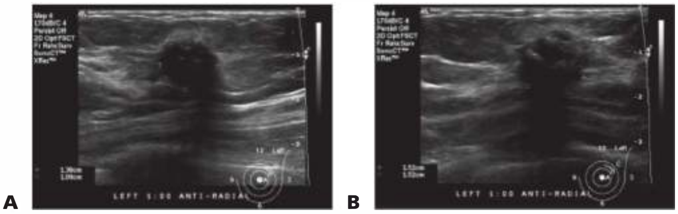

FIG 11 ● A,B. Ultrasound images of cryoablation site 4 years after treatment. Site is smaller and has residual scar of necrotic debris where lesion had previously been.

lesion is not gone. Progressive decrease in size is noticeable on ultrasound and palpation (FIG 2).

- The ultrasound picture of cryoablated tissue is similar to surgical scar. There is typically an irregular hypoechoic shadowing mass, noticeably more suspicious on ultrasound than prior to cryoablation, but smaller than original lesion. The clues of normalcy are that there is no progressive growth but slow and progressive decrease in overall size. These lesions are followed but not biopsied unless there is growth (FIG 11A,B).

OUTCOMES

- Many reports have demonstrated the effectiveness of cryoablation of fibroadenomas. These reports are consistent in their results in properly chosen patients. After treatment, clinical and imaging evidence of the lesion slowly resorbs until the area disappears. Imaging evidence of the targets also disappears (Table 2).
- After initial positive reports of this technique, a Current Procedural Terminology (CPT) code was assigned to this process. Many payers reimbursed for this procedure. However, due to limited use of this method of treatment, many payers reversed their acceptance of payment and reclassified this procedure as investigational. Yet, the data supporting this method of treatment as acceptable has been repeated in the peer-reviewed literature in many sites. The few negative comments are mostly reports of slow resorption of the treated lesion.

COMPLICATIONS

- Most complications can be prevented, or said another way, most complications are iatrogenic. These include choosing a patient who has too narrow a window between the skin and the lesion, making skin injury more likely.
- Other complications include blistering on the skin due to swelling of the skin under adhesive from Steri-Strips or the Tegaderm-like dressing.
- Although ecchymosis and swelling is expected, significant hemorrhage and infection is quite rare.

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Chapter 5 Lumpectomy for Breast Cancer

Michael S. Sabel

DEFINITION

- Lumpectomy is defined as the complete excision of a breast tumor with an adequate margin of surrounding normal tissue. Lumpectomy plus breast irradiation are the essential components of successful breast conservation therapy (BCT). Lumpectomies for nonpalpable cancers require wire localization. Other terms for lumpectomy include partial mastectomy, tumorectomy, or tylectomy.

PATIENT HISTORY AND PHYSICAL FINDINGS

- For BCT to be successful, it must be possible to (1) obtain negative surgical margins around the tumor while still maintaining a cosmetically acceptable result and (2) safely deliver radiation therapy. A thorough history and physical examination is necessary to carefully select patients for BCT. Absolute contraindications to BCT are listed in Table 1.
- A thorough history should be performed prior to treatment, including a detailed past medical history, present medications and allergies, and a personal and family history of cancer.
- Prior radiation to the breast is a contraindication to BCT. For patients who may have had chest wall radiation for indications other than a prior breast cancer (such as mantle radiation for Hodgkin disease), it may be helpful to obtain the prior records and review the fields treated. These patients may be eligible for a partial breast irradiation technique (Part 5, Chapter 7).
- Patients with a history of autoimmune or collagen-vascular diseases, such as scleroderma, lupus, or dermatomyositis, may have abnormal reaction to radiation therapy, which significantly compromises the cosmetic outcome. For some types of collagen-vascular disease, such as Raynaud phenomenon, rheumatoid arthritis, or Sjögren's syndrome, the response to radiation is not as severe and these patients may be considered for BCT.
- A detailed family history is critical to assess the risk of a future breast cancer, and consider genetic counseling and testing. High-risk patients may want to consider bilateral mastectomy as they are at considerable risk of a second primary cancer. The data is mixed regarding the local recurrence rate among patients with a known or suspected BRCA 1 or 2 mutations who opt for BCT. Some, but not all, studies suggest an increased risk.[1,2] The decision to pursue BCT in known BRCA1/2 carriers should be made following extensive discussion with a genetic counselor.

Table 1: Absolute Contraindications to Breast Conserving Surgery

Unable to receive radiation therapy
Previous chest wall irradiation
Need to deliver radiation during pregnancy
Scleroderma or active systemic lupus erythematosus
Multicentric disease
Diffuse suspicious calcifications on mammography
Inability to achieve adequately negative margins

- Patient age, nodal status, histologic tumor type, tumor grade, and extensive intraductal component (EIC) are not contraindications to BCT as long as negative margins can be obtained.
- If an adequate lumpectomy can be performed, prior breast augmentation with breast implants are not an absolute contraindication, and radiation can be delivered to the augmented breast using standard techniques and doses. However, capsular contraction is a risk. If the tumor is close to the implant, preventing negative margins (cancers sometimes invade the fibrous capsule around the implant), the implant may need to be removed.
- A complete, bilateral breast examination should focus on both assessing the cosmetic implications of lumpectomy and identifying additional areas of concern to rule out multicentric disease. Any additional suspicious masses should be biopsied, and cancer ruled out, prior to proceeding with BCT.
- The size of the mass relative to the size of the breast, location of the mass, proximity to the skin and amount of skin needed to be resected, and symmetry of the breasts should be noted. For some patients with a large tumor relative to the size of the breast, neoadjuvant chemotherapy may be considered to downstage the primary tumor. For other patients in whom a poor cosmetic outcome with standard lumpectomy is predicted, an oncoplastic approach should be considered (Part 5, Chapter 6).
- A detailed examination of the bilateral axillary, supraclavicular, and cervical lymph nodes should be undertaken, and any suspicious lymphadenopathy worked up prior to surgery.

IMAGING AND OTHER DIAGNOSTIC STUDIES

- All patients require bilateral mammographic evaluation, with appropriate magnification views, within 3 months of surgery (**FIG 1**). The tumor size, the presence of microcalcifications, and the extent of calcifications outside of the mass should be noted. Some patients with palpable cancers may still require wire localization of the calcifications to assure complete removal at the time of lumpectomy.
- Any additional areas of abnormality should be worked up and biopsied to rule out multicentric cancer. Multicentric disease is typically a contraindication to BCT; however, patients with two tumors close enough that they can be removed in one specimen with an acceptable cosmetic outcome can still be considered candidates for BCT.
- The use of magnetic resonance imaging (MRI) to determine eligibility for BCT has been increasing. Although MRI may more accurately determine the extent of the tumor or identify multicentricity, particularly in women with dense breast tissue (for whom mammography is less sensitive), its use is

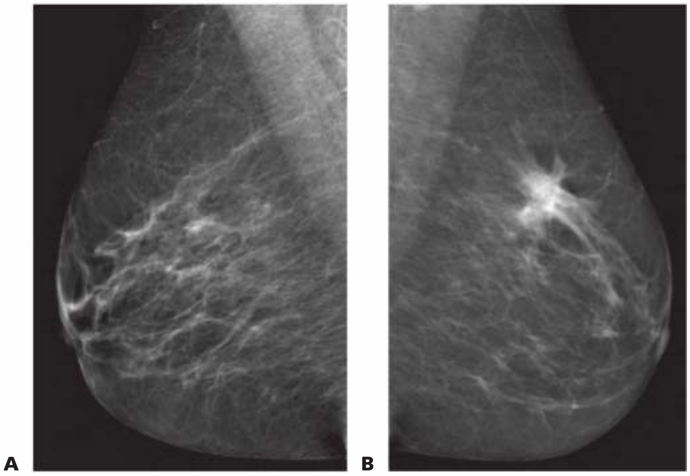


FIG 1 ● Bilateral mammogram demonstrating a left breast cancer. **A.** Right breast. **B.** Left breast.

controversial. MRI is highly sensitive but has limited specificity and is limited in its ability to visualize ductal carcinoma in situ (DCIS). Studies have shown that the use of MRI appears to increase the mastectomy rate without decreasing reexcision or local recurrence rates.[3] The need for MRI should be evaluated on a case-by-case basis.

- Accurate histologic assessment of the primary tumor, including histologic subtype and hormone receptor status, is necessary in evaluating the breast cancer patient for suitability for BCT. This is best accomplished through a core needle biopsy rather than fine needle aspiration biopsy or excisional biopsy.

SURGICAL MANAGEMENT

Preoperative Planning

- Prior to taking the patient back to the operating room, the presence of the palpable cancer should be confirmed with the patient. In the preoperative area, the mass should be examined in both the upright and supine positions.
- With the patient in the supine position, the mass should be carefully marked.
- Although the risk of infection after breast cancer surgery is low, it tends to be higher than average for a clean surgical procedure, and several studies have shown that antibiotic prophylaxis significantly reduces the risk of postoperative infection.[4]

Positioning

- Lumpectomy is often performed in conjunction with a sentinel lymph node biopsy. Therefore, the patient should be positioned supine with the ipsilateral arm at 90 degrees.
- If intraoperative analysis of the sentinel lymph node and possible axillary lymph node dissection is planned, the ipsilateral arm should be prepped into the sterile field. Otherwise, the ipsilateral arm can be secured.
- If sentinel lymph node biopsy is to be performed in conjunction with lumpectomy, then the blue dye should be injected at this point. The skin is prepped with alcohol and either isosulfan or methylene blue dye is injected peritumoral (see Part 5, Chapter 8, Sentinel Lymph Node Biopsy for Breast Cancer) (**FIG 2**).

FIG 2 ● Peritumoral injection of blue dye prior to lumpectomy for performance of sentinel lymph node (SLN) biopsy.

PLACEMENT OF INCISION

- The skin incision should be placed directly over the palpable mass (**FIG 3**). One should avoid excessive tunneling. This may compromise the margins and make a reexcision for close or positive margins unnecessarily difficult.
- When there is adequate distance between the skin and the tumor, skin does not need to be removed. However, when the tumor is close to the skin, an ellipse of skin over the tumor should be removed with the lumpectomy specimen.
- In the upper hemisphere of the breast, curvilinear incisions following the Langer lines (the normal lines of tension in the skin) are ideal. In the lower hemisphere, the incisions can either be circumareolar or radial (**FIG 4**). For smaller tumors in relatively larger breasts, where there is adequate breast parenchyma, curvilinear incisions are acceptable. However, when skin or a fair amount of tissue is to be removed, curvilinear incisions will collapse the breast inferiorly so that the nipple points downward. In this situation, radial incisions will result in less distortion of the nipple–areolar complex.
- All incisions must be planned with an eventual mastectomy in mind should attempts at breast conservation fail (**FIG 5**). The incision size needs to be adequate to remove the mass and surrounding margin. Using a small incision for cosmetic benefit results in excessive manipulation of the tumor and involved margins that require reexcision.

FIG 3 ● Placement of incision within the Langer lines of the breast directly over the palpable cancer. The incision is planned large enough to remove the cancer without excess manipulation.

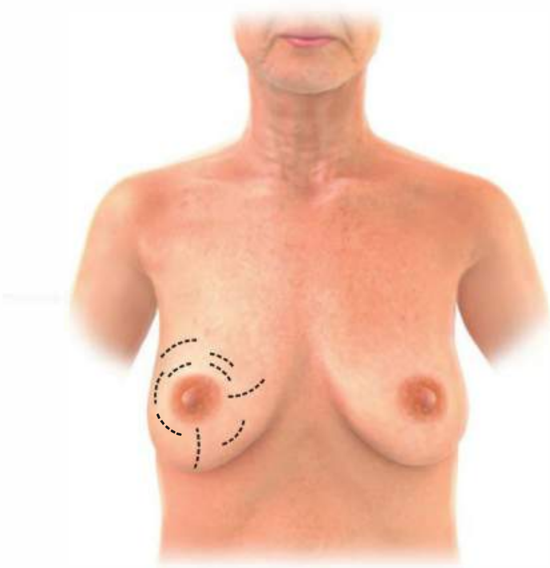


FIG 4 ● Potential lines of excision for breast lumpectomy. In the upper hemisphere of the breast, curvilinear incisions are best, keeping within the Langer lines of the skin. In the lower hemisphere, either curvilinear or radial incisions are acceptable.

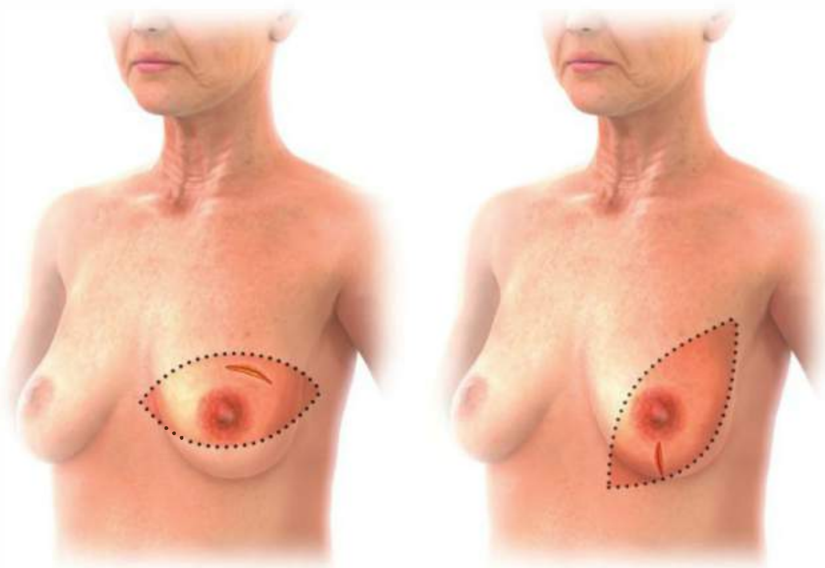


FIG 5 ● Potential mastectomy incisions if breast conservation fails. Lumpectomy incisions should be planned with a possible mastectomy in mind should negative margins not be attainable.

SKIN INCISION AND RAISING OF FLAPS

- An incision is made in the skin going just deep to the dermis. For lesions closer to the skin, skin flaps should be immediately elevated in all directions over the mass (FIG 6). Adequate subcutaneous fat should be left on the flaps, which should get progressively thicker as the flaps are elevated (approximately 45 degrees). Excessively thin flaps lead to excessive retraction and concavity with radiation and should be avoided by excising the skin over the mass.
- For deep-seated tumors, after dividing the skin, the breast tissue may be divided straight down to approximately 1 cm over the mass before beginning the dissection around the tumor (FIG 7).

A

B

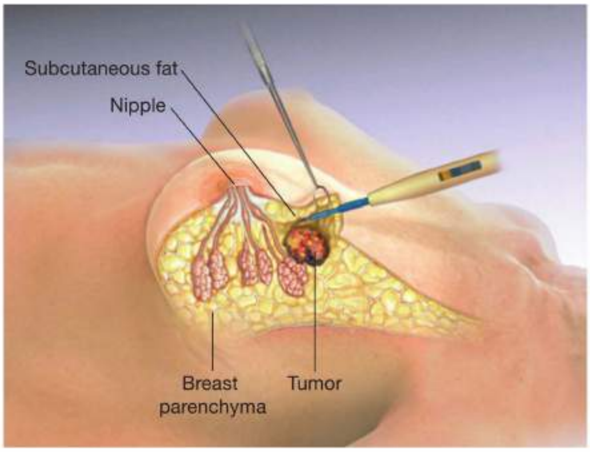


FIG 6 ● Raising of flaps over the tumor. Excessively thin flaps should be avoided. The flaps should get thicker as they are elevated.

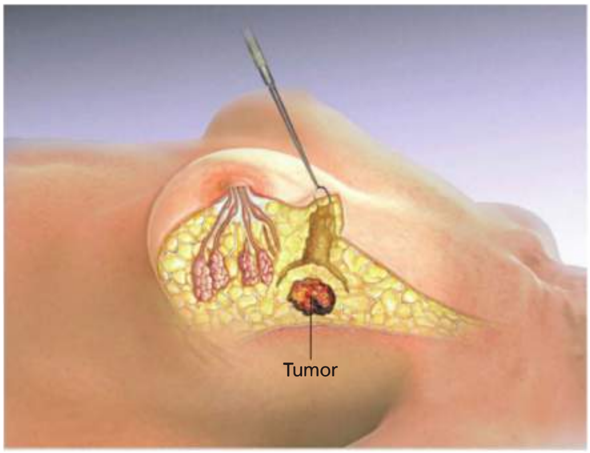
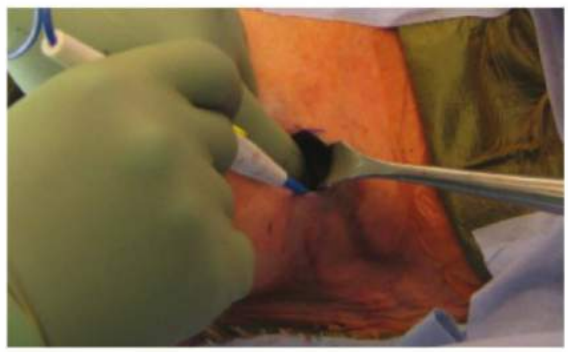


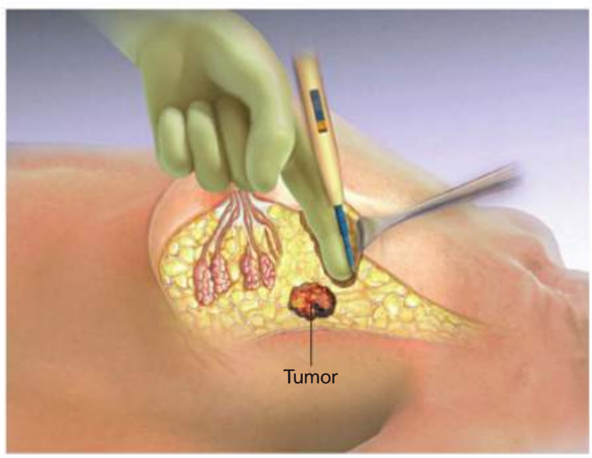
FIG 7 ● The breast parenchyma is divided until approximately 1 cm above the tumor before dissecting around the tumor for a deep-seated tumor.

EXCISION

- The excision is then carried out with the goal of maintaining 1-cm grossly free margins around the mass. This is best accomplished by retracting the mass with the index finger of the nonoperative hand so you are constantly aware of the margin and maintaining a 1-cm rim of normal breast tissue or fat as dissection continues toward the chest wall (**FIG 8A,B**).
- The tissue is divided circumferentially around the mass. Once it is free, it can usually be elevated out of the wound (**FIG 9**). The skin incision must be large enough so that the resected portion can be easily brought out; struggling to deliver a mass through a small incision leads to excessive manipulation and positive margins on final pathology.
- Before the lesion is completely removed from the body, the specimen should be oriented with 2-0 silk sutures. Orientation is critical so that if reexcision for close or positive margins are needed, this can be limited to just the involved margin (as opposed to reexcising the entire cavity). Three sutures are necessary to orient the mass correctly for the pathologist and avoid errors (**FIG 10**).[5] At this juncture, we recommend placing a short 2-0 silk suture at the superior margin and a long silk suture at the lateral margin (**FIG 11**).
- The specimen is now completely removed by dividing the deep margin (**FIG 12**). For lesions close to the chest wall, the deep margin should include the fascia of the pectoralis major muscle. In rare cases, excision of some of the pectoralis is necessary to assure a negative deep margin. Once excised, a third double-stranded orientation suture is placed at the deep margin (**FIG 13**).



A



B

FIG 8 ● With the tumor retracted with the index finger, the surgeon dissects around it, maintaining 1 cm of normal breast tissue around the tumor.

FIG 9 ● The entire tumor is excised circumferentially and delivered from the wound.

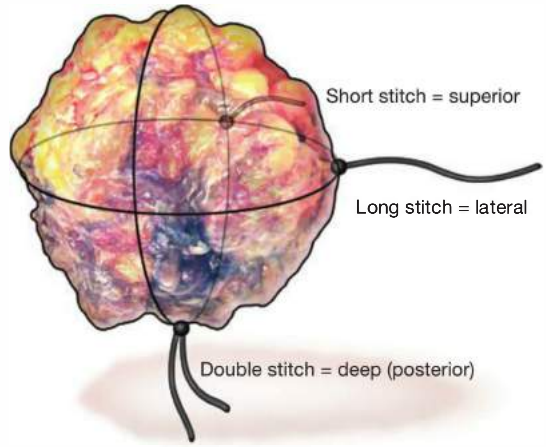


FIG 10 ● Three suture marking system for lumpectomy specimens. A 3-0 silk short stitch is placed superiorly, a long stitch is placed laterally, and a double stitch is placed deep (posteriorly).

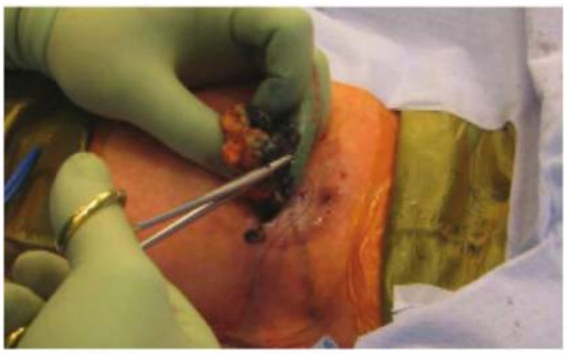


FIG 11 ● Marking sutures are placed prior to complete excision of the specimen so as not to lose the orientation.

FIG 12 ● The posterior tissue is divided last, completing the lumpectomy.

FIG 13 ● Lumpectomy specimen with marking sutures.

INTRAOPERATIVE MARGIN ANALYSIS

- Without intraoperative margin analysis, reexcision rates to obtain negative margins can be as high as 30% to 50%. Intraoperative margin analysis is highly recommended to minimize reexcision rates to as low as 10%.[6] After orientation, the margins of the specimen are inked using six colors and then sectioned at 2- to 3-mm intervals (**FIG 14**).
- After gross examination of the margin status, sections are taken for each suspicious margin (**FIG 15**). Sections 6- to 7-μm thick are cut on a −20°C cryostat and stained with a rapid hematoxylin and eosin technique (with two levels of each tissue block examined). Any margins in which invasive or in situ carcinoma extend to within 2-mm are reported to the surgeon (**FIG 16**).
- A reexcision of the close margin can then be performed by grasping the top of the margin with an Allis clamp and excising back another 0.5 to 1 cm around the hemisphere in need of reexcision (**FIG 17A,B**). The new margin should be appropriately marked for the pathologist (**FIG 18**).

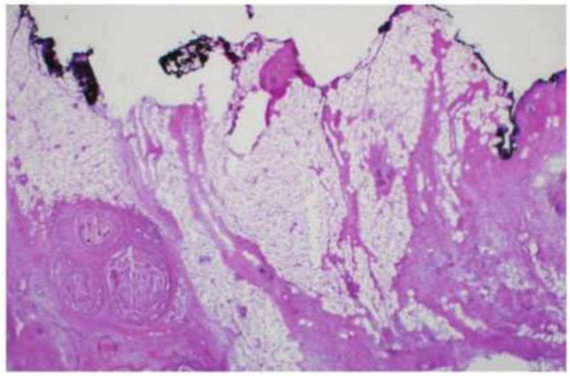


FIG 16 ● DCIS is identified close to the margin. This information is relayed to the surgeon so a reexcision of that margin can be performed.

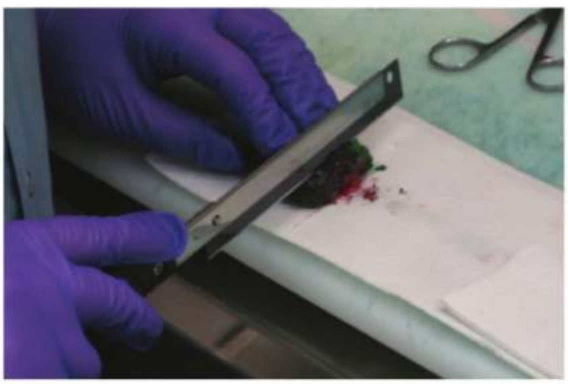


FIG 14 ● The specimen is inked with six colors and sectioned for intraoperative margin analysis.

FIG 15 ● The sections are grossly examined for involved margins.

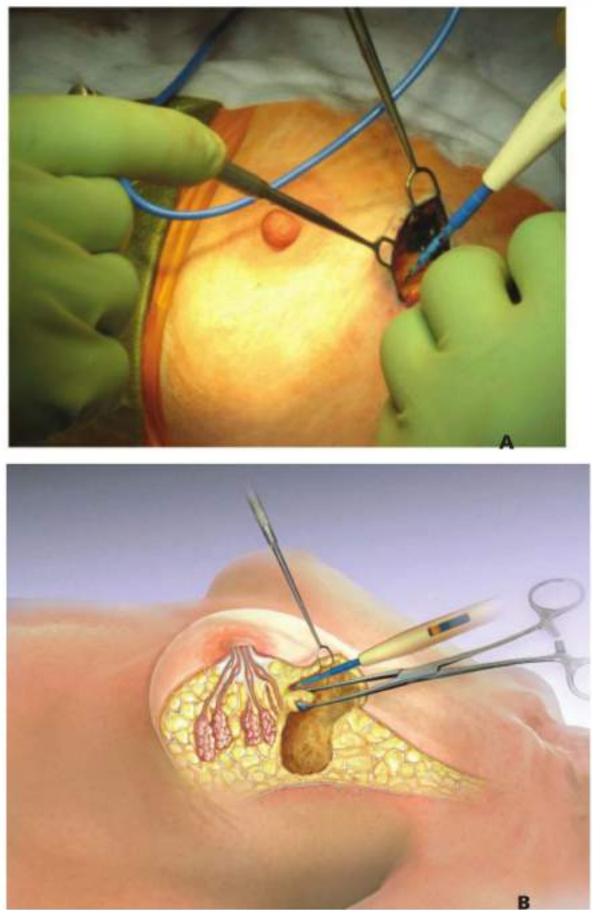


FIG 17 ● **A.** An additional inferior margin is obtained based on the intraoperative margin analysis. **B.** The top of the cavity is grasped with an Allis and the entire hemisphere is excised approximately 1 cm back from the cavity.

FIG 18 ● A marking stitch designating the new, true margin after reexcision.

CLOSURE

- Once the lumpectomy is complete, hemostasis is assured and then surgical clips are placed within the cavity at the six anatomic locations (anterior, posterior, medial, lateral, superior, and inferior) (**FIG 19**). This helps in the planning of radiation therapy, particularly for a boost or for partial breast irradiation.
- For the standard lumpectomy, the surgeon should *not* try to reapproximate the breast tissue. The cavity will fill with seroma and fibrin, and ultimately fibrous tissue, which will maintain the normal contour. For large defects, oncoplastic techniques can be considered, which are discussed in Part 5, Chapter 6.
- The incision is closed with absorbable deep dermal sutures, followed by either a subcuticular stitch or tissue adhesive (**FIG 20**). Drains should not be used.

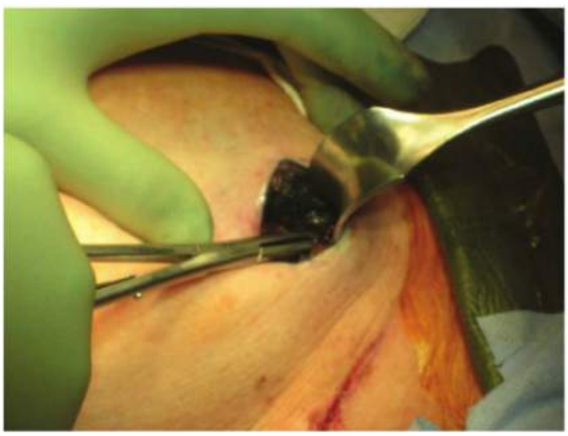


FIG 19 ● Clips are placed around the lumpectomy cavity to aid in the delivery of radiation.

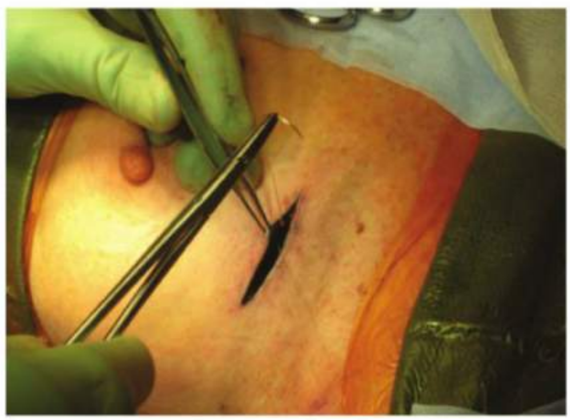


FIG 20 ● The skin is reapproximated with absorbable deep dermal sutures.

PEARLS AND PITFALLS

Indications	■ A complete history and physical and review of the breast imaging should take place to assure the patient is a suitable candidate for BCT. ■ Suspicious lesions on exam or imaging should be biopsied prior to proceeding with BCT.
Placement of incision	■ Incisions should be created, keeping in mind a possible mastectomy should BCT fail. ■ In the inferior portion of the breast, radial incisions can give superior cosmetic outcomes compared to curvilinear incisions. ■ Make the incision large enough to remove the tumor without excessive manipulation. This decreases the close/positive margin rate and the need for reexcision.
Raising of flaps	■ Thin flaps will lead to excessive retraction and concavity after radiation. Avoid them by excising the skin over the tumor with the lumpectomy. ■ Flaps should get progressively thicker as they are raised.
Excision	■ Maintain at least 1 cm of grossly normal margins around the mass throughout the excision. ■ Intraoperative margin analysis can greatly reduce reexcision rates, leading to lower mastectomy rates and improved cosmetic outcome.
Orientation	■ Three orientation sutures are necessary to avoid error. ■ Place two sutures before complete excision of the tumor to avoid losing the orientation.
Closure	■ Do not try to reapproximate the breast tissue or place a drain.

POSTOPERATIVE CARE

- After a lumpectomy, the patient should be placed in a breast binder or supportive brassiere. This helps sustain hemostasis and relieves tension on the skin closure imposed by the weight of the breasts. The patient should be encouraged to wear the support bra day and night for 1 week after surgery.

OUTCOMES

- Long-term recurrence rates after lumpectomy and radiation therapy range from 5% to 22%, compared with 4% to 14% for mastectomy. Survival rates are equivalent.[7]
- Among women undergoing lumpectomy and radiation, excellent or excellent/good cosmetic results were noted at 3 years in 73% and 96%, respectively.[8] This is primarily driven by the volume of breast tissue resected, with scores higher among women with less than 35 cm^3 resected compared to women with greater than 85 cm^3.[9,10]

COMPLICATIONS

- Seroma
- Hematoma
- Infection (cellulitis or abscess)
- Altered sensation to the nipple
- Close or positive margins
- Poor cosmetic outcome

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Chapter 6 Oncoplastic Breast Surgery

Kristine E. Calhoun Benjamin O. Anderson

DEFINITION

- Breast-conserving therapy was first introduced as a treatment option for women with breast cancer beginning in the 1970s, with multiple clinical trials having since demonstrated equivalency in terms of overall survival between lumpectomy with radiation and mastectomy.[1,2]
- For breast conservation to be effective, the cancer must be resected with adequate surgical margins while simultaneously maintaining the breast's shape and appearance. Unfortunately, satisfying these dual goals may prove to be challenging.[3]
- In a traditional lumpectomy, the skin is opened, the tumor removed, and the wound closed without any specific effort being made to obliterate the internal cavity. Closing the remaining fibroglandular tissue may result in cosmetic defects if alignment of the breast tissue is suboptimal. Although such an approach may work well for smaller tumors, declivity of the skin and/or displacement of the nipple–areolar complex (NAC) may be the end result if the lesion removed from the breast is sizable.
- In 1994, Werner P. Audretsch was one of the first to advocate the use of "oncoplastic surgery" for repair of partial mastectomy defects by combining the techniques of volume reduction with immediate flap reconstruction.[4] Although initially used to describe partial mastectomy combined with large myocutaneous flap reconstruction using the latissimus dorsi or the rectus abdominis muscles, oncoplastic surgery currently refers to a series of surgical approaches that use partial mastectomy and breast flap advancement to address tissue defects following wide resection.
- The most widely used techniques, which will be described in this chapter, include the parallelogram mastopexy lumpectomy, batwing mastopexy lumpectomy, lateral segmentectomy lumpectomy, donut mastopexy lumpectomy, reduction mastopexy lumpectomy, and the central lumpectomy.[3,5]

ANATOMY

- One of the fundamental challenges for the oncoplastic breast surgeon is to determine how the individual cancer is distributed within the breast and to assess whether the lesion can be resected as a single en bloc fibroglandular resection.
- The modern anatomic analysis of ductal anatomy suggests that the number of major ductal systems is probably fewer than 10. The size of ductal segments can be incredibly variable, with some presenting as a narrow "pie slice" of tissue; in other cases, a single ductal segment can occupy up to 25% of the total breast volume.[6]
- Not all ducts pass radially from the nipple to the periphery of the breast, as some travel directly back from the nipple toward the chest wall. Single ductal segments may radiate to the sternal (medial) and clavicular (superior) aspects of the breast, with two or three ductal branches layered on each other, creating a fuller pad of fibroglandular tissue in the axillary (lateral) and abdominal (inferior) aspects of the breast.[7] Although the ductal branches appear to interdigitate with each other within the breast parenchyma, the segments do not communicate with each other via ductal anastomoses.
- In contrast to breast ductal anatomy, the fibroglandular tissue of the breast has a rich anastomotic circulatory bed, which allows oncoplastic resection and mastopexy fibroglandular advancement to be safely performed with minimal threat to tissue viability. This well-collateralized breast vasculature allows the surgeon to remodel large amounts of fibroglandular tissue within the skin envelope without major risk of breast devascularization and subsequent necrosis.
- The axillary and internal mammary arteries are the most common origins of the arterial blood supply of the breast. By maintaining communication with one of these two arterial connections, adequate blood supply to the breast parenchyma is maintained during tissue advancement and mastopexy closure.

PATIENT HISTORY AND PHYSICAL FINDINGS

- Patients should undergo standard preoperative history and physical, with special attention given to any prior breast surgical history, including the placement and location of breast implants.
- Tissue biopsy, preferably using core needle sampling, should be performed and conclusive proof of malignancy documented, with mandatory internal review of all external pathology slides required at our institution.
- Every effort should be made to make the tissue diagnosis by needle sampling, as an excisional biopsy scar may complicate the placement of the subsequent lumpectomy incision.

IMAGING AND OTHER DIAGNOSTIC STUDIES

- Patients considered for oncoplastic lumpectomy should undergo a standard preoperative breast imaging workup, which typically includes a combination of mammography and ultrasound, with or without breast magnetic resonance imaging (MRI). Although mammography may underestimate the extent of disease, especially if ductal carcinoma in situ (DCIS) is present, it is still warranted and is often the initial diagnostic study.[8]
- Although still controversial, the use of MRI may contribute greatly to the surgeon's ability to preoperatively determine the extent of disease present, especially for more mammographically subtle or occult cancers. Compared with mammographic and ultrasound images, the extent of disease seen on MRI may correlate best with the extent of tumor found at pathologic evaluation.
- Although sensitivity is high, MRI has a low specificity of 67.7% in the diagnosis of breast cancer before biopsy.[9] Up to one-third of MRI studies will show some area of enhancement

that needs further assessment but ultimately prove to be histologically benign breast tissue.[3]

- For cancers containing both invasive and noninvasive components, a combination of imaging methods (mammography with magnification views, ultrasonography, and/or MRI) may yield the best estimate of overall tumor size.[10]

SURGICAL MANAGEMENT

- The indications, as well as the contraindications, for oncoplastic surgery are the same as those of traditional breast-conserving surgery. In general, such techniques are only offered to those otherwise believed to be breast preservation candidates, including patients with single quadrant disease and individuals who can tolerate and have access to postsurgical radiation therapy.
- The techniques described in this chapter are easily learned and implemented by breast surgeons, even those lacking formal plastic surgery training.

Preoperative Planning

- While planning oncoplastic resections, as with traditional lumpectomy, the surgeon needs to accurately identify the area requiring removal, which is often aided by the use of preoperatively or perioperatively placed localization wires.
- Single wire localization for larger breast lesions may be more likely to result in positive margins, because the surgeon lacks landmarks to determine where the true boundaries of nonpalpable disease are located. For such scenarios, multiple bracketing wires may assist the surgeon in achieving complete excision at the initial intervention (**FIG 1**).

Positioning

- Before the procedure, consideration should be given to marking skin landmarks with the patient in the upright sitting position.
- Relevant landmarks to be identified include the inframammary crease, the anterior axillary fold at the pectoralis major muscle, the posterior axillary fold of the latissimus dorsi muscle, the sternal border of the breast, and the periareolar circle. Identifying these structures with the patient in the sitting position is very important to the final cosmetic outcome, because these sites may be challenging to accurately locate once the patient is anesthetized and lying supine on the operating room (OR) table.

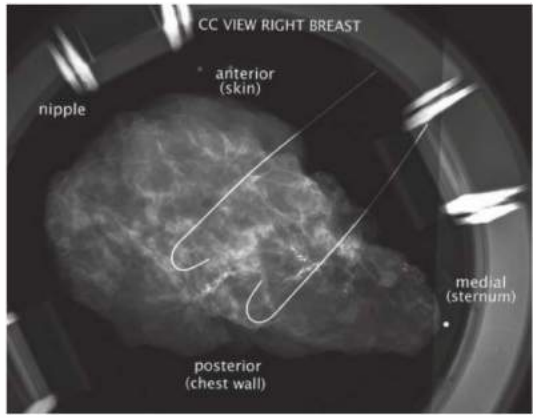

FIG 1 • Multiple bracketing wires used to perform a wire localized excision of a larger lesion.

Approach

- The patient should be supine on the OR table with the arms abducted.
- It is preferable to have both breasts prepped and draped into the field so that visual comparison with the patient in a beach chair position is possible as the wound is closed. Such an approach allows the surgeon to identify areas of unsightly tugging or dimpling inadvertently created during closure so that they can be addressed at that time.
- Multicolored inking can help orient the specimen and is best performed by the operating surgeon (**FIG 2**).

FIG 2 • Multiple ink colors are used to orient the lumpectomy specimen.

TECHNIQUES

PARALLELOGRAM MASTOPEXY LUMPECTOMY

- The most basic of the oncoplastic techniques, this involves removal of the skin island located directly superficial to the known disease and is most commonly used for superior pole or lateral cancers.[11]
- For upper inner quadrant lesions, the skin island excisions should be small or performed using a simple reapproximation of breast tissue and skin without removal of any skin island.[12]
- Removal of the overlying parallelogram of skin avoids excessive, redundant skin from being left behind after excision and helps prevent declivity.
- Be cautious when designing the skin ellipse, because removal of too broad of an island can cause substantial shifting of the NAC.
- A rounded parallelogram with two equal length lines is drawn, thus marking the skin island to be excised in conjunction with the underlying target lesion and surrounding tissues (**FIG 3**). For lesions in the upper breast, incisions should be curvilinear, whereas lesions

FIG 3 ● The rounded parallelogram, with two equal line lengths, to excise a skin island en bloc with the tumor.

FIG 5 ● The lumpectomy specimen is lifted off the pectoralis muscle.

located within the lower breast, including the 3 o'clock and 9 o'clock positions, should have a radially placed parallelogram.

- The proposed skin incision is made to breast parenchyma (FIG 4).
- After excision of the skin island, short-distance mastectomy-type skin flaps are raised along both sides of the wound.
- Dissection is carried down to the chest wall, the breast gland is lifted off the pectoralis muscle (FIG 5), and a standard tumor resection is performed.
- Four to six marking clips are typically placed at the base of the defect within the surrounding fibroglandular tissue.
- Once resection is complete and hemostasis obtained, the fibroglandular tissue at the level of the pectoralis fascia is undermined so that breast tissue advancement can be performed over the muscle (FIG 6).
- The margins of the residual cavity are then shifted together by the advancement of breast tissue over muscle and the defect is sutured at the deepest edges using 3-0 absorbable suture. The direction of tissue advancement can be adjusted depending on the location of the fibroglandular defect and the excess tissue that can be shifted to close it. The goal of the mastopexy is to perform as complete of a closure over the pectoralis muscle as possible to discourage communication between the anterior skin and the deeper tissues (FIG 7).
- The superficial tissue layer is closed with interrupted subdermal absorbable sutures (we use 3-0 sutures), whereas the skin is closed by absorbable subcuticular sutures (we use 4-0 sutures) in routine fashion (FIG 8).

FIG 4 ● The skin of the rounded parallelogram is divided with a scalpel down to the breast parenchyma.

FIG 6 ● The fibroglandular tissue is elevated off the pectoralis fascia in order to advance it over the muscle.

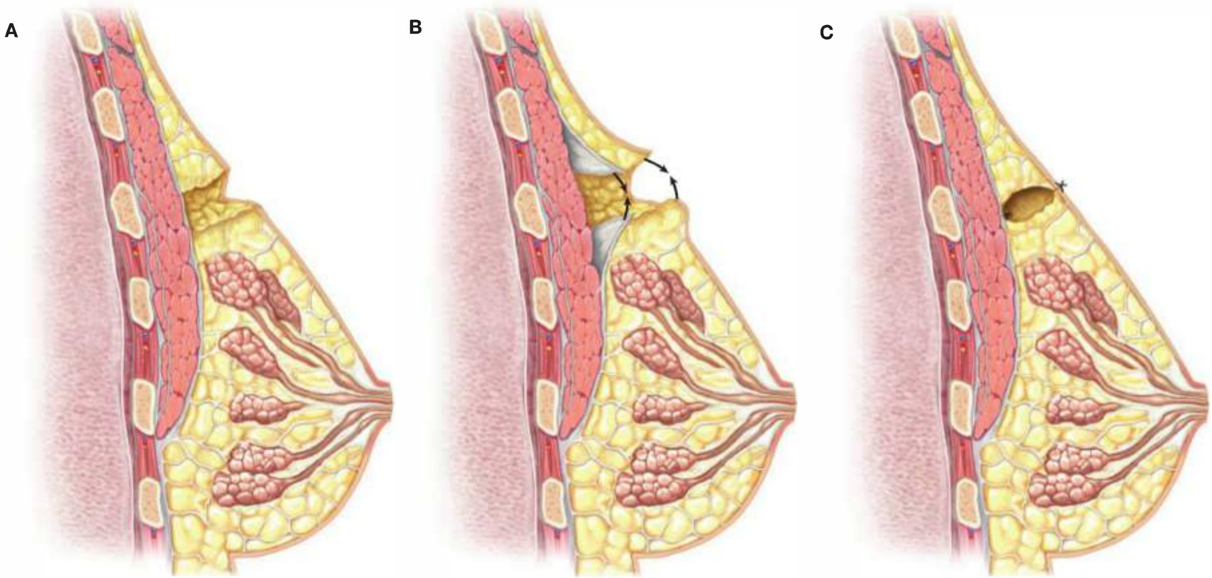

FIG 7 ● **A–C.** The fibroglandular tissue is advanced over the pectoralis muscle to separate the deeper tissues from the overlying skin.

FIG 8 ● Closure of the rounded parallelogram.

BATWING MASTOPEXY LUMPECTOMY

- For cancers adjacent to or deep to the NAC, but without direct involvement of the nipple, lumpectomy can be performed without sacrifice of the nipple itself.
- The batwing approach simultaneously preserves NAC viability as well as the breast mound by using mastopexy closure to close the resulting fibroglandular defect of the full-thickness resection.
- Two similar semicircle incisions are made with angled "wings" on each side of the areola (**FIG 9**). The two half circles are positioned to allow them to be reapproximated to each other at wound closure.
- Removal of these skin wings allows the semicircles to be shifted together without creating redundant skin folds at closure (**FIG 10**).
- Fibroglandular tissue dissection is carried down deep to the known cancer. In most situations, this dissection is carried down to the chest wall, with the breast gland lifted off the pectoralis muscle in a fashion similar to that for the parallelogram lumpectomy (**FIG 11**).
- Following full-thickness resection of the targeted lesion, some mobilization of the fibroglandular tissue for

FIG 9 ● Planned incision for a batwing mastopexy. Two semicircular incisions with angled wings on each side of the areola.

FIG 10 ● The skin is incised for a batwing mastopexy.

mastopexy closure may be required. The breast tissue is elevated off of the chest wall at the plane between the pectoralis muscle and breast gland and the remaining fibroglandular tissue is then advanced to close the resulting defect.

- We typically secure the fibroglandular tissue to itself but do not place anchoring stitches into the chest wall, thereby allowing the reapproximated breast tissues to move on the chest wall and adjust to find its most natural way to settle in for final healing. It is important to remember that what looks perfect on the chest wall when the patient is supine on the OR table may not sit as well when she sits upright and the breast becomes pendulous.
- The superficial layer is closed in the same fashion as the parallelogram mastopexy lumpectomy (**FIG 12**).
- As this procedure can cause some lifting of the nipple, it may create asymmetry when compared to the contralateral breast. If desired, a contralateral lift can be performed. Although this can be performed concurrently at the time of lumpectomy, it may be preferable after adjuvant radiation has finished and the treated breast has "declared" its new size and shape.

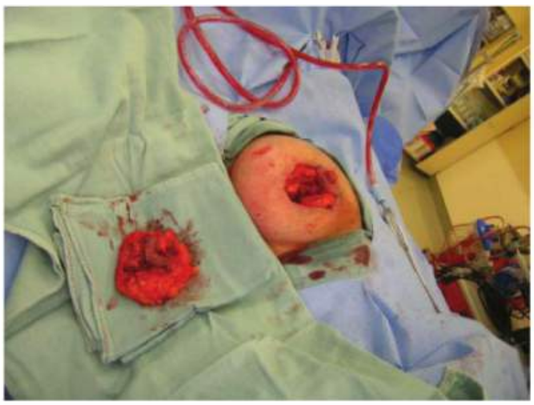

FIG 11 ● The excision is carried down to the chest wall and excised off of the underlying pectoralis muscle.

FIG 12 ● The semicircles are shifted together without creating redundant skin folds at closure.

LATERAL SEGMENTECTOMY

- A variation of the parallelogram lumpectomy, the lateral segmentectomy is especially useful for lesions located within the lower breast, including the 3 o'clock and 9 o'clock positions.
- The skin parallelogram is placed radially and, at the corner of the parallelogram which comes closest to the nipple, the design should be positioned such that the closed incision after resection will approach the NAC tangential to the periareolar line (**FIG 13**). This reduces deviation

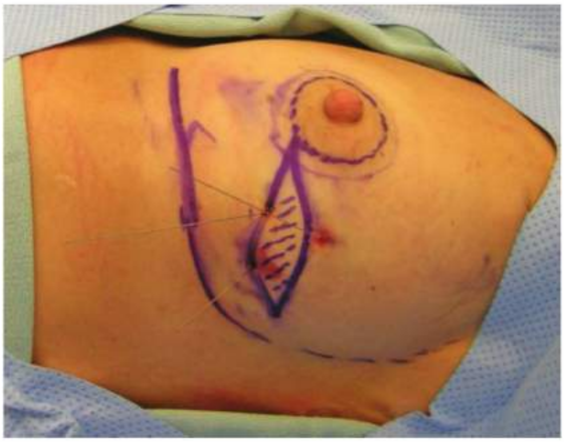

FIG 13 ● A parallelogram for a lateral segmentectomy, placed radially so that when closed, the incision will approach the NAC tangential to the periareolar line.

A

B

FIG 14 ● **A,B.** The entire specimen down to the chest wall is excised off of the pectoralis muscle.

of the NAC toward the lesion, a condition that can result from scar contraction.

- This radial approach gives more projection to the nipple, avoiding the downward displacement, which can be caused by a purely horizontal scar in the lower pole of the breast.
- The proposed skin incision is made to breast parenchyma.
- After excision of the skin island, short-distance mastectomy-type skin flaps are raised along both sides of the wound.
- Dissection is carried down to the chest wall, the breast gland is lifted off the pectoralis muscle, and a standard tumor resection is performed (**FIG 14**).
- Four to six marking clips are typically placed at the base of the defect within the surrounding fibroglandular tissue.
- Once resection is complete and hemostasis obtained, the fibroglandular tissue at the level of the pectoralis fascia is undermined so that breast tissue advancement can be performed over the muscle.
- The margins of the residual cavity are then shifted together by the advancement of breast tissue over muscle and the defect is sutured at the deepest edges using 3-0 absorbable suture.
- The superficial tissue layer is closed with interrupted subdermal absorbable sutures (we use 3-0 sutures), whereas the skin is closed by absorbable subcuticular sutures (we use 4-0 sutures) in routine fashion (**FIG 15**).

FIG 15 ● The lateral segmentectomy incision after closure.

CENTRAL LUMPECTOMY

- The cosmetic impact of nipple removal, which is an unfortunate necessity when cancer involves the NAC, likely accounts for the common use of mastectomy among these individuals despite the existence of the alternative option of central lumpectomy.
- Although central lumpectomy removes the NAC and underlying central tissues, it typically leaves behind a significant breast mound.
- The cosmetic outcome with central lumpectomy can range from good to outstanding, depending on the woman's body habitus, and may be better tolerated than mastectomy and subsequent reconstruction, particularly in women with large breasts where total mastectomy may create prominent asymmetry.
- In central lumpectomy, the incision can be made in the pattern of a large parallelogram, which encompasses the entire NAC. Angling the incision along the lay of the breast when the patient is upright may lead to a more natural position of the scar.
- After excision of the skin island, short-distance mastectomy-type skin flaps are raised along both sides of the wound.

FIG 16 ● The central segmentectomy cavity after excision of the tumor down to the underying pectoralis muscle.

- Dissection is carried down to the chest wall, the breast gland is lifted off the pectoralis muscle, and a standard tumor resection is performed (FIG 16).
- Four to six marking clips are typically placed at the base of the defect within the surrounding fibroglandular tissue.
- Once resection is complete and hemostasis obtained, the fibroglandular tissue at the level of the pectoralis fascia is undermined so that breast tissue advancement can be performed over the muscle.
- The margins of the residual cavity are then shifted together by the advancement of breast tissue over muscle and the defect is sutured at the deepest edges using 3-0 absorbable suture. The superficial tissue layer is closed with interrupted subdermal absorbable sutures (we use 3-0 sutures), whereas the skin is closed by absorbable subcuticular sutures (we use 4-0 sutures) in routine fashion (FIG 17).

FIG 17 ● The breast tissue is advanced over the muscle and the skin closed in routine fashion.

REDUCTION MASTOPEXY LUMPECTOMY

- For cancers in the lower pole of the breast, traditional lumpectomy using circumareolar incision may result in unacceptable downturning of the nipple due to scar contracture after radiotherapy.
- This unpleasant cosmetic outcome can be prevented by using the technique of reduction mastopexy lumpectomy, especially for resection of lesions in the lower hemisphere of the breast between the 4 o'clock and 8 o'clock positions.
- A reduction mammoplasty keyhole pattern incision is made (FIG 18A,B) and the skin above the areola is de-epithelialized in preparation for skin closure.
- A superior pedicle flap is created by inframammary incision and undermining of the breast tissue off the pectoral fascia to mobilize the NAC and underlying tissues (FIG 19).
- For cancers located in the inferolateral or inferomedial quadrants, the keyhole pattern can be rotated slightly to allow for a more lateral or medial excision while at the

A

B

FIG 18 ● **A,B.** Planned incision for a reduction mastopexy, including a keyhole pattern inferiorly and de-epithelialization above the areola.

FIG 19 ● Through the inframammary incision the breast tissue is elevated off the pectoralis fascia to mobilize the NAC and underlying tissues.

FIG 20 ● The resultant cavity after a full-thickness excision of the tumor.

FIG 21 ● A,B. The NAC is recentralized and the medial and lateral flaps are undermined and re-approximated, resulting in the classic inverted T scar.

same time, the NAC is moved in a direction opposite to that of the surgical defect.[12]

- Commencing inferiorly and proceeding superiorly beneath the tumor, full-thickness excision of the lesion is accomplished, with at least a 1-cm macroscopic margin of normal tissue, and the skin overlying the lesion is removed (FIG 20).
- Recentralization of the NAC is performed to recreate a harmonious breast size and shape. The medial and lateral breast flaps are undermined and sutured together to fill the excision defect, leaving a typical inverted T scar (FIG 21A,B).
- Uplifting of the NAC by virtue of removal of the superior skin island helps restore a youthful appearance to the breast but can create mild asymmetry in comparison to the contralateral breast (FIG 22).
- For patients with macromastia, consistent positioning of the breast for radiotherapy may be difficult, resulting in dosing inhomogeneity and suboptimal treatment.[13] These patients can benefit from reduction mastopexy lumpectomy using a unilateral or bilateral approach.

FIG 22 ● The reduction mastopexy can result in asymmetry compared to the contralateral breast that may require a contralateral reduction in the future.

DONUT MASTOPEXY LUMPECTOMY

- The donut mastopexy lumpectomy is best used for segmentally distributed cancers located in the upper or lateral breast to achieve resection of long, narrow segments of breast tissue.
- This technique avoids a visible long radial scar placed against Kraissl's or Langer's lines while allowing for adequate margin resection.
- Two concentric lines are placed around the areola and a periareolar "donut" skin island is excised, with only a periareolar scar visible after this operation (FIG 23).
- De-epithelialization by separating this skin island from the underlying tissues is performed, taking care to avoid full devascularization of the areolar skin.

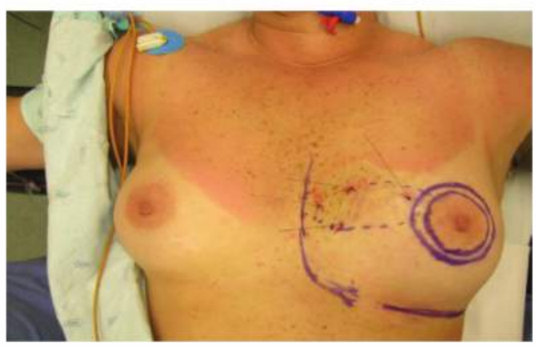

FIG 23 ● Two concentric circles are drawn around the areola, with approximately 1 cm between them.

FIG 24 ● The donut mastopexy incision.

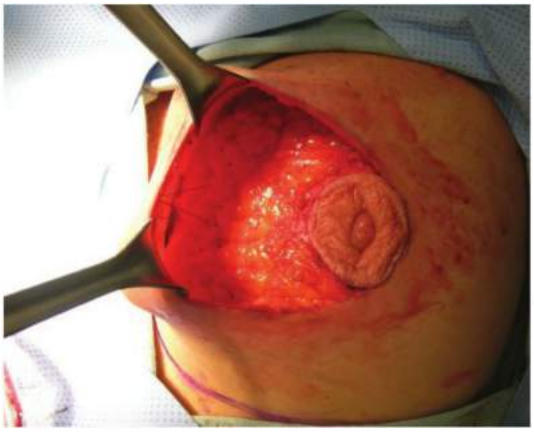

FIG 25 ● A skin flap is developed off of the tumor-bearing quadrant.

- The width of the donut skin island should be approximately 1 cm but is somewhat dependent on the size of areola and expected extent of excision (FIG 24).
- Removal of this tissue ring is required to allow for both adequate access and exposure to the breast tissue and closure of the skin envelope around the remaining fibroglandular tissue that will reduce tissue volume overall.
- A skin envelope is created in all directions around the NAC.
- The quadrant of breast tissue containing the target lesion is fully exposed using the same dissection used for a skin-sparing mastectomy (FIG 25).
- The full-thickness breast gland is then separated from the underlying pectoralis muscle and delivered through the circumareolar incision.
- The tumor-bearing segment of breast tissue is resected in a wedge-shaped fashion (FIG 26), with the width of tissue excision balanced against the difficulty that will be created by virtue of an oversized segmental defect.
- The remaining fibroglandular tissue is returned to the skin envelope; the peripheral apical corners of the fibroglandular tissue are secured to each other and then anchored to chest wall (FIG 27). This anchoring maintains proper orientation of the mobilized fibroglandular tissue within the skin envelope during the initial phases of healing.
- A purse string using absorbable 3-0 suture is placed around the areola opening at a size that reapproximates the original NAC.
- Interrupted inverted 3-0 absorbable sutures are placed subdermally around the NAC, at which time the purse-string suture is tied and then 4-0 subcuticular sutures are used to close the wound (FIG 28).
- Uplifting of the NAC may create mild asymmetry in comparison to the untreated breast, so if desired, a contralateral lift can be performed to achieve symmetry (FIG 29).

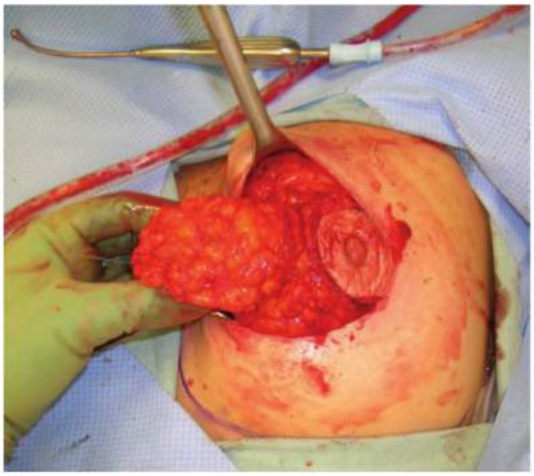

FIG 26 ● A wedge-shaped excision of the tumor-bearing tissue is performed down to the underlying pectoralis muscle.

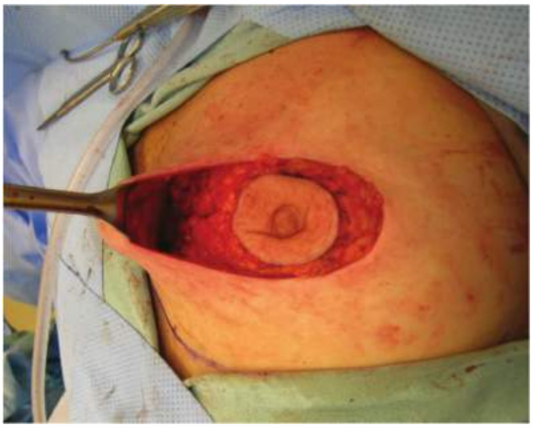

FIG 27 ● The fibroglandular tissue is reapproximated to fill the defect and anchored to the chest wall.

FIG 28 ● The circimareolar incision is closed in standard fashion.

FIG 29 ● As with the reduction mastopexy, the donut mastopexy will result in asymmetry that may require a contralateral lift and/or reduction.

PEARLS AND PITFALLS

Indications	▪ The same contraindications exist as with traditional lumpectomy: ▪ Multicentric disease ▪ Radiation contraindication ▪ Inability to obtain negative surgical margins
Nipple areolar uplifting and asymmetry	▪ May occur with some techniques, namely the batwing, reduction, and donut mastopexy lumpectomies ▪ Contralateral reduction and/or lift may be necessary.
Seroma formation	▪ More common with larger volume resections ▪ Consider small drain placement for a short time period.
Inadequate margins	▪ Will need to be addressed again surgically ▪ With limited involvement, reexcision likely is feasible. ▪ Multiple involved margins may require mastectomy to clear.
Long-term outcomes	▪ Appear to have superior cosmetic results with similar local recurrence rates

POSTOPERATIVE CARE

- Drains are rarely required in standard partial mastectomy cases, as any seroma will generally be reabsorbed.
- With more extensive dissections, such as the donut mastopexy lumpectomy, fluid accumulation can become more pronounced and may require postoperative aspiration on occasion. A 15-Fr round Blake drain left overnight will help avoid excessive fluid accumulation in the dissected breast that might distort the oncoplastic closure.
- Drains are typically removed either prior to discharge if kept overnight or on postoperative day 1 in the clinic.

OUTCOMES

- As with traditional lumpectomy, the main goal of all the oncoplastic approaches remains negative surgical margin resection.
- Excision of calcified lesions, masses, and the intended targeted lesion should be confirmed with specimen radiography during surgery.
- Additional oriented margins can be resected prior to mastopexy closure when the radiograph suggests inadequate resection may have occurred, hopefully eliminating the need for a delayed reexcision.
- Some centers use intraoperative analysis with frozen section or cytology to aid in decisions regarding the resection of additional segments of tissue.
- If subsequent reexcision is needed for inadequate surgical margins following the initial resection, use of the same incision is preferred.
- When the positive margin involves a minority of the specimen, the entire biopsy cavity does not need to be reexcised with only the involved margins of the previous biopsy cavity taken.
- When all the margins of resection are involved, mastectomy may be needed to attain satisfactory surgical clearance. In this instance, it may be technically challenging to include both the initial oncoplastic incision and the NAC in a subsequent total mastectomy and consultation with the plastic surgeon in the event that immediate postmastectomy reconstruction is mandatory.

- Although there are few large volume studies of long-term outcomes specifically addressing oncoplastic approaches in breast conservation, the results that are available are promising. One investigation from Europe followed 148 women for a median of 74 months (range 10 to 108 months) and only 2 were lost to follow-up. Among the remaining 146 individuals, there were only 5 (3%) women who suffered an ipsilateral in-breast cancer recurrence after 5 years and all had either T2 or T3 tumors at presentation.[14]
- Although additional studies are needed, it seems reasonable to presume that oncoplastic approaches, which often results in wider margins of resection than the traditional segmental mastectomy, will continue to be a sound option for breast conservation therapy.

COMPLICATIONS

- When using oncoplastic approaches, surgeons without formal training must determine which procedures they are comfortable performing without plastic surgery consultation or intraoperative collaboration.[3]
- In addition to standard potential postsurgical complications, wound infection, fat necrosis, and delayed healing in the more advanced reduction mastopexy lumpectomy have all been reported with oncoplastic resections.[15]
- The blood supply of the external nipple arises from underlying fibroglandular tissue using major lactiferous sinuses rather than the collateral circulation from surrounding areolar skin, so nipple necrosis may occur if dissection extends high up behind the nipple.[3]

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Chapter 7

Brachytherapy Catheter Insertion for Breast Cancer

Peter D. Beitsch

DEFINITION

- Breast conservation therapy (BCT) requires postlumpectomy radiation.
- Radiation can be given to the entire breast as whole breast irradiation (WBI) or to the area at the highest risk of recurrence—the breast tissue surrounding the lumpectomy cavity—by accelerated partial breast irradiation (APBI).
- APBI can be delivered from an external source (3-D conformal) or an internal source (brachytherapy).

DIFFERENTIAL DIAGNOSIS

- Brachytherapy can be delivered via multiple inserted catheters (interstitial multicatheter; **FIG 1**) or via a single insertion/multiple catheter device (**FIGS 2–4**) (see videos 1 and 2 in the accompanying eBook).

FIG 1 ● Multiple catheter interstitial brachytherapy.

FIG 2 ● Strut-adjusted volume implant (SAVI)—single insertion multicatheter strut-based device. ©Cianna Medical, Inc.

FIG 3 ● MammoSite ML—single insertion multicatheter balloon device.

FIG 4 ● Contura—single insertion multicatheter balloon device.

- Radiation oncologists usually perform the multiple catheter insertions and surgeons insert the single insertion/multiple catheter devices (which is the focus of this chapter).

PATIENT HISTORY AND PHYSICAL FINDINGS

- Patient selection for APBI is critically important (not everyone is a candidate).
- The American Society of Breast Surgeons[1] and the American Brachytherapy Society[2] have published guidelines for patient selection (Table 1).
- The American Society of Radiation Oncology (ASTRO) has published a consensus statement on patient selection for APBI (Table 2).[3]

IMAGING AND OTHER DIAGNOSTIC STUDIES

- Controversy exists whether all patients undergoing APBI should get preoperative advanced breast imaging (magnetic resonance imaging [MRI] or positron emission mammography); however, most surgeons only do so selectively.
- Ultrasound skills by the surgeon are helpful for insertion but are not mandatory.

Table 1: Patient Selection Guidelines for Accelerated Partial Breast Irradiation

Criteria	American Brachytherapy Society	American Society of Breast Surgeons
Age	≥50	≥45
Histology	IDC	IDC, DCIS
Tumor size	≤3 cm	≤3 cm
Node status	N0	N0
Margins	Negative	Negative

IDC, invasive ductal carcinoma; DCIS, ductal carcinoma in situ.

Table 2: American Society of Radiation Oncology Consensus Statement on Patient Selection for Accelerated Partial Breast Irradiation

	"Suitable"	"Cautionary"	"Unsuitable"
Definition	*Off clinical trial*	*Limited clinical data*	*Only on trial*
Age	≥60 y	50–59 y	<50 y
T size	≤2 cm	2–3 cm	>3 cm
Nodes	Neg	—	Pos
Histology	IDC	ILC or DCIS	—
Margins	Neg (>2 mm)	Close (<2 mm)	Pos
Path features	No EIC or LVI	EIC or focal LVI	>3 cm EIC/DCIS
Grade	Any	—	—
Multicentricity	Unifocal	—	—
ER status	Pos	Neg	—

IDC, invasive ductal carcinoma; ILC, invasive lobular carcinoma; DCIS, ductal carcinoma in situ; EIC, extensive intraductal component; LVI, lymphovascular invasion; ER, estrogen receptor.

SURGICAL MANAGEMENT

- Brachytherapy devices are routinely placed in the surgeon's office.
- Cavity evaluation devices (CEDs) (**FIG 5**) can be inserted at the time of the lumpectomy as a "space holder" until exchanged in the office for the brachytherapy device.

Preoperative Planning

- Preoperative consultation with the radiation oncologist will be helpful in facilitating postoperative treatment scheduling.
- Postlumpectomy placement in the office begins with the preoperative plan for the lumpectomy including
  - Location of incisions (do not perform sentinel lymph node biopsy through the lumpectomy incision)
  - Use of oncoplastic techniques (minimal flap rearrangement is okay but major flap movement with obliteration of the lumpectomy cavity negates the use of APBI)
  - Thicker wound closure if possible (more tissue between skin and cavity may require skin resection and multilayer closure)

Positioning

- Operative: No changes needed for CED placement.
- Office: Generally, brachytherapy devices are placed from lateral to medial to minimize the nontherapeutic radiation that other parts of the body receive as the brachytherapy seed travels into and out of each of the catheters.

FIG 5 ● Cavity evaluation device.

OPERATIVE PLACEMENT OF A CAVITY EVALUATION DEVICE

First Step

- After lumpectomy but before closure, a small skin nick is made laterally or inferiorly and the CED is tunneled from the skin nick into the lumpectomy cavity (**FIG 6**).

Second Step

- Inflate the balloon with enough saline to fill the cavity (**FIG 7**).

Third Step

- Deflate the balloon and close the lumpectomy wound.

Fourth Step

- Reinflate the balloon and note the volume used. This will assist in choosing the correct size of brachytherapy device to be placed in the office.
  - There is no need to suture the CED to the skin as the inflated balloon will hold it in place.

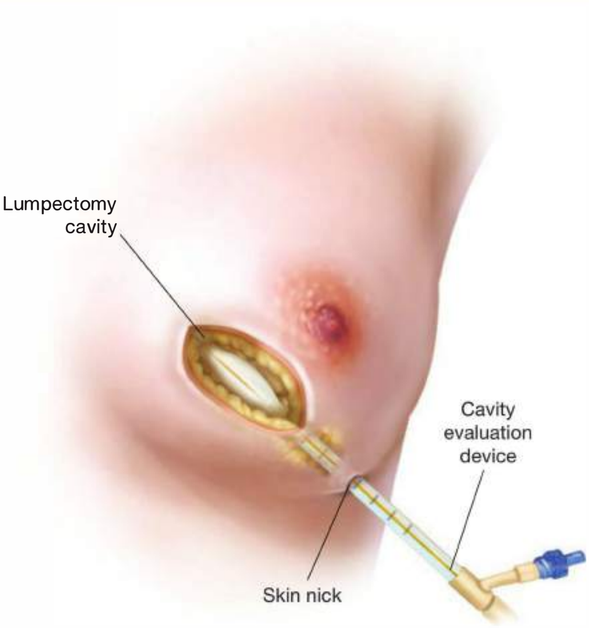

FIG 6 ● Operative placement of CED.

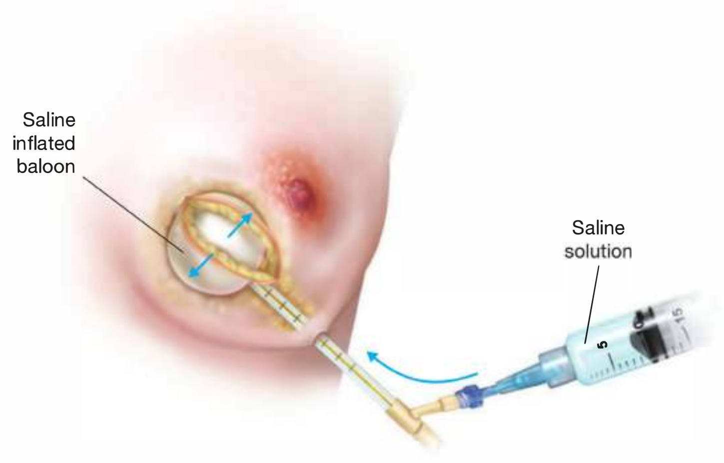

FIG 7 ● Inflating the CED.

OFFICE EXCHANGE OF CAVITY EVALUATION DEVICE FOR BRACHYTHERAPY DEVICE

First Step

- Review the pathology to ensure negative margins and negative sentinel node(s) and confirm with the radiation oncologist that the patient is a candidate for APBI.

Second Step

- Prep and drape the CED and the surrounding breast tissue with Betadine or chlorhexidine and sterile drape or towels (FIG 8).
  - Inject local anesthetic around the skin nick.

Third Step

- Deflate the CED (noting the volume used) and remove it, immediately placing the brachytherapy device through the same track into the lumpectomy cavity (FIG 9).

Fourth Step

- Inflate the balloon with the same amount of saline or expand the struts until they engage the cavity walls.

Fifth Step

- Sterilely dress the entrance site of the device.

FIG 8 ● Prep and drape the CED and surrounding breast.

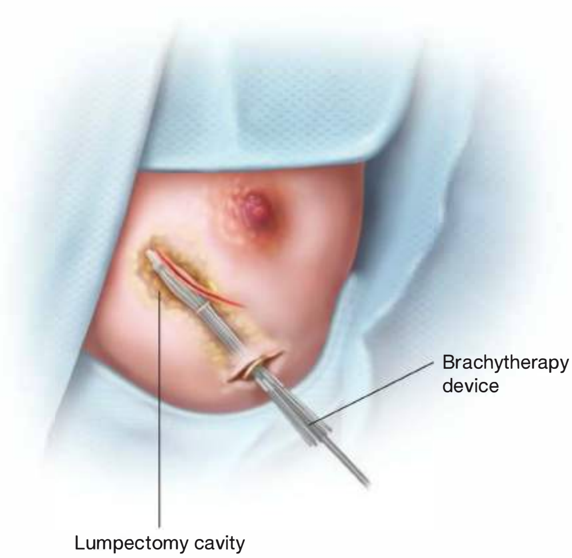

FIG 9 ● Exchange of brachytherapy device for CED through same track without need for ultrasound.

OFFICE PLACEMENT OF BRACHYTHERAPY DEVICE WITH ULTRASOUND GUIDANCE

First Step

- Review the pathology to ensure negative margins and negative sentinel node(s) and confirm with the radiation oncologist that the patient is candidate for APBI.

Second Step

- Examine the lumpectomy cavity with ultrasound to determine the best size of brachytherapy device and the best approach to place the device (**FIG 10**).
  - The approach is particularly important for the strut-based device because it is elliptical and should be placed along the long axis of the lumpectomy cavity (balloon devices will expand and make the lumpectomy cavity conform to the balloon).
  - Plan incision ~2 cm from the edge of the cavity.

Third Step

- Inject local anesthetic into the skin nick site and the track that leads to the lumpectomy cavity (**FIG 11**).

Fourth Step

- Sterilely prep and drape the site and place the ultrasound transducer into a sterile drape onto the field.
  - If a sterile transducer cover is not available, you can clean the transducer with alcohol swab and use sterile gel, but the hand using the ultrasound will no longer be sterile and therefore that hand cannot touch any of the instruments or brachytherapy device.

Fifth Step

- Use a no. 11 blade and make an approximately 12-mm incision (**FIG 12**).

Sixth Step

- The trocar is inserted into the cavity under ultrasound guidance (the lumpectomy seroma may partially evacuate at this time) (**FIG 13A,B**).

FIG 10 ● Ultrasound examination of the lumpectomy cavity.

FIG 11 ● Local anesthetic at the insertion site.

Seventh Step

- Insert the brachytherapy device through the trocar track into the lumpectomy cavity (**FIG 14**).

Eighth Step

- Inflate the balloon until you meet resistance or deploy the struts until they engage the cavity walls (**FIG 15**).

Ninth Step

- Examine the device placement with ultrasound (**FIG 16**).

Tenth Step

- Remove the center stiffener rod and replace with a catheter cap to keep fluid out of the catheter (**FIG 17**).

Eleventh Step

- Sterilely dress the device entrance site (**FIG 18**).

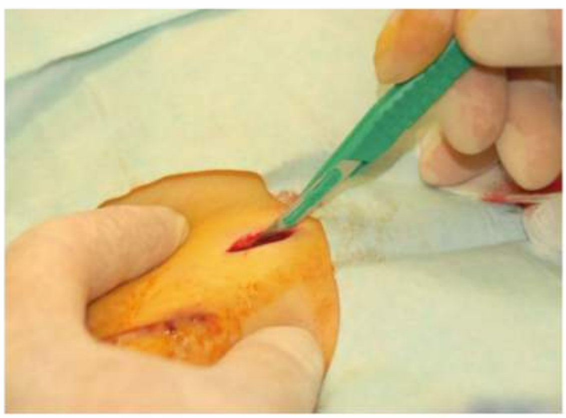

FIG 12 ● Skin incision at insertion site.

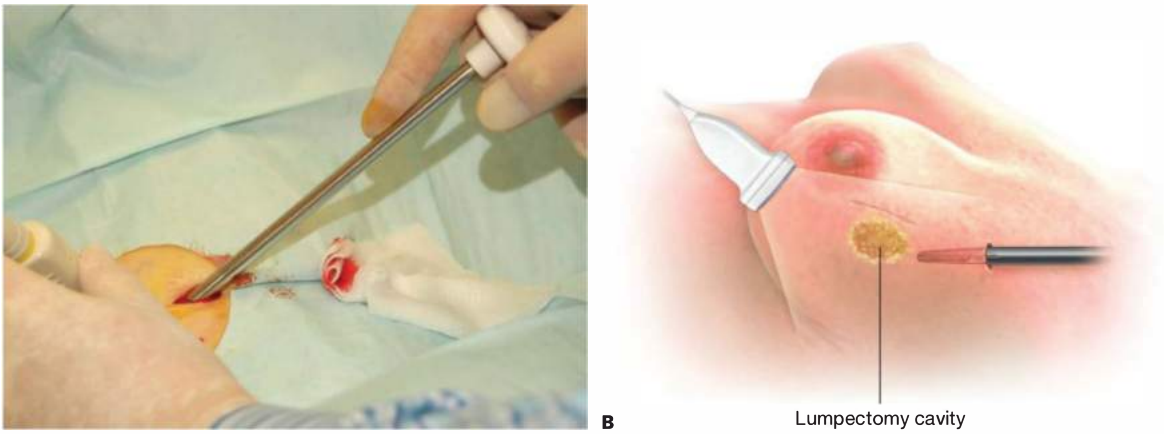

FIG 13 ● **A,B.** Trocar insertion into lumpectomy cavity under ultrasound guidance.

FIG 14 ● Brachytherapy device placement into cavity under ultrasound guidance.

FIG 15 ● Inflating the brachytherapy device balloon.

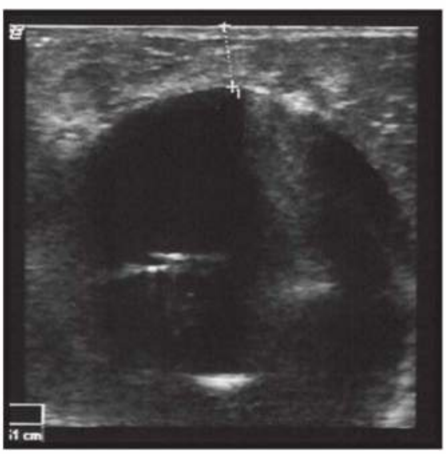

FIG 16 ● Ultrasound examination of the brachytherapy device placement.

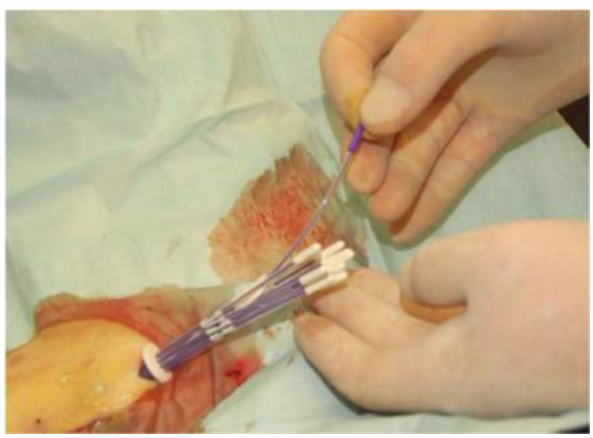

FIG 17 ● Replacing the center catheter cap.

FIG 18 ● Sterile dressing around the brachytherapy device.

PEARLS AND PITFALLS

Poor conformance of balloon device to cavity wall	■ If there is a pocket of fluid or air between the balloon and lumpectomy cavity wall (as seen by ultrasound), gently massage the breast to evacuate the fluid/air.
Drainage through track	■ There is often fluid that will drain out through the track of the CED or device. Warning your patient about this will often save a phone call at bedtime (usually occurs when patient lays down for bed).
Delay in device placement after lumpectomy	■ As the lumpectomy wound heals, the cavity will become fibrotic and eventually obliterates. This can vary between patients, but it is generally best to place the device within 4 weeks of the lumpectomy.
Avoiding radiation recall	■ If the patient is going to be receiving chemotherapy, it is best to wait a minimum of 3 weeks after the last APBI treatment to prevent radiation recall (poorly understood phenomena of noninfectious erythema overlying the lumpectomy cavity).
Minimizing skin radiation	■ Although the newer devices have multiple catheters that allow much better tailoring of the radiation to minimize radiation to normal structures (skin, lungs, ribs, heart, pectoral muscle), it is still best to create as much distance between the skin and the brachytherapy device as possible, so you may need to excise skin overlying the breast cancer and close the cavity in multiple layers.

POSTOPERATIVE CARE

- Postinsertion care includes daily dressing changes, no showering (sponge baths only until device removed).
- Most surgeons place the patient on antibiotics while the device is in.
  - Cephalexin, Bactrim DS, and ciprofloxacin are commonly used.
- Typically, the radiation oncologist will remove the device after the last treatment and Steri-Strip the opening.

OUTCOMES

- APBI has local recurrence rates of 2% to 5% at 5 years—similar to WBI.[4–7]
- Overall survival and breast cancer–specific survival are also equivalent to similarly staged patients who receive WBI.
- True recurrences (tumor bed) are usually treated with mastectomy, but elsewhere, recurrences (presumably new primaries) may be treated with lumpectomy and APBI.

COMPLICATIONS

- Early complications[4]
  - Infections—~9% (no catheter explant due to infection)
  - Seromas—~30%
    - Painful seromas—~13%
- Late complications
  - Cosmesis—excellent/good, 90%; and fair/poor, 10%
  - Fat necrosis—~2%

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Chapter 8

Sentinel Lymph Node Biopsy for Breast Cancer

Anees B. Chagpar

DEFINITION

- Sentinel node biopsy is a minimally invasive means to accurately stage the axilla in breast cancer patients.

PATIENT HISTORY AND PHYSICAL FINDINGS

- As always, a complete history and physical exam is warranted. If the patient has obvious clinically enlarged axillary lymph nodes on physical exam, ultrasound, and/or fine needle aspiration (FNA) or core needle biopsy may provide diagnostic information. If the biopsied node is positive, one could proceed to neoadjuvant chemotherapy and/or axillary dissection if primary surgery is planned. Alternatively, if the biopsied node is negative, sentinel node biopsy is still indicated for definitive evaluation.

IMAGING AND OTHER DIAGNOSTIC STUDIES

- Lymphoscintigraphy is commonly performed in conjunction with sentinel lymph node (SLN) biopsy for breast cancer, although it is not absolutely necessary.[1] Depending on how the radionucleotide tracer is injected, lymphoscintigraphy may show drainage to the internal mammary nodes (see Part 5, Chapter 9). If patients have had previous sentinel node biopsy and/or axillary node dissection, repeat sentinel node biopsy may be considered for staging ipsilateral recurrent or new primary disease. In this circumstance, alternative drainage patterns are possible, and therefore, preoperative lymphoscintigraphy may be useful.[2]

SURGICAL MANAGEMENT

- Sentinel node biopsy is indicated for staging of patients with invasive breast cancer or those with ductal carcinoma in situ undergoing mastectomy.

Preoperative Planning

- Timing of sentinel node biopsy vis-à-vis neoadjuvant chemotherapy is controversial; some opt to perform this procedure prior to initiation of neoadjuvant chemotherapy so as to most accurately stage the axilla, whereas others will do a sentinel node biopsy after completion of neoadjuvant chemotherapy so as to potentially spare patients who have had a pathologic complete response to the morbidity of a complete axillary dissection.

Positioning

- Patients are positioned supine. A roll may be placed under the ipsilateral shoulder so as to elevate the latissimus dorsi muscle. Care should be exercised to ensure that the arm is supported on folded sheets so as to avoid a brachial plexus stretch injury (**FIG 1**).
- Intravenous lines, pulse oximeter devices, and blood pressure cuffs should be placed on other extremities if possible.

FIG 1 • Patient positioned with roll under ipsilateral latissimus and folded sheets to support arm.

TECHNIQUES

INJECTION OF RADIOACTIVE TRACER AND/OR BLUE DYE

- Use of dual tracer has been shown to be associated with higher identification and lower false-negative rates[3]; however, particularly in patients undergoing skin-sparing mastectomy, surgeons may wish to forego blue dye, as the dye may discolor the skin and make it more difficult to evaluate for skin ischemia or necrosis.
  - In general, the radioactive tracer used is technetium Tc 99m sulfur colloid. For patients not undergoing lymphoscintigraphy, the tracer can be injected in the preoperative holding area. However, injection of this material is painful, and adequate counts can often be obtained with intradermal injection after induction of anesthesia. The radiotracer can be injected peritumoral, intradermal (in the skin over the location of the cancer), or periareolar (four intradermal injections around the areola). If injection is done on the same day as the operative procedure, a dose of 0.5 mCi is adequate. If injection is done the day prior to surgery, 2.5 mCi should be used.
- Both isosulfan and methylene blue dye have been used for SLN biopsy; they vary in their color, complication profile, and cost. Isosulfan blue is a more azure blue (which is easier to distinguish from venous structures) but is associated with less than 1% risk of anaphylaxis[4] and is significantly more costly than methylene blue. Methylene blue is darker, associated with a higher rate of skin necrosis, but is far cheaper.[5]

In general, 5 mL of these tracers are used; if methylene blue is chosen, it should be diluted 1:2 with saline.

- Blue dye may be injected peritumoral or using a subareolar approach. The latter allows for lymphatic mapping of multiple tumors and those which are not easily identifiable[6] (**FIG 2**). For patients undergoing breast conservation, the subareolar approach may leave the patient with a "blue breast" for some time.

FIG 2 ● Subareolar injection of blue dye.

PREPPING AND DRAPING

- The arm is prepped circumferentially along with the breast. The arm is draped into the field and kept free such that the surgeon may move the arm in a sterile fashion during the case (**FIG 3**).

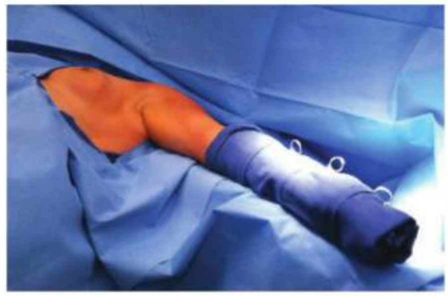

FIG 3 ● Patient draped with breast and axilla in the field; the ipsilateral arm is draped in the sterile field.

INCISION

- Identification of the area of maximal radioactivity in the axilla using a handheld gamma probe allows one to position the incision over the sentinel node.
- Landmarks of the pectoralis and latissimus dorsi muscle are used to fashion an incision for an axillary dissection of which the sentinel node incision would be a segment (**FIG 4**). A lazy S incision will allow for optimal cosmesis and will allow for extension superiorly and inferiorly if needed for maximal visualization. Alternatively, if a conventional mastectomy is planned, the sentinel node biopsy can often be performed through the lateral aspect of the same incision.
- Local anaesthetic may be used for preemptive analgesia. The incision is taken down through skin, subcutaneous tissue, and clavipectoral fascia.

FIG 4 ● Incision planning. The pectoralis and latissimus dorsi muscle borders are identified. An "X" marks the area of maximal radioactivity. A lazy S incision is fashioned for a potential axillary dissection going through the X. A smaller segment (marked by the crosshatch lines) delineates the incision for the sentinel node biopsy.

IDENTIFICATION OF SENTINEL NODES

- Care is taken to remove the hottest node, and any node with radioactive counts greater than 10% of the ex vivo counts of the hottest node. In addition, all blue nodes and those at the end of a blue lymphatic channel are also removed (**FIG 5**).
- Palpation is critical to identify any clinically suspicious lymph nodes; these should also be removed regardless of whether they are blue or hot, as tracers may not have travelled to positive lymph nodes if lymphatics are obstructed with tumor.
- Although some have argued that the procedure can be terminated after three SLNs have been removed,[7] others have argued that all nodes that fit the earlier mentioned criteria be removed.[8] On average, however, two sentinel nodes are identified.

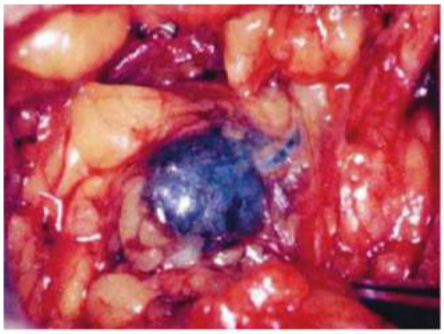

FIG 5 ● Blue SLN at the end of a blue lymphatic channel.

INTRAOPERATIVE EVALUATION

- Intraoperative evaluation with either touch preparation cytology or frozen section has been found to have a high specificity and fairly high sensitivity (**FIG 6**).
- Some surgeons may opt to forego intraoperative evaluation if they do not intend to complete the axillary node dissection at the same operative setting given the findings of the sentinel node biopsy. For patients who fit the American College of Surgeons Oncology Group Z0011 criteria, completion axillary node dissection may be avoided if only one to two sentinel nodes are positive and whole breast irradiation after partial mastectomy is planned.[9]

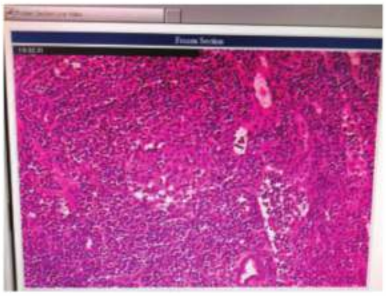

FIG 6 ● Intraoperative frozen section results.

CLOSURE

- In general, if axillary node dissection is not performed, no drains are required. The incision is closed in standard fashion with subdermal and subcuticular sutures followed by Steri-Strips. If, however, an axillary dissection is indicated, the incision can be extended (as planned in the earlier discussion).

POSTOPERATIVE CARE

- After sentinel node biopsy alone (i.e., without axillary dissection), patients can go back to usual activities. No special exercises are required nor is there any need for lymphedema compression garments.

OUTCOMES

- Outcomes after sentinel node biopsy alone are outstanding, with no detriment in survival or local recurrence. Morbidity is low, especially compared to axillary dissection.

COMPLICATIONS

- Bleeding/hematoma
- Infection
- Seroma
- Numbness/paresthesia
- Lymphedema
- Allergic reaction to isosulfan blue dye
- "Blue breast" from blue dye injection
- Skin or fat necrosis from methylene blue dye

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Chapter 9

Internal Mammary Sentinel Node Biopsy

A. Marilyn Leitch

DEFINITION

- Internal mammary node dissection is performed for both diagnostic and therapeutic purposes. This surgery is generally performed in conjunction with breast cancer surgery as part of nodal staging. In modern times, this usually involves removal of lymph nodes from one or two parasternal interspaces as part of a sentinel node staging procedure. In the first descriptions of internal mammary node dissection, the entire internal mammary nodal chain was resected including the adjacent ribs.[1] With the advent of sentinel lymph node mapping, it is possible to perform a more minimally invasive procedure to resect in a directed fashion internal mammary nodes that are demonstrated to have lymphatic drainage from the breast. Internal mammary sentinel node drainage is identified on lymphoscintigraphy in 10% to 22% of mapping studies. Internal mammary drainage is more likely to be identified if the radionucleotide is injected in the peritumoral region rather than subareolar. The technique described here to retrieve sentinel nodes can also be used to surgically biopsy small suspicious internal mammary nodes identified on preoperative imaging with computed tomography (CT) scan or breast magnetic resonance imaging (MRI).

PATIENT HISTORY AND PHYSICAL FINDINGS

- The breast cancer patient should have a careful evaluation with a complete history and physical examination as well as appropriate imaging studies. The patient's history should focus on specific breast complaints including how long the patient has been aware of the cancer in her breast, associated symptoms and signs, and focal chest wall pain. It is important to ascertain the patient's medical history to assess the patient's risk for surgery related to intercurrent medical conditions. Prior surgery such as sternotomy, coronary artery bypass graft, thoracotomy, and breast augmentation should be noted, as these may complicate the performance of internal mammary node dissection. Past history should include annotations about prior radiation to the chest wall such as mantle radiation for Hodgkin's disease. The patient should be queried about prior trauma to the anterior chest wall.
- Physical examination includes the full examination of the breast to document any palpable mass lesion, including the size and location with respect to the quadrant of the breast and its distance from the nipple. The nodal basin should be carefully examined including the cervical, supraclavicular, axillary basins, as well as the palpation of the parasternal region. If there are any evident abnormal nodes, these should be further evaluated with imaging including mammography and ultrasound. Needle biopsy of suspicious nodes can be undertaken preoperatively in order to plan the therapeutic intervention.

IMAGING AND OTHER DIAGNOSTIC STUDIES

- The standard imaging workup for a newly diagnosed breast cancer patient would include mammography and ultrasound of the breasts. Many patients will have an MRI performed as well. This study permits visualization of the internal mammary nodal chain. If an abnormal lymph node is identified, it can be biopsied with a needle or targeted for excision at the time of surgery (**FIG 1A,B**).
- CT scanning of the chest is not routine for the workup of that early-stage breast cancer. However, if a CT scan of the chest or positron emission tomography (PET)-CT is performed for other indications, internal mammary node enlargement may be identified (**FIG 2A,B**). If the patient has palpable fullness in the parasternal region, a CT scan should be ordered to evaluate for internal mammary nodal metastases.
- In order to identify the internal mammary nodal drainage in the sentinel node procedure, it is critical to inject a radiolabeled tracer for mapping of the pathways to the internal mammary nodes. To maximize the chance of identifying internal mammary lymphatic drainage, it is important to perform the injections of technetium sulfur colloid in the peritumoral region rather than performing a subareolar injection only. Lymphoscintigraphy can be performed to have a visual representation of the location of the internal mammary drainage (**FIG 3A–D**). The area of radioactivity in the parasternal region can be marked on the skin by the nuclear medicine technician at the time of scanning (**FIG 4A,B**). This increases the efficiency of identifying the appropriate interspace for exploration for the sentinel node. Most commonly, there will be one interspace that demonstrates a hot spot. However, more than one interspace may demonstrate a radioactive focus. The most common areas of drainage are the 2nd and 3rd interspaces.

SURGICAL MANAGEMENT

Preoperative Planning

- The lymphoscintigraphy should be reviewed prior to going into the operating room. It is important to consent the patient specifically for the internal mammary exploration. Knowing from the lymphoscintigraphy that there is internal mammary lymphatic drainage, the surgeon can convey to the patient that this pathway can be pursued if the patient is agreeable. If it is the practice of the surgeon not to perform lymphoscintigraphy prior to surgery, then the interspaces can be examined intraoperatively with the gamma probe to identify foci of increased radioactivity in the parasternal interspaces. It remains important to consent the patient for the possibility of an internal mammary exploration with its potential complications.

Positioning

- The patient is positioned supine with the arms abducted to 90 degrees on padded arm boards. The skin prep of the chest wall should cross to the contralateral breast so that the sternum and parasternal regions are draped into the field of operation.

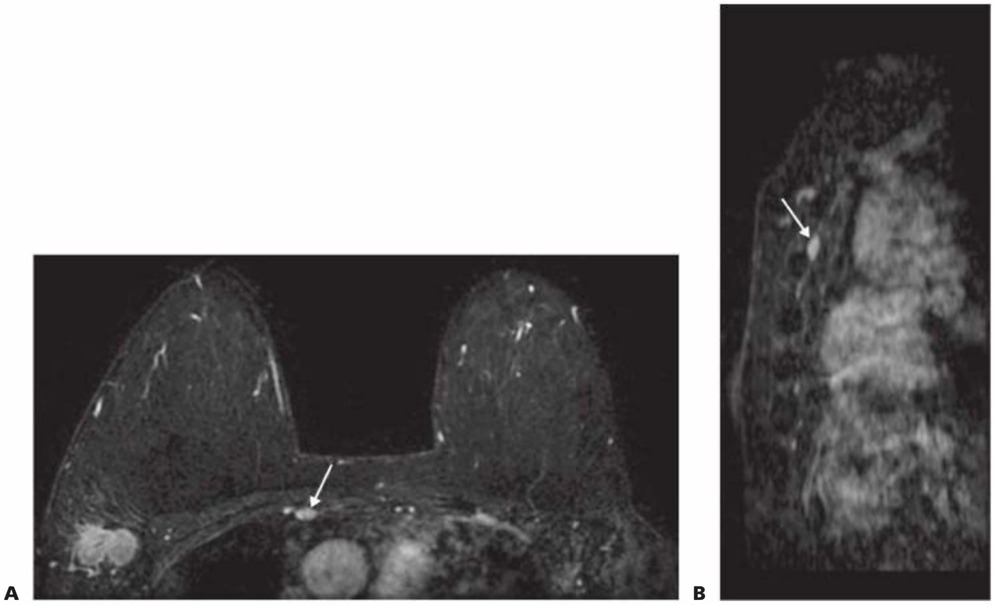


FIG 1 ● **A.** Abnormal right internal mammary lymph node and right axillary lymphadenopathy seen on breast MRI axial T1 postcontrast subtraction series. **B.** Breast MRI. Sagittal T1 reconstruction demonstrating the abnormal internal mammary node. (Courtesy of Stephen Seiler, MD, University of Texas Southwestern Medical Center.)

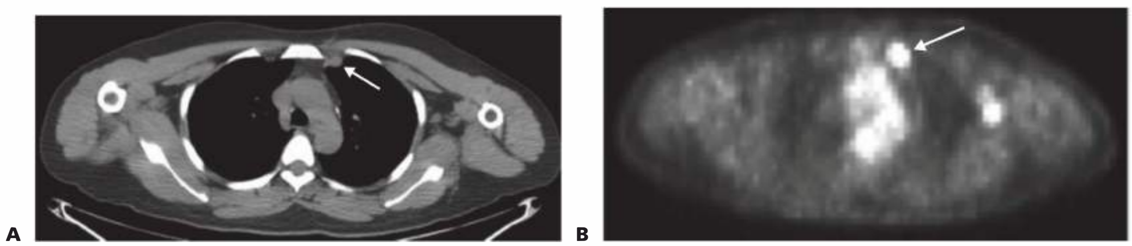


FIG 2 ● **A.** Chest CT scan demonstrating enlarged left internal mammary node. **B.** PET scan image shows fluorodeoxyglucose (FDG) uptake in the left internal mammary node. (Courtesy of Stephen Seiler, MD, University of Texas Southwestern Medical Center.)

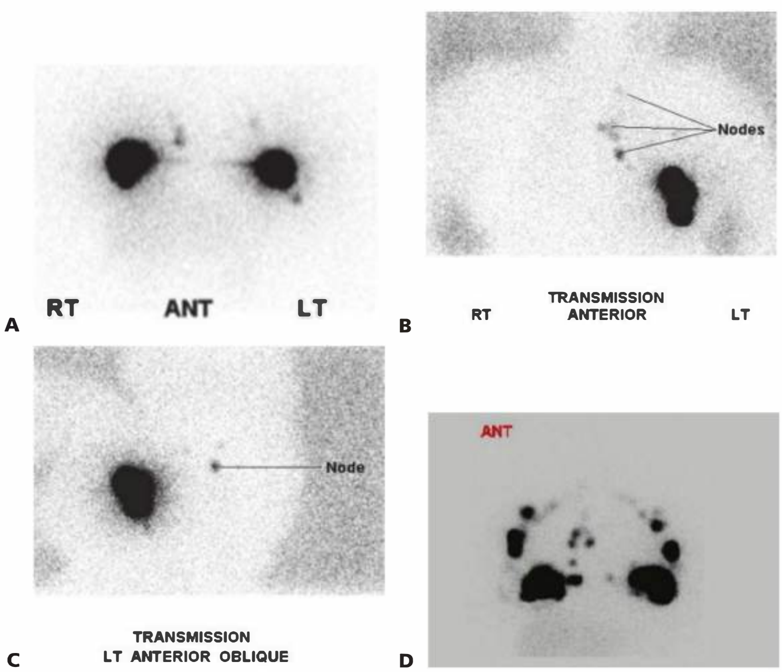


FIG 3 ● **A.** Lymphoscintigraphy of bilateral breasts demonstrating internal mammary nodal drainage on the right in the anterior projection. **B.** Anterior projection of lymphoscintigraphy showing radioactive uptake in two interspaces with faint uptake base of neck. In this view, the axillary node is faint. **C.** Left anterior oblique projection shows the axillary uptake more intensely. **D.** Lymphoscintigraphy (anterior projections) with lymphatic drainage to multiple internal mammary nodes.

TECHNIQUES

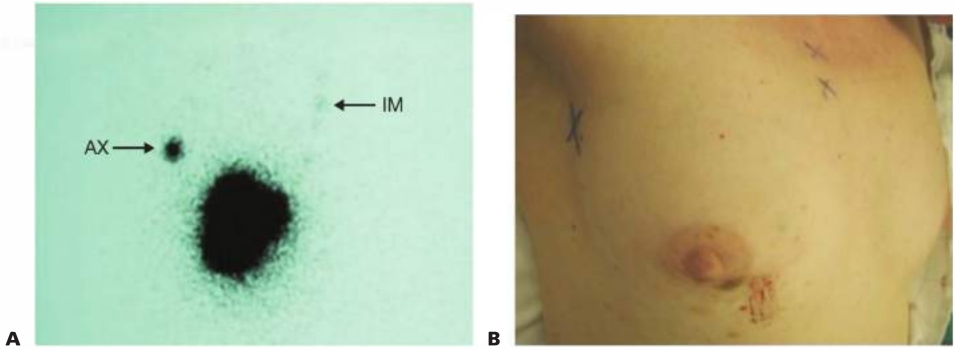


FIG 4 ● **A.** Lymphoscintigraphy demonstrating intense radioactivity in the right axillary node basin and very faint radioactivity in the internal mammary basin. **B.** Note "X" marks placed by the nuclear medicine technician to guide gamma probe examination.

INCISION AND INITIAL IDENTIFICATION OF AREA OF INTERNAL MAMMARY SENTINEL NODE

- Placement of the incision is governed by the procedure planned for resection of the breast tumor. For patients having breast-conserving surgery, the incision for the primary tumor is placed overlying the primary lesion. If the primary lesion is near to the area of internal mammary drainage, then it may be feasible to explore the interspaces via the partial mastectomy incision. However, if the primary lesion is distant from the parasternal region, then the incision for exploration of the interspace is placed overlying the area of focal radioactivity.
- If the patient is undergoing a mastectomy, the standard mastectomy incision is used for accessing the parasternal interspaces (FIG 5). When reconstruction is planned, the mastectomy incision is generally more limited with the skin-sparing technique. However, the parasternal region can be generally accessed via these incisions with retraction of skin flaps, unless there is nipple preservation with the incision placed in the inframammary line. In this circumstance, the incision location would be determined in a similar fashion as patients having breast-conserving surgery.
- It is much easier to identify the area of focal radioactivity in the interspaces after the breast is removed or after the partial mastectomy is completed. This reduces the amount of background radioactivity, which increases the ease of identifying radioactivity in an internal mammary node. In order to find an internal mammary sentinel node, it is imperative to have a strong signal that can be picked up by the gamma probe to direct the incision placement.
- Lymphazurin blue, which is often injected for identification of the sentinel nodes in the axilla, should be injected prior to beginning any resective procedure in the operating room. Lymphazurin blue alone will not be successful in identifying the internal mammary sentinel nodes. However, once the area of radioactivity is identified and exploration is begun, blue lymphatics or staining of the sentinel nodes may be identified but not with the frequency that it is seen in the axillary nodes. As with the radioactive tracer, the blue dye is more likely to be identified in the internal mammary nodes if the injection is peritumoral.
- After the blue dye is injected, the axillary sentinel node exploration is then begun. (Refer to Part 5, Chapter 8 for more information on sentinel node dissection.) In most cases, there will be an axillary sentinel node identified in those patients who also have internal mammary drainage.
- The mastectomy or partial mastectomy is then performed.

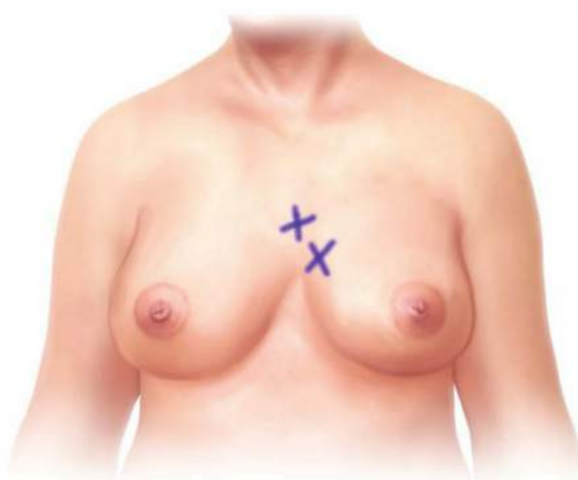


FIG 5 ● Skin sparing mastectomy incision with edge retracted to expose parasternal interspace.

EXPLORATION OF THE PARASTERNAL INTERSPACES

- Using the gamma probe, the **parasternal interspaces** are examined in sequence from superior to inferior. In patients having a standard or skin-sparing mastectomy incision, the skin edges can be retracted with a Richardson retractor or with Lone Star hooks, which can obviate the need for an assistant to retract. With the pectoralis muscle exposed, the gamma probe is then placed directly on the muscle after palpating the interspace. When an area of focal radioactivity is identified, counts are taken for 10 seconds, two or three times with a background taken a centimeter away to confirm that it is a focal hot spot. Counts are taken at each interspace.
- For the partial mastectomy patients, the initial examination with a gamma probe may have to be done through the skin overlying the interspaces if the partial mastectomy incision is away from this area. Because the skin surface is farther from the node, it can be more technically difficult to identify the hot spot. Each interspace is examined and counts taken as described for the mastectomy. When the focal hot spot is identified, the incision is made overlying the interspace along the axis of the ribs (**FIG 6**). The incision is carried through the skin, the subcutaneous tissue, and any underlying breast tissue down to the pectoralis muscle. A self-retaining retractor is placed to expose the pectoralis muscle widely. Lone Star hook retractors may be used if the thickness of the tissue in this portion of the breast is thin.

A B

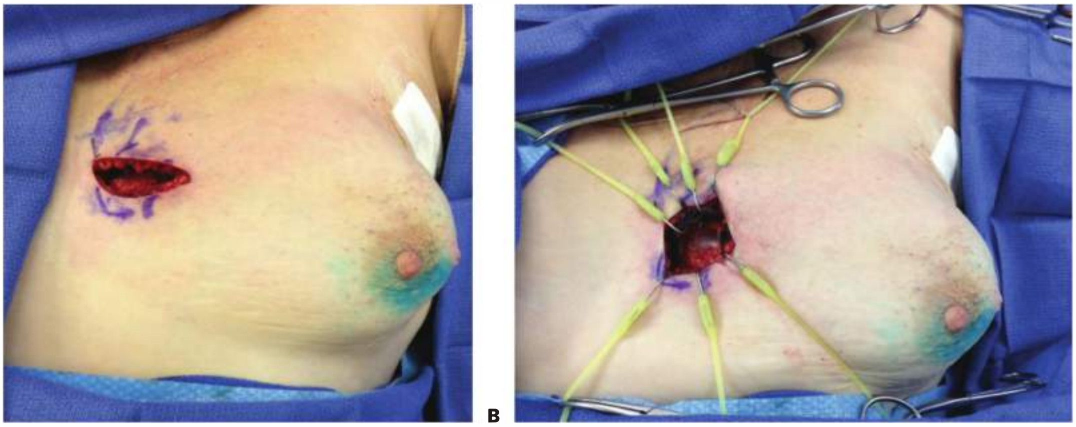


FIG 6 ● **A.** Parasternal incision in conserved breast with exposure of pectoralis muscle. **B.** Lone Star hook retractors placed to retract skin to expose muscle.

DISSECTION THROUGH THE CHEST WALL

- Once the pectoralis major muscle is exposed overlying the radioactive interspace, the fibers of the pectoralis muscle are split along their axis. A small self-retaining retractor or Lone Star hooks are placed to hold the fibers apart (**FIG 7**). Examination is performed again with the gamma probe to confirm that the radioactivity is persistent deep to the pectoralis muscle (**FIG 8**). If there is persistent radioactivity, then the intercostal muscles are incised with electrocautery over a 3- to 4-cm length extending from the sternal edge laterally (**FIG 9A**).

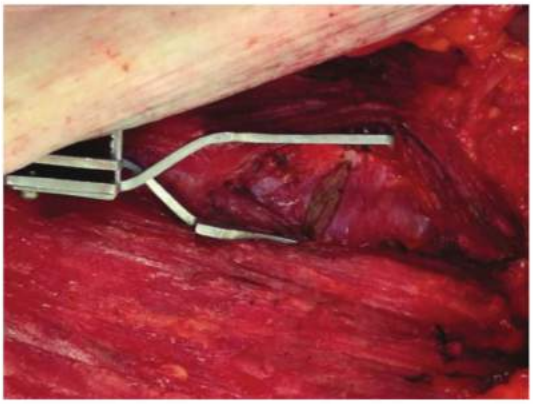
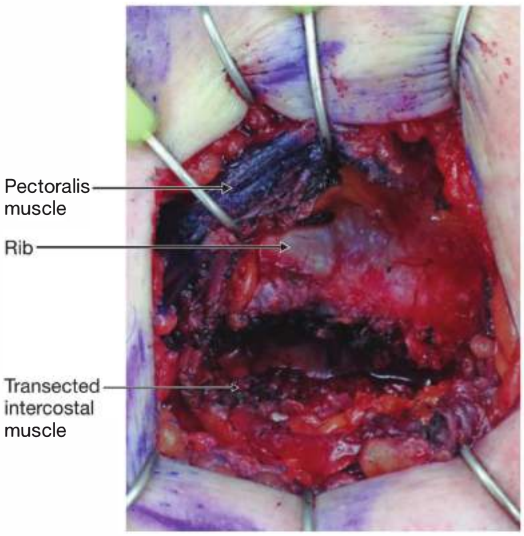


FIG 7 ● Pectoralis muscle fibers split and retracted to expose intercostal muscle.

FIG 8 ● Examination is performed again with the gamma probe to confirm that the radioactivity is persistent deep to the pectoralis muscle.



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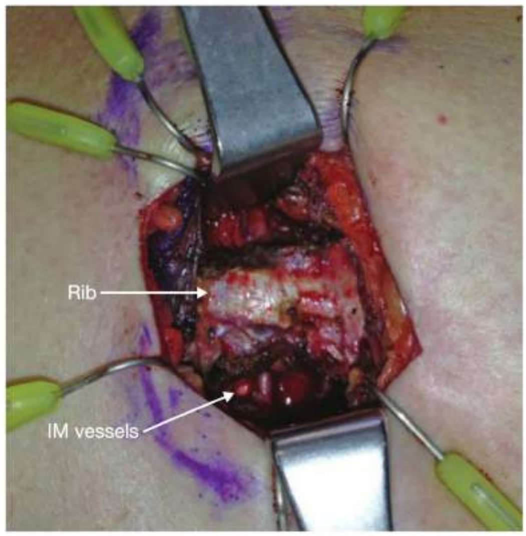


B

FIG 9 ● Exposure of intercostal space in breast conserving surgery with intercostal muscle divided **(A)**. Two interspaces exposed by dividing intercostal muscle above and below the rib via this limited incision. The internal mammary vessels are medially located in the interspace **(B)**.

DISSECTING IN THE INTERSPACE TO RETRIEVE THE SENTINEL NODE

- A thin, filmy fascia is incised deep to the intercostal muscles to expose a thin plaque of fatty tissue that lies just anterior to the pleura. Again, the gamma probe is used to localize the node that will be in fatty tissue deep to the intercostal muscles. The internal mammary vessels are most medial in the interspace (FIG 10)
- The sentinel nodes are often quite small and are yellow to yellow tan in color. Thus, their identification may be somewhat tedious. Frequent use of the gamma probe helps to direct the dissection. Fine instruments are used to tease out the fat around the nodal tissue. A small Kittner may be used to gently tease away the fatty tissue to expose the nodes. Small titanium clips can be used to ligate fine capillaries. It is critical to avoid any bleeding, which can obscure the small operative field. The lymph nodes may be intimately related with the internal mammary vessels, so any branches must be securely ligated in dissecting the node away from these vessels. The pleura will be exposed as the fatty tissue is teased away with the movement of the lung visible through the thin pleura (FIG 11).
- When the node is removed, gamma counts are taken of the node to confirm its radioactivity (FIG 12). The interspace is again examined with the gamma probe to confirm there is no residual radioactivity. If there is residual activity, further exploration is done to identify any other sentinel nodes in the interspace.

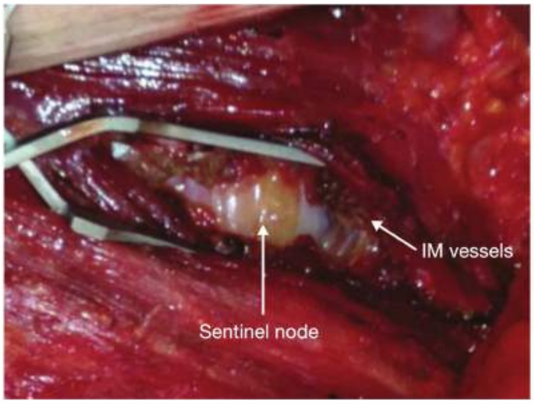


FIG 10 ● Right mastectomy procedure with exposure of interspace showing internal mammary vessels medially and yellow sentinel node lateral to vessels.

FIG 11 ● Mastectomy site with pectoralis muscle retracted and pleura visible after removal of sentinel node.

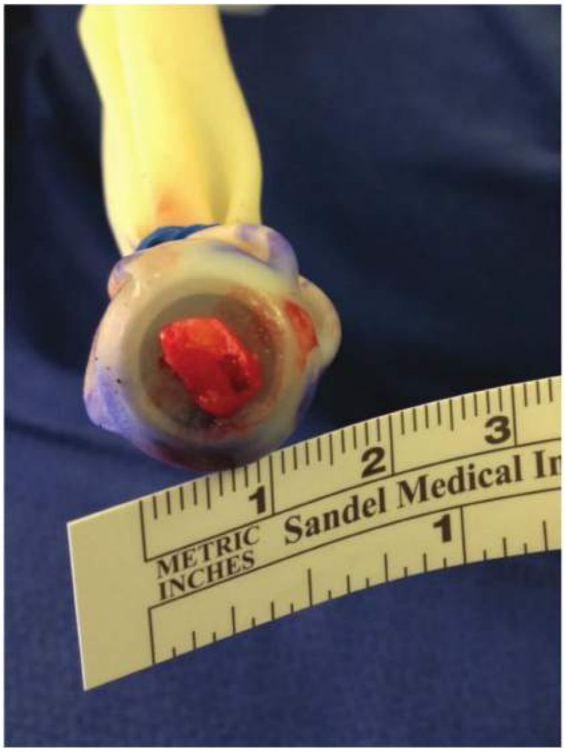


FIG 12 ● Internal mammary node ex vivo on gamma probe to confirm radioactivity in resected specimen.

EXAMINATION OF THE INTERSPACE FOR A PLEURAL TEAR

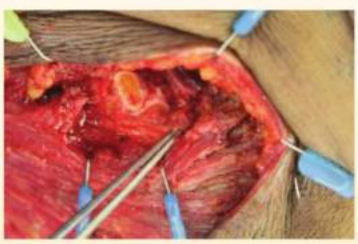
- The wound is irrigated to clear all blood and loose fat tissue that may obscure the field. Then, irrigation fluid is instilled and left to pool in the interspace. The anesthesiologist can then deliver a sustained breath into the endotracheal tube. The interspace is observed for air bubbles. If air bubbles are seen, a pleural tear can be assumed.
- One can aspirate the fluid and look for the tear. If the tear can be identified, it can be repaired with a 5-0 suture. This is more important if the tear is large. A small red rubber catheter can be put in the opening with repair performed up to it. Prior to tying the suture, the tube can be aspirated with the anesthesiologist giving a sustained breath to the patient to inflate the lung. The tube is removed and the suture tied down.
- If the tear if quite small, attempting repair may enlarge the hole. Fluid can be placed in the interspace and wound closure begun with the anesthesiologist maintaining lung inflation.

WOUND CLOSURE

- The intercostal muscles cannot be reliably closed, as the sutures tear through the muscle.
- Close the posterior fascia of the pectoralis muscle in a running fashion with 3-0 Vicryl suture.
- Then, close the anterior pectoralis muscle or muscle fascia, if present, with a running 3-0 suture (**FIG 13**).
- With mastectomy, a drain is placed overlying the chest wall in the usual fashion. Closed suction bulb is attached. Skin closure is then performed. The dermis is closed with interrupted 3-0 or 4-0 absorbable suture. The skin is closed with a running monofilament absorbable suture.
- Wound closure in the partial mastectomy circumstance should include closure of the divided breast tissue anterior to the interspace to avoid a soft tissue defect over the interspace. This is performed with either a running or an interrupted 3-0 absorbable suture. The dermis and subcutaneous tissue is closed with interrupted 3-0 or 4-0 absorbable suture. The skin is closed with a running monofilament absorbable suture.

FIG 13 ● Closure of the anterior pectoralis muscle or muscle fascia, if present, with a running 3-0 suture.

PEARLS AND PITFALLS

Preoperative planning	■ The injections of the radionuclide for lymphatic mapping should be performed in the peritumoral region rather than subareolar alone in order to identify the lymphatic pathways to the internal mammary nodes.
Placement of incision and exposure	■ Making exposure easier—If free flap breast reconstruction is being done with anastomosis of vessels to the internal mammary vessels, wait to remove the internal mammary sentinel node until the vessel exposure is done with removal of the costochondral cartilage which gives much wider exposure (**FIG 14**). If the patient has breast implants, prepectoral, or subpectoral, be certain that the implant is well retracted from the interspace to permit adequate exposure but also to avoid implant injury. There will be a fibrous capsule to be dissected through to get to the intercostal muscle.  **FIG 14** ● Removal of the costochondral cartilage.
Exploration of the parasternal interspaces	■ Performing examination with the gamma probe after the breast or breast lesion is removed will make identification of the area of radioactivity in the internal mammary nodal chain easier, because of reduction of background radioactivity.
Dissection through the chest wall	■ Reexamine with the gamma probe at each layer through the chest wall to be certain there is persistent radioactivity in the next layer. There can be an intramammary node medially that picks up radioactivity or background radioactivity may have complicated the exam.
Dissecting in the interspace	■ Avoid excessive bleeding. Dissection must be careful and deliberate with securing of even very small vessels. An obscured field will increase chance of pleural tears or more major vasculature injury. When biopsy is being performed for an abnormal internal mammary node identified on preoperative imaging, it may be necessary to remove the costochondral cartilage to expose and successfully remove the enlarged node.
Closure	■ Know when to stop. When performing the surgery for staging, do not risk major vasculature injury if you are not able to find the node with usual maneuvers. Place a titanium clip to mark the area of increased radioactivity, which can inform radiation planning.

POSTOPERATIVE CARE

- In the recovery room, a chest x-ray should be performed if a pleural tear occurred to be certain there is no significant pneumothorax.
- If the surgeon is early in experience, a chest x-ray may be done as routine postoperatively.
- A small pneumothorax will generally not require therapy, as there is no intrinsic lung injury with ongoing air leak.
- If there is a large pneumothorax causing symptoms, then a chest tube can be placed, which can usually be removed in 1 to 2 days.
- Usual postoperative pain management is acceptable for these patients. They generally do not complain of focal pain in the area of the internal mammary node resection.
- Patients having breast-conserving surgery can be discharged home on the same day if there is no pneumothorax.

OUTCOMES

- Success in identification of the internal mammary sentinel node at surgery varies from 70% to 100%.[2]
- Complications from internal mammary node biopsy are rare, ranging from 0% to 5%. Even when a pleural injury occurs, chest tube drainage is rarely required.
- Recovery from this procedure is similar to that of the mastectomy or breast-conserving surgery performed at the same time.
- Patients who undergo lymphoscintigraphy and biopsy of internal mammary nodes that demonstrate lymphatic drainage have more accurate staging of their breast cancer, which can result in treatment changes. The rate of internal mammary sentinel node positivity ranges from 10% to 24%. Among five series of internal mammary sentinel node biopsy, in approximately 37% of cases, the internal mammary sentinel node was positive when the axillary sentinel node was negative.[3–7]
- The 10-year survival for patients who are internal mammary node positive and axillary node negative is similar to those who are axillary node positive alone as reported by Veronesi and colleagues.[8] In this study, patients with either axillary or internal mammary node metastasis only had a 10-year survival of approximately 54% compared to 30% if both internal mammary and axillary nodes were positive.[8] This indicates the equivalent significance of knowing the internal mammary nodal status as well as the axillary, if there is lymphatic drainage to the internal mammary nodal basin. In a modern series, patients with internal mammary nodal metastases had an overall survival of 97% at 5 years with multimodality therapy.[9]

COMPLICATIONS

- Pleural injury with or without pneumothorax
- Bleeding from injury to internal mammary vessels

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Chapter 10 Simple Mastectomy

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DEFINITION

- A simple mastectomy, also commonly referred to as a total mastectomy, is the surgical removal of all breast tissue, including the nipple–areolar complex and enough overlying skin to allow closure. A simple mastectomy does not include removal of the axillary contents; when the breast tissue and axillary lymph nodes are removed en bloc, this is referred to as a modified radical mastectomy (MRM) (see Part 5, Chapter 12). Variations of the simple mastectomy, typically performed in concert with immediate reconstruction include the "skin-sparing mastectomy," where the nipple–areolar complex is removed but the overlying skin is preserved; and the "nipple–areolar sparing mastectomy," where the native skin and nipple–areolar complex are preserved. These are described in Part 5, Chapter 11.

PATIENT HISTORY AND PHYSICAL FINDINGS

- In clinically early-stage breast cancer, survival is largely driven by risk of distant organ micrometastatic disease and ability to control/eliminate this aspect of the cancer with adjuvant systemic therapy. Locoregional manifestations of disease in the breast and axilla can usually be controlled with surgery and radiation. Multiple prospective, randomized clinical trials have therefore documented survival equivalence between breast-conserving and mastectomy surgery for invasive breast cancer as well as for ductal carcinoma in situ (DCIS). Lumpectomy for a diagnosis of breast cancer is usually followed by breast radiation to sterilize microscopic/occult foci of disease in the remaining breast tissue, thereby reducing the incidence of ipsilateral breast tumor recurrence. Many women will nonetheless undergo total mastectomy as the primary breast surgical option either because of personal preference, medical contraindication to breast radiation, or because of disease features suggesting inability to achieve a margin-negative lumpectomy with a cosmetically acceptable result (e.g., diffuse suspicious-appearing microcalcifications on mammogram, multiple breast tumors not amenable to resection within a single lumpectomy, unfavorable tumor-to-breast size ratio). It is important for the clinician to remember that aesthetic acceptability must be defined by the patient. Total mastectomy is also the conventionally accepted surgical approach for breast cancer prophylaxis in high-risk women such as those with hereditary susceptibility.
- A detailed history and physical examination is imperative on the first consultation with these patients. In addition to the details of their breast cancer diagnosis, the history should cover medical comorbidities, medications, surgeries, allergies, and also any musculoskeletal issues, which could affect operative positioning and/or radiation treatment planning. Prior chest wall irradiation (such as for Hodgkin's lymphoma or as part of breast-conserving treatment for a past ipsilateral breast cancer) is a contraindication to reirradiation and breast conservation for a new or recurrent breast cancer. Connective tissue disorders such as Sjögren's syndrome or scleroderma can result in severe radiation-related toxicity and patients with these medical conditions will typically require mastectomy for management of breast cancer, even if the tumor is detected at a small size that would otherwise have been amenable to breast-conserving surgery. Patients that are unable to raise the arm above shoulder level may have difficulty tolerating the breast radiation tangents.
- All breast cancer patients should have a detailed family cancer history, focusing on both the maternal and paternal sides of the family. Patients with a strong family history, particularly of breast and ovarian cancer, should receive genetic counseling. These patients may want to consider bilateral mastectomies for prevention of second cancers.
- A bilateral breast and lymph node examination, including the axillary, cervical and supraclavicular lymph nodes, is critical. Any patient with clinically evident lymph nodes should undergo further evaluation, including axillary ultrasound and fine needle aspiration (FNA) biopsy.
- Breast examination should focus on the size and location of the tumor, fixation to the underlying musculature or overlying skin, and skin changes, particularly those consistent with inflammatory breast cancer (erythema, swelling, peau d'orange) or locally advanced disease (bulky tumors, tumors with secondary inflammatory changes, or cancers associated with matted nodal disease). These patients may require neoadjuvant chemotherapy in order to downstage the cancer and to improve resectability. A coordinated multidisciplinary approach, including input from medical and radiation oncology specialists promptly following the breast cancer diagnosis, is important for efficient management planning and is vital to the successful treatment of these patients.
- Early-stage breast cancer patients with a clinically negative axillary exam undergoing total mastectomy require axillary staging, which can usually be performed as lymphatic mapping and sentinel lymph node (SLN) biopsy. Mastectomy patients with axillary metastases documented by either needle biopsy or SLN dissection require standard levels 1 and 2 axillary lymph node dissection (ALND) or MRM, and postmastectomy locoregional radiation needs are then determined by the full pathologic extent of disease identified in the breast and axillary contents.
- All patients planning mastectomy should be presented the option of immediate reconstruction and a consultation with a plastic surgeon. Patients who opt for immediate reconstruction may be candidates for a skin-sparing or nipple–areolar sparing mastectomy. If postmastectomy radiation is being considered, this might impact the patient's options and eligibility for immediate reconstruction. Because the axillary nodal status is a strong predictor of postmastectomy radiation benefit, it may therefore be helpful to perform the SLN biopsy prior to the mastectomy surgery in cases where immediate breast reconstruction is planned.

IMAGING AND OTHER DIAGNOSTIC STUDIES

- Breast imaging plays a vital role in the screening and diagnostic workup for breast cancer. Imaging can define the extent of the disease and help assess for any abnormalities in the contralateral breast. Bilateral mammography is essential for any patient with breast cancer. Any suspicious contralateral lesions should be worked up before making the final surgical decision.
- Axillary ultrasound can be performed in many patients with a biopsy-proven invasive cancer to identify suspicious nodes suggestive of regional involvement. Suspicious nodes on axillary ultrasound should undergo an FNA biopsy with ultrasound guidance.
- It should not be assumed that any axillary node that is palpable or suspicious on ultrasound is malignant, as often they may be reactive. They should always be interrogated with FNA biopsy; and if the FNA is negative, then definitive axillary staging should be performed by SLN biopsy. At the time of lymphatic mapping and sentinel node dissection, it is important to excise any palpable/suspicious node, regardless of whether or not the node has any appreciable radiocolloid or blue dye uptake. If local resources permit, intraoperative evaluation of the sentinel node(s) with frozen section analysis can also be useful so that the patient can proceed onto immediate completion of the ALND if metastatic nodal disease in confirmed. When frozen section analyses are available and planned, the patient must be consented preoperatively for possible conversion from total mastectomy to MRM.
- The use of magnetic resonance imaging (MRI) is controversial. For patients undergoing mastectomy, MRI may detect contralateral cancers that were not visualized on mammography. For patients that hope to pursue breast-conserving surgery, a preoperative breast MRI may detect suspicious foci of disease in the breast such that mastectomy may be recommended. MRI usage has therefore been associated with increased rates of bilateral mastectomies. However, MRIs are sensitive but not specific and may lead to false-positive findings that necessitate additional biopsies. Furthermore, the natural history of MRI-detected multifocal/multicentric lesions in the cancerous breast is unclear, as these areas of otherwise occult disease would typically be radiated following lumpectomy for the known cancer. Retrospective and prospective studies of outcome following breast-conserving surgery in patients whose breast-conserving surgery eligibility was planned with versus without breast MRI have failed to demonstrate any significant differences in cancer-related outcomes.[1–3] We do not recommend routine MRI but rather its use should be on a patient by patient basis.
- In the absence of locally advanced disease (skin or muscle involvement, multiple matted nodes), routine staging tests, such as computed tomography (CT) scan of the chest, abdomen and pelvis, or bone scan, are not indicated.

SURGICAL MANAGEMENT

Preoperative Planning

- In the preoperative area, the breast to be removed should be clearly marked and confirmed with the patient.
- Prophylactic antibiotics have been shown to reduce postoperative infections and are indicated.[4] Sequential compression devices should be placed prior to initiation of general anesthesia for venous thromboembolism (VTE) prevention.

Positioning

- The patient should be positioned supine with the arm out laterally, taking care not to abduct the arm greater than 90 degrees as this may cause an injury to the brachial plexus. For a simple mastectomy, it is not necessary to prep and drape the ipsilateral arm into the field. However, if an SLN biopsy with frozen section and possible ALND is planned, it may be reasonable to include the arm using a sterile stockinette and Kerlix wrap. The endotracheal tube should be positioned toward the contralateral side of the mouth from the side of the mastectomy.
- Position the table and lights to allow enough room above the arm for an assistant to stand.
- If an SLN biopsy is to be performed and blue dye is to be injected, this can be done at this time. Either isosulfan blue dye or dilute methylene blue dye can be injected subareolar, periareolar, or peritumoral, according to surgeon preference.
- The chest wall, axilla, and upper arm are prepped into the field. Be sure to prep widely, extending across the midline and onto the abdomen and neck.

CHOICE OF INCISION

- The standard incision for a simple mastectomy is the classic Stewart incision, an ellipse oriented medial to lateral, encompassing the nipple–areolar complex and any prior biopsy scar (**FIG 1**). Alternatively, the modified Stewart incision is angled toward the axilla. It has been suggested that the modified Stewart incision, by excising more of the dermal lymphatics running toward the axilla, may provide better local control.
- In addition to the Stewart and modified Stewart, there are alternate options for a simple mastectomy. The placement and orientation of the incision must be based on the location of the biopsy scar and/or the location of the tumor. For a palpable tumor, particularly one close to the skin, the skin over the tumor should be included in the excised skin. Planning of the skin incision in conjunction with the plastic surgeon can be quite helpful in patients undergoing skin-sparing mastectomy and immediate reconstruction. If the patient has a surgical cancer biopsy incision, this scar should be resected with the underlying mastectomy specimen. Incisions located in proximity to the nipple–areolar complex can be resected within the central skin ellipse that is being sacrificed. Incisions that are located remote from the central nipple–areolar skin can sometimes be resected as a separate ellipse of sacrificed skin, as long as the remaining skin bridge is wide enough to remain viable. The original surgical cancer biopsy scars should not be left intact in the mastectomy skin flaps because of the oncologic concern that this skin

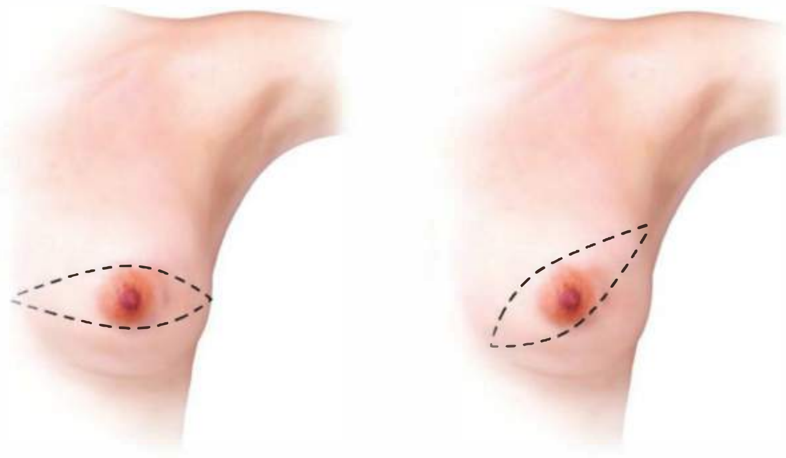

FIG 1 ● Standard incisions for a simple mastectomy. The Stewart incision **(left)** involves a horizontal ellipse that encompasses the nipple–areolar complex and adequate skin to allow a flat closure. The modified Stewart incision is angled toward the ipsilateral axilla.

may potentially harbor cancer cells (and the mastectomy skin is usually not being radiated, as is the case following lumpectomy); and from a wound healing perspective, the subcutaneous fat deep to the traumatized incisional skin will be less healthy and more likely to necrose. Old surgical biopsy scars that are unrelated to the cancer diagnosis can be left in place. Also, percutaneous needle biopsy scars can be left intact on the skin flaps, as these have not been shown to contribute to risk of local recurrence.

- It is important to remove enough skin so that there is no redundancy but not so much that there is undue tension on the incision. A useful method to determine the placement of the superior and inferior incisions is to hold a marking pen in the air over the nipple and retract the breast inferiorly. Mark this site on the skin and then retract the breast superiorly to mark the inferior extent (FIG 2A,B).
- When designing the ellipse, closure will be facilitated by making sure the superior and inferior incisions are of equal length (FIG 3). This can easily be assessed using a 3-0 silk suture.

A

B

FIG 2 ● With a marking pen held over the nipple, the breast is retracted inferiorly **(A)** and the extent of the superior flap is marked. The breast is then retracted superiorly **(B)** and the inferior extent is marked. This allows the surgeon to estimate how much skin should be excised to eliminate redundancy without undue tension.

FIG 3 ● Confirming the superior and inferior incisions are of equal length will facilitate closure.

- Before making the incision, mark the boundaries of the breast tissue. Although the breast is an obvious external feature of the human anatomy, its boundaries deep to the skin are less well defined. Lacking any clear-cut capsule to delineate breast tissue from surrounding fat and subcutaneous tissue, the surgeon must identify anatomic landmarks that serve as reasonable and relatively constant structures, beyond which it is unlikely to find significant amounts of breast tissue. These radial boundaries for the skin flaps essentially serve as a picture frame; and once these flaps are completed, the breast is dissected off the pectoralis major muscle en bloc with the pectoralis fascia. The conventionally accepted peripheral mastectomy flap boundaries are as follows: superior margin—clavicle or 2nd rib (identified by palpation); inferior margin—inframammary fold (IMF); medial margin—lateral border of the sternum (identified by palpation); lateral margin—the lateral extent of the breast tissue can be marked externally on the skin surface and the edge of the latissimus dorsi muscle is a useful vertical boundary that can be visually identified from within the mastectomy surgical field (**FIG 4**).

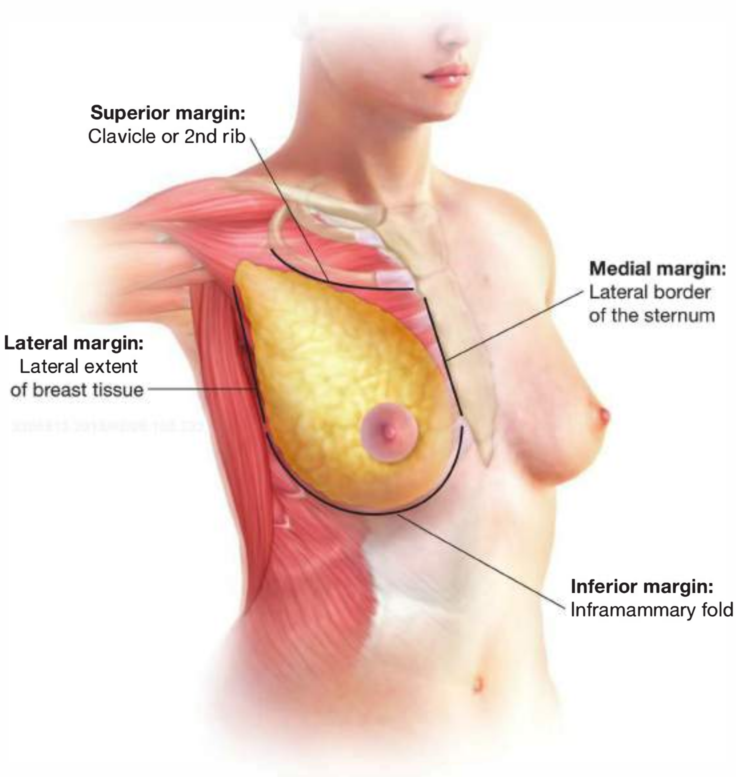

FIG 4 ● To assure removal of all breast tissue, the dissection is performed to the clavicle or 2nd rib superiorly, the IMF inferiorly, the lateral border of the sternum medially, and the lateral extent of the breast tissue or edge of the latissimus dorsi muscle laterally.

SKIN INCISION AND CREATION OF FLAPS

- Once the skin incision has been mapped out on the breast, a scalpel is used to cut through the skin and dermis. Cautery is used to then obtain hemostasis. It is important to get into the right plane to raise flaps at the start. The initial incision should extend through full-thickness skin, just barely exposing the subcutaneous fat, and no further. Incising through deeper layers of subcutaneous fat will result in a splaying out of those fatty planes, and these deeper tissues will spuriously appear as anterior margin surfaces when analyzed and inked in the pathology laboratory. The actual anterior margin of the mastectomy specimen (beyond the central ellipse of sacrificed nipple–areolar skin) should be defined by the surgeon via dissection of the appropriate-thickness skin flaps. Failing to leave a small amount of tissue beneath the dermis can lead to ischemia and wound complications, and this can be particularly concerning in cases involving immediate reconstruction. Conversely, an excessively thick skin flap leaves the patient at risk for residual breast tissue on the chest wall, thereby increasing risk of local recurrence.

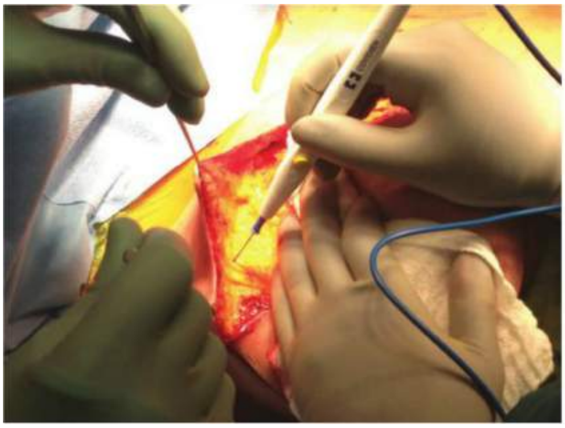

FIG 5 ● The surgeon's opposite hand is used to provide adequate tension on the breast tissue to allow elevation of the superior flap in the correct plane.

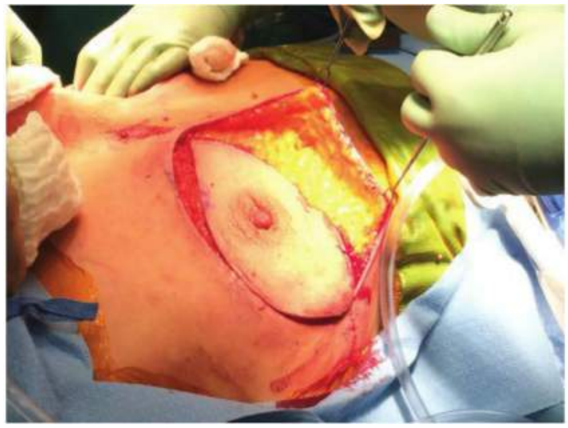

FIG 7 ● If done correctly, there will be a small amount of subcutaneous fat beneath the dermis so that the blood supply is preserved.

- Starting with the superior flap, skin hooks are used to elevate the skin and provide appropriate tension for elevation of the flap (**FIG 5**). The key to elevating an appropriate flap is the tension on the breast tissue. Initially, a forceps can be used to get into the right plane; but once that plane is identified, traction with the contralateral hand of the surgeon using a laparotomy pad on the breast tissue will be critical. As the flap elevation proceeds, it is important to reposition the contralateral hand accordingly.
- It is imperative that the assistant holding the skin hooks maintain retraction straight up (**FIG 6**). Often, a resident will retract toward themselves so they have a better view of the dissection. However, this can lead to exposing the dermis and possibly a buttonhole injury to the skin.

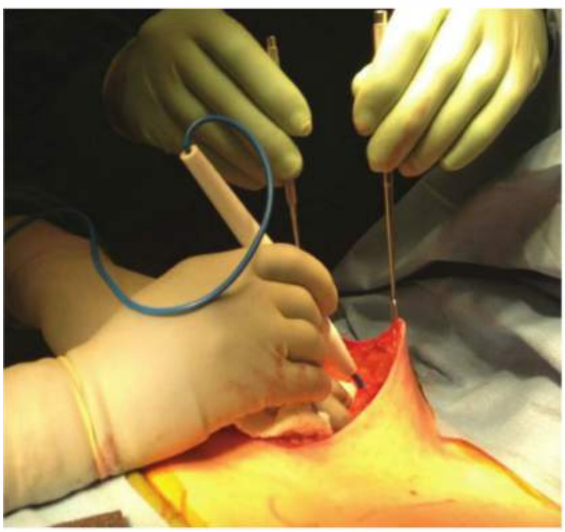

FIG 6 ● It is important that the assistant retract straight up while the flap is raised; otherwise, exposure of the dermis or injury of the flap is more likely.

- The correct plane will leave a small amount of subcutaneous fat beneath the dermis so that the blood supply is preserved while not leaving any breast tissue. This plane is often avascular (**FIG 7**). Intermittently inspecting and palpating the flap will assure the correct thickness. Older women (where much of the breast is fatty-replaced) and heavier patients often have a thicker flap of subcutaneous fat separating the skin from the underlying breast parenchyma. In contrast, younger and thin patients may have breast tissue closely abutting the dermis, allowing for a very narrow margin of error while raising the flap.
- Flaps can be elevated using cautery, scissors, or a scalpel. Cautery will help provide hemostasis during the procedure. If sharp dissection is used, pressure on the breast with a laparotomy sponge will help maintain hemostasis.
- The superior flap is complete when you reach the level of the clavicle. At this point, the pectoralis muscle should be identified and the pectoralis fascia divided (scored) along the length of the flap (**FIG 8**).
- At this point, if an SLN biopsy is to be performed, this can usually be performed through this incision. Performing the SLN at this time point allows adequate time for intraoperative analysis if conversion to an MRM is being considered. The lateral edge of the pectoralis muscle is identified and the clavipectoral fascia is identified and divided. This allows access to the fibrofatty tissue of the axilla. The sentinel nodes can now be identified by using the gamma probe or by following any blue-stained lymphatics.
- The medial margin should extend to the lateral edge of the sternum. Going too far medially can lead to excessive dog-earing, which will need excision and thus lengthen the incision. In the case of bilateral mastectomies, going too far medially can accidently connect the two incisions,

FIG 8 ● At the superior extent (clavicle or 2nd rib), the pectoralis fascia is divided along its length.

FIG 9 ● Visualization of the edge of the latissimus dorsi muscle assures the completeness of the lateral flap.

potentially contaminating the prophylactic side and complicating reconstruction.

- The inferior flap is then elevated in an identical manner to the level of the IMF. It is important to mark this, as it can easily be lost while elevating the flap. The assistant can provide feedback to the surgeon as the IMF is approached. Elevating past the IMF is not only unnecessary but can also complicate reconstruction, necessitating the plastic surgeon to recreate it to assure symmetry.
- Finally, the lateral margin is developed. As this is not an MRM, it is not necessary to thoroughly mobilize the latissimus dorsi muscle but identifying the edge of these fibers can enhance the completeness of the lateral flap (**FIG 9**). Avoiding an unnecessary mobilization of the latissimus dorsi muscle in total mastectomy patients undergoing immediate reconstruction is especially important, as creating extra dissection flaps in this lateral tissue can compromise the plastic surgery aesthetics. It is important that the lateral extent of the breast tissue is removed. This includes the axillary tail of Spence, which extends around the superior aspect of the pectoralis muscle to the clavipectoral fascia.

REMOVAL OF THE BREAST TISSUE

- Once the flaps have been completed circumferentially to the appropriate landmarks, it is time to excise the breast tissue and the pectoralis fascia off the pectoralis major muscle. It is important to remove the fascia with the specimen to assure negative margins. Failure to excise the fascia with the specimen may lead to a positive deep margin, increase chest wall recurrence, and prompt the use of postmastectomy radiation.[5] It can be useful to resect a tiny sample of pectoralis muscle fibers (labeled as sample of additional posterior margin) to serve as pathologic documentation that the mastectomy specimen included the pectoralis fascia. Some patients can have diffuse DCIS extending throughout the breast to its posterior surface, but by definition, the noninvasive nature of this disease is such that documenting resection of the pectoralis fascia is consistent with an adequate resection and further local therapy in the form of postmastectomy radiation is unnecessary. Patients with palpable breast tumors abutting the chest wall surface should have a wedge of underlying pectoralis muscle at the site of the tumor resected en bloc with the mastectomy specimen.
- The breast tissue is retracted inferiorly. This is typically done with the contralateral hand but grasping the fascia with a right-angle clamp can facilitate this. The fascia is elevated off the muscle using cautery, moving the cautery back and forth in the direction of the fibers of the muscle (**FIG 10**). This technique minimizes the damage to the pectoralis muscle.
- Small perforators extending from the pectoralis to the breast should be grasped with a hemostat or forceps and cauterized. There are slightly larger perforators medially. It is best to preserve these if possible. If not, these should be grasped and cauterized or suture

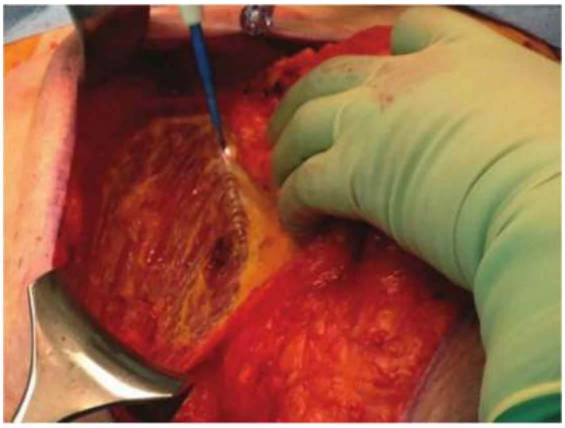

FIG 10 ● Retracting the breast inferiorly, the breast tissue and pectoralis fascia are taken off the pectoralis major. The cautery is moved back and forth in the direction of the fibers of the muscle.

FIG 12 ● As opposed to the pectoralis fascia, which is taken with the breast tissue, the fascia over the serratus anterior is left intact.

ligated (**FIG 11**). If these are accidentally divided, they often retract into the muscle and can be difficult to control. Some patients (especially older and/or less fit patients) will have a weakened, attenuated, and fatty-replaced pectoralis musculature. Caution should be exercised during the lateral retraction of the breast in these cases, as overly aggressive tugging on the breast can result in the muscle being inadvertently avulsed from its costochondral and sternal attachments.

- Dissection of the breast off the pectoralis muscle continues inferiorly toward the IMF and then out laterally. Resecting the pectoralis fascia has oncologic significance; however, fascia overlying the serratus anterior muscle can be left intact (**FIG 12**). Dissecting deep to this fascia and exposing the serratus muscle bed results in unnecessary bleeding and can place the long thoracic nerve at risk for injury, because this important motor nerve is not routinely identified through visual exposure unless the patient is undergoing an ALND.
- Intercostal nerve block: Many mastectomy patients will benefit from intraoperative injection of approximately 5 mL of 0.5% ropivacaine into 2 or 3 intercostal spaces along the surgical field lateral to the pectoralis muscle. The surgeon should notify the anesthesia staff who will then give the patient a few extra deep breaths. At maximal end expiration, the patient is taken off the ventilator while the surgeon injects the long-acting anesthetic just at the inferior edge of the selected rib to block the associated intercostal nerves. Ventilator-assisted respirations then resume. If intercostal nerve blocks as well as incisional long-acting anesthetic injection is planned, then the maximum volume of safe anesthetic delivery (based on body weight of the patient) should be calculated.

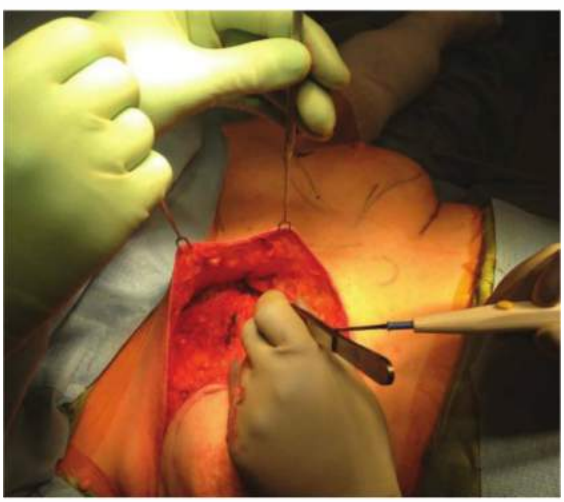

FIG 11 ● Medial perforators are grasped and cauterized.

DRAIN PLACEMENT

- A closed suction drain is placed over the pectoralis major muscle through a separate stab incision and sutured in place with a monofilament suture (**FIG 13**). When inserting the drain through the skin flap, it is useful to be mindful of the location of the latissimus dorsi muscle. Inadvertent insertion of the drain through this muscle can result in excessive bleeding from the tract. In cases where the drain tract does bleed excessively, the best remedy is to simply remove the drain, apply pressure, and replace the drain through a different tract.

FIG 13 ● A flat channel drain is placed over the pectoralis major muscle through a separate stab incision prior to closing.

CLOSURE

- Although excess tension on the incision can lead to wound complications, excess skin will lead to redundant flaps, which can be uncomfortable for the patient; they can be difficult to monitor for recurrence and can interfere with wearing a prosthesis. In cases where postmastectomy radiation and delayed reconstruction is planned, it may be helpful to leave the skin flaps a little looser, but a floppy anterior skin flap will be unsightly and serves as a site for recurrent seroma accumulation. Excess skin can be excised, so that the incision approximates flat on the chest wall. Remember that the patient is lying flat back, but once awake will slouch forward slightly, so a small amount of tension will be released.
- Commonly, the medial and lateral aspects of the incision will "dog ear." Often, these can be easily excised as an ellipse. There are times, particularly in older, heavier women, where excising the lateral dog ear simply moves the dog ear more posteriorly. In these cases, a fish-tail plasty (**FIG 14A–C**) can be useful.[6]
- The dermal layer should be closed with interrupted deep dermal absorbable sutures. Because the Jackson-Pratt (JP) drain will evacuate the postoperative seroma formation, the mastectomy skin flap closure should be subject to minimal tension. A reasonable closure alternative can therefore rely on a few interrupted sutures to line up the appropriate skin closure, followed by a running, continuous absorbable deep dermal suture. The skin can be approximated with an absorbable 4-0 monofilament suture in a running subcuticular closure or a surgical adhesive.

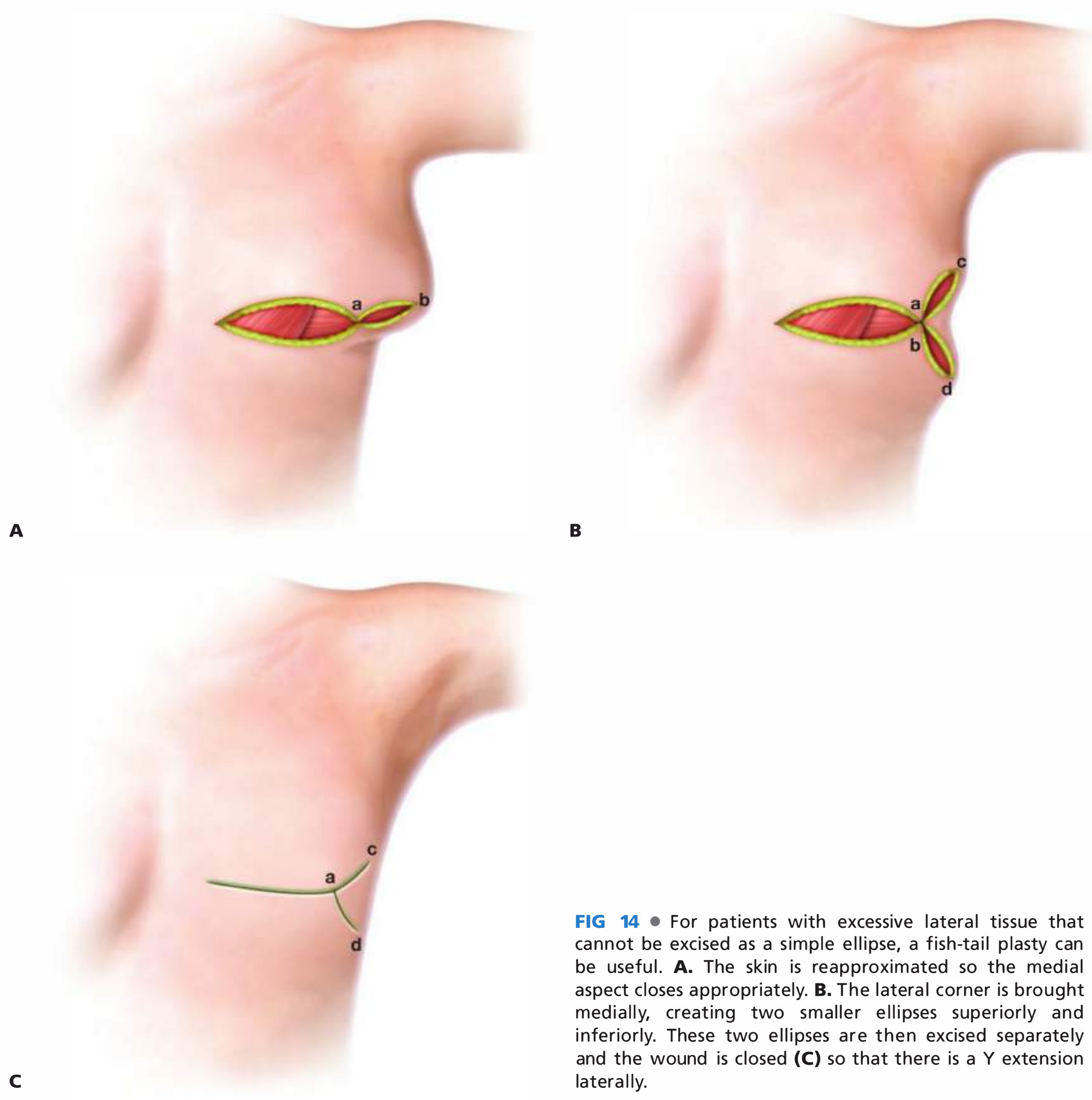

FIG 14 ● For patients with excessive lateral tissue that cannot be excised as a simple ellipse, a fish-tail plasty can be useful. **A.** The skin is reapproximated so the medial aspect closes appropriately. **B.** The lateral corner is brought medially, creating two smaller ellipses superiorly and inferiorly. These two ellipses are then excised separately and the wound is closed **(C)** so that there is a Y extension laterally.

PEARLS AND PITFALLS

Patient expectations	■ Patients who are candidates for breast conservation therapy (BCT) should understand there is no improvement in survival with a mastectomy. ■ All patients undergoing mastectomy should be offered consultation with a plastic surgeon to discuss reconstruction options. ■ Patients may have concerns regarding cosmesis and sexual identity after mastectomy that should be addressed preoperatively. ■ Patients should also understand the potential for redundancy or dog ears after mastectomy and how these can be addressed.

Planning the incision	■ Include the excisional biopsy scar in the ellipse. For palpable tumors, include an adequate amount of skin over the tumor. ■ Plan the ellipse so that it will lie flat, without excess laxity, yet not too tight. ■ Measure the superior and inferior incisions to confirm they are roughly the same length.
Raising the flaps	■ Make sure to start in the right plane with the initial incision and not go too far into the subcutaneous fat. ■ The assistant should hold the skin hooks straight up. Bending the skin backward can inadvertently lead to exposing dermis or "buttonholing." ■ Countertension with the opposite hand is the key to being in the right plane. As you progress, reposition the hand accordingly. ■ Be careful not to pass the IMF while raising the inferior flap.
Removing the breast	■ Retract the breast inferiorly and move the cautery medial to lateral, parallel to the pectoralis major muscle fibers. ■ Remove the fascia of the pectoralis with the specimen. ■ Grasp perforators with a forceps or clamp and coagulate rather than try to directly cauterize. ■ Do not retract the breast laterally with excess force, this will avulse the muscle from the sternum.
Closure	■ Excise excess skin so that the flaps close flat against the chest wall. ■ Medial and lateral dog ears should be excised, but do not keep repositioning a lateral dog ear more posteriorly. A plasty can eradicate a dog ear but can make reconstruction more difficult. A dog ear can always be corrected at a later date under local anesthetic.

POSTOPERATIVE CARE

- A nonadherent dressing can be placed over the incision. Patients can be placed in a breast binder with Kerlix fluffs in order to apply even compression. This will help prevent hematoma but should not be excessively tight.
- Patients do not need to be admitted to the hospital overnight, they may be safely discharged to home. Arranging for a visiting nurse can be helpful for drain management and wound checks.
- The drain can be removed when the output is less than 30 mL/24 hours for 2 days in a row.

OUTCOMES

- Overall, local (chest wall) recurrence after mastectomy is low, ranging from 0.6% to 9.5%, increasing with increasing stage, the presence of nodal metastases, and positive margins after mastectomy. However, local recurrence rates also appear to be decreasing as systemic therapies improve.[7] Local recurrence is also related to the histologic subtype, with luminal subtype tumors (ER/PR positive) less likely to recur than *HER2/neu* overexpressing or triple negative tumors after mastectomy.[8]
- Because local recurrence rates remain higher among patients with node-positive disease or positive margins, postmastectomy radiation therapy (PMRT) should be considered in these situations. PMRT is strongly indicated for patients with positive margins or more than four positive lymph nodes. It should also be considered for patients with one to three positive lymph nodes, particularly, if they have other risk factors for chest wall recurrence.

COMPLICATIONS

- Seroma
- Wound infection
- Hematoma
- Wound dehiscence
- Flap necrosis
- Positive margins

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Chapter 11

Skin-Sparing and Nipple/Areolar-Sparing Mastectomy

Eleni Tousimis   Rache Simmons

DEFINITION

- Skin-sparing mastectomy is defined as removal of the breast tissue while preserving the natural skin envelope for immediate breast reconstruction. This is an effective treatment option for patients with operable breast cancer without skin involvement. By preserving the patient's skin envelope with a smaller incision, it markedly improves the aesthetics of the breast reconstruction. To further enhance cosmesis, the nipple and areola can be preserved at the time of mastectomy in select patients. This is called nipple-sparing mastectomy.

ANATOMY

- As with all types of mastectomy, a thorough understanding of the anatomy of the breast, chest wall, and axilla is necessary. The goal of mastectomy is to remove the breast tissue while maintaining the viability of the skin envelope.
- The breast tissue is encapsulated by the superficial fascia that adheres to the subcutaneous tissue in a lobulated fashion (**FIG 1**). This makes it difficult to remove all of the breast tissue during mastectomy and maintain skin viability.
- The boundaries of the breast (**FIG 2**) are defined by the clavicle superiorly, the sternum medially, the 6th rib inferiorly, and the latissimus dorsi muscle laterally.
- The axillary tail of the breast extends toward the low axilla and is called the axillary tail of Spence. Posteriorly, the breast adheres to the pectoralis major muscle and is separated by the deep fascia of the breast (see **FIG 1**).
- A skin-sparing mastectomy involves preserving the skin envelope while removing the nipple–areolar complex and underlying breast via a small incision (**FIG 3**). Nipple-sparing mastectomy is a total skin-sparing mastectomy with preservation of the nipple–areolar complex.
- When performing a skin-sparing mastectomy, it is important to remove as much breast tissue as possible while maintaining the viability of the skin. This is a balancing act from the oncologic standpoint to remove the majority of the breast tissue but not make the skin flaps so thin, resulting in skin necrosis and flap loss. The anatomic plane that divides the

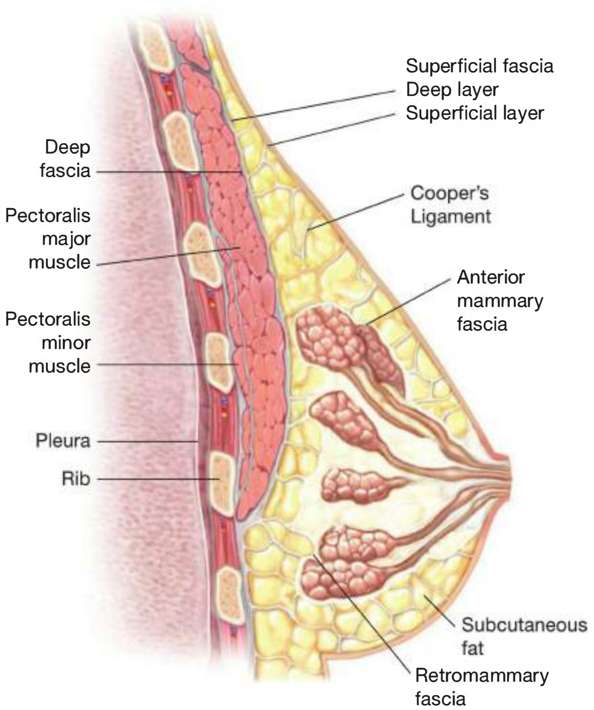


FIG 1 ● Cross-section of the breast demonstrating the superficial fascia, including both the superficial and deep layers.

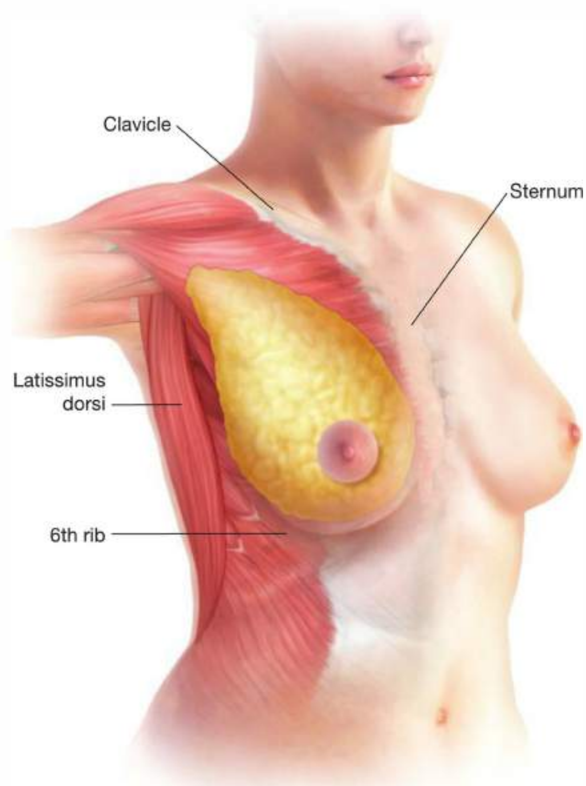


FIG 2 ● Anatomic boundaries of the breast.

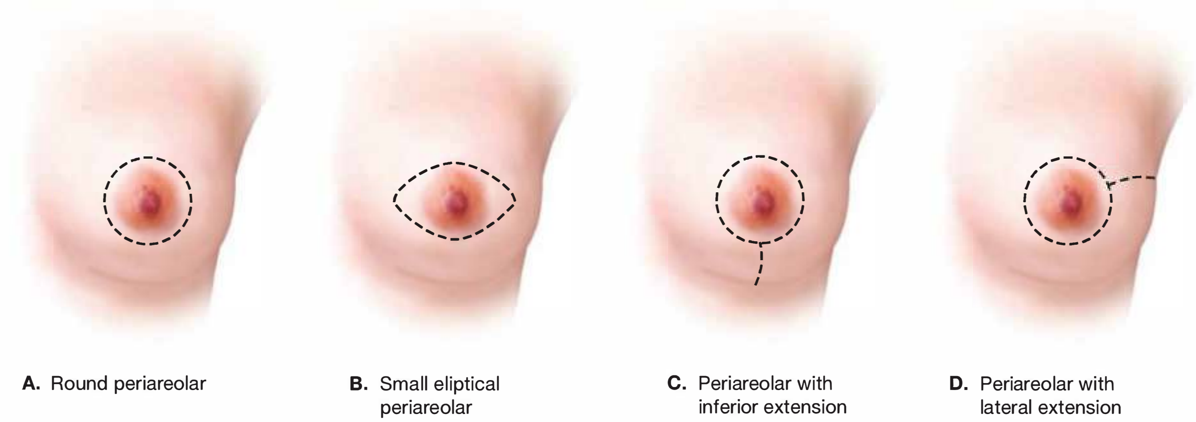


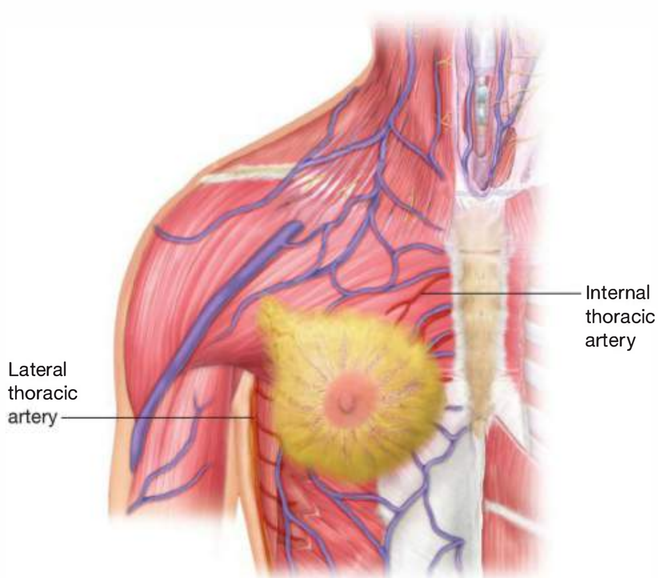
FIG 3 ● **A–D.** Surgical incisions used for a skin-sparing mastectomy.

subcutaneous tissue and the underlying breast parenchyma is formed by the superficial fascia of the breast. This is an ill-defined thin layer visualized by a faint white fascial line (see **FIG 1**). The dissection is carefully performed in this plane. The remaining tissue on the skin envelope usually ranges between 2 and 5 mm in thickness depending on the patient's anatomy.

- It is crucial to flap viability to preserve both the subcutaneous venous plexus under the skin as well as the branches of the 2nd intercostal perforator in the upper medial flap as it exits the ribs. This is the largest blood supply to the skin flap (**FIG 4A,B**).
- Once the flaps are created to the clavicle superiorly including the axillary tail of Spence, medially to the sternum, laterally to the latissimus dorsi muscle, and inferiorly to the 6th rib, the breast is then removed posteriorly from the pectoralis major muscle including the underlying deep fascia overlying the muscle. It is important when creating the flap medially not to extend to the contralateral breast.

PATIENT HISTORY AND PHYSICAL FINDINGS

- Patients with operable breast cancer are candidates for either breast conservation therapy (BCT) or skin-sparing mastectomy with or without reconstruction. It is important for patients to understand that the survival between BCT and mastectomy is equal. However, mastectomy does carry a slightly lower locoregional recurrence rate of about 2% versus 5% in 10 years after BCT.[1]
- Another important difference between the two surgical treatment options is that mastectomy usually does not require postoperative radiation therapy. Postmastectomy radiation is recommended for patients with tumors greater than 5 cm in size, patients with positive margins after mastectomy, or select patients with axillary lymph node involvement for locoregional control and to improve survival.[2]



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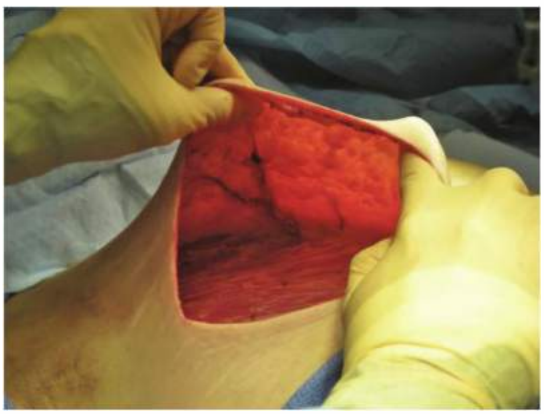

B

FIG 4 ● **A.** The blood supply to the breast comes primarily from the lateral (mammary) thoracic artery, the internal (mammary) thoracic artery, and the intercostal arteries. It is crucial to preserve the branches of the 2nd intercostal artery in the upper medial flap to ensure viability. **B.** The subcutaneous venous plexus and branch off the 2nd intercostal artery are seen preserved with the flap.

Table 1: Methods for Examining the Breast and Pathognomonic Signs

Examination	Technique	Grading	Significance
Breast exam	Upright Supine	Symmetry Skin changes Palpable masses Adenopathy Nipple discharge	Cancer causing enlargement Peau d'orange, associated with inflammatory breast cancer, or an underlying tumor pulling on Cooper's ligaments Cancer, benign mass or cyst Lymph node metastasis or reactive lymph nodes Bloody or clear spontaneous unilateral discharge associated with carcinoma risk

- Prior to determining whether a patient will be a candidate for mastectomy or BCT, a thorough history and physical examination should be performed.
- The medical history should focus on the patient's family history of breast cancer in first-degree relatives and ovarian cancer in the family. Patients with a strong family history of breast or ovarian cancer, premenopausal breast cancer, patients with bilateral breast cancer, male family members with breast cancer, or those of Ashkenazi Jewish descent should be recommended for genetic counseling and testing for the BRCA 1 and 2 gene mutations. Also included in the medical history, the surgeon should ask about personal risk factors for developing breast cancer such as early menses, late menopause, a personal history of an atypical breast biopsy, lobular carcinoma in situ (LCIS), a history of previous chest wall radiation for Hodgkin's lymphoma, or use of hormone replacement therapy. Many of these high-risk patients who decide to undergo mastectomy also opt for contralateral mastectomy at the time of mastectomy to decrease their risk of a future breast cancer. Another reason for the recent increased incidence of contralateral prophylactic mastectomy is because of patient's anxiety, fear, and desire to reduce future risk of recurrence and cosmetic symmetry.[3]
- After obtaining a thorough medical history, a detailed physical examination would include examination of the patient in both the upright and supine positions (Table 1). While placing the patient's hands on her hips in the upright position, the patient is visually examined for symmetry, evidence of skin changes, or dimpling. The cervical and axillary areas are palpated for adenopathy and the breasts are examined. The patient is then placed supine with both arms over her head. The breasts are examined again for palpable masses and nipple discharge, and the axillae are palpated again while lowering the arms to the side. The abdomen is then examined for hepatosplenomegaly.

IMAGING AND OTHER DIAGNOSTIC STUDIES

- The purpose of preoperative imaging is to clinically stage the patient, determine operability, assist with surgical decision making, and assess the need for preoperative chemotherapy for downstaging. All patients prior to mastectomy require a recent bilateral mammogram including craniocaudal and medial lateral views. On mammogram, one should look for spiculated masses, tumor size and location, additional tumors, skin involvement, and associated calcifications (**FIG 5**).
- For patients with dense breast tissue or young age, a breast sonogram may be a helpful addition to assess the presence of additional lesions in dense breast tissue and the extent and depth of the tumor.
- Ultrasonography is also helpful to assess the axilla radiographically. Suspicious nodes have a very characteristic appearance with an obliterated hilum and nondistinct borders. An ultrasound-guided fine needle aspiration (FNA) can be performed preoperatively for suspicious nodes (**FIG 6**).

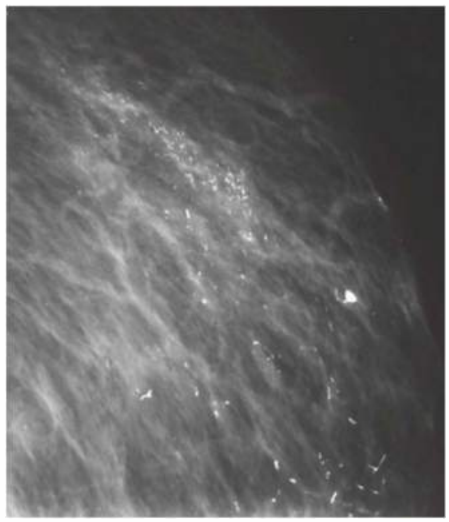

FIG 5 • Magnification mammogram showing pleomorphic calcifications suspicious for carcinoma.

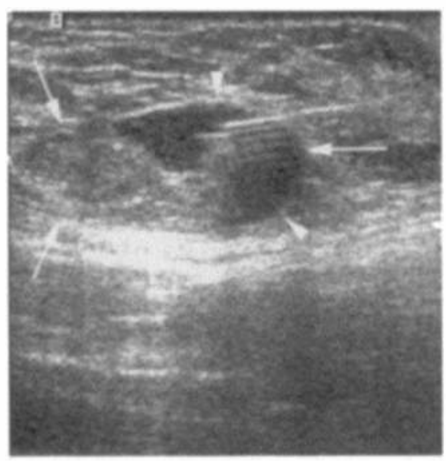

FIG 6 • Ultrasound-guided FNA biopsy of axillary lymph node metastases.

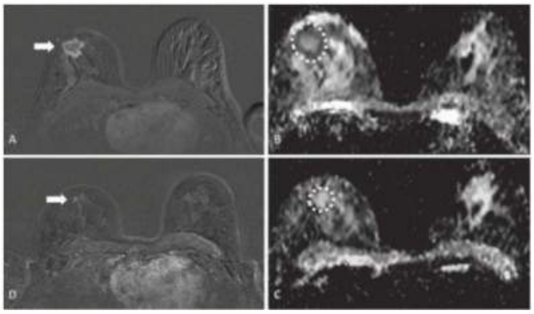

FIG 7 ● MRI showing response to chemotherapy before treatment **(A)** and after treatment **(B)**.

- Magnetic resonance imaging (MRI) of the breast is used selectively for patients who are having mastectomy. One indication is for patients with invasive lobular cancer because of a higher incidence of contralateral disease.[4]
- MRI may also be used preoperatively for high-risk patients such as those with the BRCA 1 or 2 mutation, a strong family history, dense breast tissue, difficult breast examinations, large tumors with questionable skin involvement, or those undergoing neoadjuvant chemotherapy. In patients undergoing preoperative chemotherapy, MRI helps to monitor the response to treatment. An MRI is performed before treatment begins and then repeated again after systemic treatment is completed for comparison. The MRI shows a nice relationship of the tumor location to skin distance for treatment planning and choice of surgical incision (**FIG 7**).
- Staging tests to rule out metastatic disease, such as positron emission tomography–computed tomography (PET/CT) or a computed tomography (CT) scan of the chest, abdomen, and pelvis and bone scan should be considered in patients with lymph node involvement and large tumors or those patients with signs or symptoms suggestive of metastases (Table 2).

SURGICAL MANAGEMENT

- Indications for skin-sparing mastectomy include patients who choose mastectomy to reduce their risk of a future local recurrence and patients with the *BRCA* gene mutation, other high-risk patients that have a strong family history of breast cancer, or young age at diagnosis. The patient must have operable breast cancer and not have extensive skin involvement or fungating, ulcerating lesions.
- Indications for nipple-sparing mastectomy include patients who are undergoing prophylactic surgery, *BRCA* gene mutation carriers, and have operable cancers not located close to the nipple. Patients who should not undergo nipple-sparing mastectomy are those patients with very large, ptotic breasts, cancers located directly under the nipple, radiographic evidence of nipple involvement, or those with suspicious nipple discharge or nipple retraction. Patients must be informed that it is not possible to remove all the tissue under the nipple and that there is a reported risk of recurrence in the nipple and nipple necrosis of less than 5%.[5]

Table 2: Indications for Preoperative Positron Emission Tomography–Computed Tomography

Examination	Indications Preoperatively
PET/CT	Tumors >3 cm in size Evidence of lymph node metastasis Symptomatic disease (i.e., bone pain) Locally advanced breast cancer

PET/CT, positron emission tomography–computed tomography.

Preoperative Planning

- All preoperative radiographic studies should be studied prior to surgery to determine tumor location, size, and depth.
- The breast cancer surgeon and patient discuss the optimal type of skin-sparing mastectomy preoperatively and determine whether they are candidates for skin-sparing simple mastectomy or nipple-sparing mastectomy.
- All patients undergoing immediate reconstruction consult with a reconstructive surgeon prior to surgery for preoperative planning. After the reconstructive surgeon examines the patient and determines the optimal reconstruction depending on the patient's body habitus, breast size, and clinical stage, the reconstructive surgeon collaborates with the breast surgeon for the optimal oncologic approach with the best cosmesis.
- Patients with palpable tumors close to skin or those considering nipple-sparing mastectomy with tumors close to the areola may benefit from a preoperative breast MRI to address distance of tumor to the skin or disease below the nipple–areolar complex. This may alter treatment planning such as the use of neoadjuvant chemotherapy to achieve negative margins as well as surgical decision making.

Positioning

- The optimal operative position for all patients undergoing skin-sparing mastectomy is supine with the arms abducted approximately 45 degrees. Care is taken not to hyperextend the arms in anticipation for a long surgery. The arm boards are padded in order to protect the elbows from pressure compression causing a median nerve palsy.
- Compression boots are placed preoperatively and there is no need for additional anticoagulation unless the patient is at high risk for deep vein thrombosis (DVT), including obesity, a personal history of DVT, or cardiac valves requiring prophylaxis.
- Upon induction, if the patient is undergoing immediate breast reconstruction, they should receive a dose of intravenous (IV) antibiotics to cover gram-positive bacteria, usually a first-generation cephalosporin such as cephazolin.
- A Foley catheter is inserted after induction, if a prolonged reconstruction is anticipated.
- Prior to prepping the patient, methylene blue dye is injected subareolar for those surgeons who use both blue dye in addition to radioisotope for identification of the sentinel lymph node (**FIG 8**).
- Once prepped, the patient's arm is wrapped with a free arm dressing in anticipation of an axillary node dissection if axillary metastasis is suspected; otherwise, it is draped outside the field.

FIG 8 ● Patient positioning and preoperative injection of blue dye in a subareolar fashion.

SKIN-SPARING MASTECTOMY

- Prior to surgery, the patient is skin marked by both the reconstructive and breast cancer surgeons. The nipple–areolar complex is removed by a small elliptical skin incision. There are many options of excision depending on breast size and tumor location as well as type of reconstruction (see **FIG 3**).
- The nipple–areolar complex is incised in an elliptical fashion with a no. 15 blade scalpel into the dermis. Skin hooks are placed on the flap and pulled upward by the first assistant. Care is taken to ensure the first assistant pulls directly perpendicular to the chest wall to avoid an inadvertent buttonhole in the flap (**FIG 9**).
- By retracting the breast downward against the upward traction of the skin, the superficial fascial plane is identified. The surgeon uses cautery to create the flaps by dissecting just above the superficial fascia in order to remove as much of the breast tissue as possible. Alternatively, some surgeons may use either the knife or scissors to create the mastectomy flaps. As long as the surgeon is in the correct anatomic plane, it should be relatively avascular.
- As the surgeon progresses further posteriorly, medium-sized Richardson retractors or lighted retractors are used to assist with retraction (see **FIG 15**). Because the skin ellipse opening may be quite small, the flaps are created in a spiral fashion until the pectoralis muscle is identified.
- The surgeon's hand is then used to examine the flaps. If the surgeon is in the proper plane, the flaps will only be a couple of millimeters thick and even throughout. Care is taken to ensure that the axillary tail of the breast has been adequately dissected and removed en bloc with the specimen.
- Next, the breast is removed from the pectoralis muscle. Medium-sized or large Richardson retractors are used to retract the skin superiorly and Kelly clamps may be placed on the superior aspect of the breast to assist with downward traction.
- Electrocautery is then used to separate the breast from the pectoralis muscle by dissecting parallel to the muscle fibers from medial to lateral (**FIG 10**). All perforating vessels are carefully cauterized prior to cutting to prevent retraction into the muscle and subsequent bleeding.
- Once the breast is removed from the chest wall, a silk stitch is used to mark the axillary tail for orientation for the pathologist. The breast is passed off the field for permanent section and attention is paid to the axilla to perform either a sentinel lymph node biopsy or axillary lymph node dissection, depending on the stage of the cancer. This may be performed via the mastectomy incision if there is no tension on the wound. If the axilla is too far away, a separate axillary incision is made.

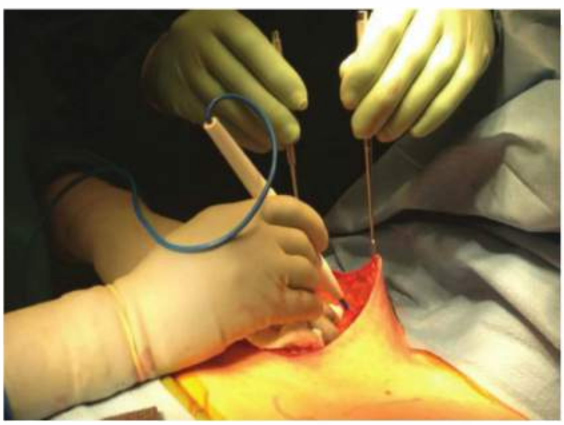

FIG 9 ● Skin hooks are placed on the flap and pulled upward by the first assistant. Care is taken to ensure the first assistant pulls directly perpendicular to the chest wall to avoid an inadvertent button hole in the flap.

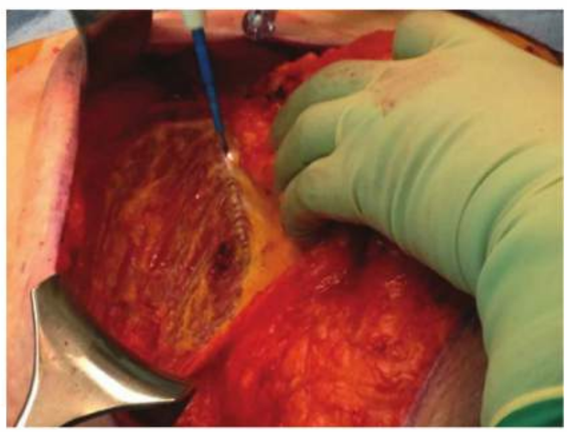

FIG 10 ● Electrocautery is used to dissect the breast and pectoralis fascia off the underlying muscle. Cautery is moved parallel to the muscle fibers from medial to lateral.

NIPPLE-SPARING MASTECTOMY

- Nipple-sparing mastectomy is performed similar to skin-sparing mastectomy (**FIG 11**); however, the nipple–areolar complex is spared.This can be done through various approaches (**FIG 12**).
- The most cosmetic approach is via an inframammary fold skin incision (**FIG 13A,B**). The entire flap is created from the inframammary fold inferiorly to the clavicle superiorly. This is a long flap and is therefore best used on women with small to medium-sized breasts. The inframammary fold incision is usually approximately 9 cm in length. It extends from just below the medial aspect of the areola in the inframammary fold to 9 cm laterally. The most challenging technical aspect of this approach is getting sufficient upward traction of the skin in order to create the flap in the appropriate plane.
- Skin hooks are used for upward traction, as in the traditional skin-sparing mastectomy. However, when approaching the nipple–areolar complex, it is best to have the first assistant gently pinch and retract the nipple upward or alternatively place a 2-0 silk stitch through the nipple in order to give upward traction and use a lighted retractor lateral to the nipple–areolar complex in order to visualize the area adequately (**FIGS 14** and **15**).
- The ductal tissue posterior to the nipple is usually more dense and lighter in color (**FIG 16**). Once through this area, the silk stitch can be removed and the lighted retractors are advanced in order to complete the superior aspect of the flaps to the clavicle. The first assistant can apply gentle traction of the skin flap by placing the palm of his or her hand on the superior aspect of the flap and pushing away from the surgeon.
- To create even flaps, it is important that both the first assistant and surgeon apply steady, even traction and avoid readjusting multiple times.
- After the breast is removed from the chest wall, attention is paid to the nipple to take an additional nipple margin.
- The surgeon's finger is placed on the outside of the nipple and the nipple is everted. An Allis clamp is then placed on the tissue inside the nipple and a no. 15 blade scalpel is used to perform a shave biopsy of any residual ductal tissue within the nipple. The tissue is then sent to pathology for frozen or permanent section.

FIG 11 ● Nipple-sparing mastectomy via inframammary skin incision versus skin sparing mastectomy on patient with left centrally located tumor. (Photo courtesy of Sherman J, MD.)

- All patients undergoing nipple-sparing mastectomy are consented preoperatively that if the nipple margin is positive for cancer, then the nipple–areolar complex will be removed. If this is recognized intraoperatively on frozen section, the nipple–areolar complex can be removed at this time. If this is deferred to permanent section, it will be removed postoperatively by the reconstructive surgeon.
- If the skin flaps and nipple–areolar complex appear well vascularized and the nipple margin is negative on

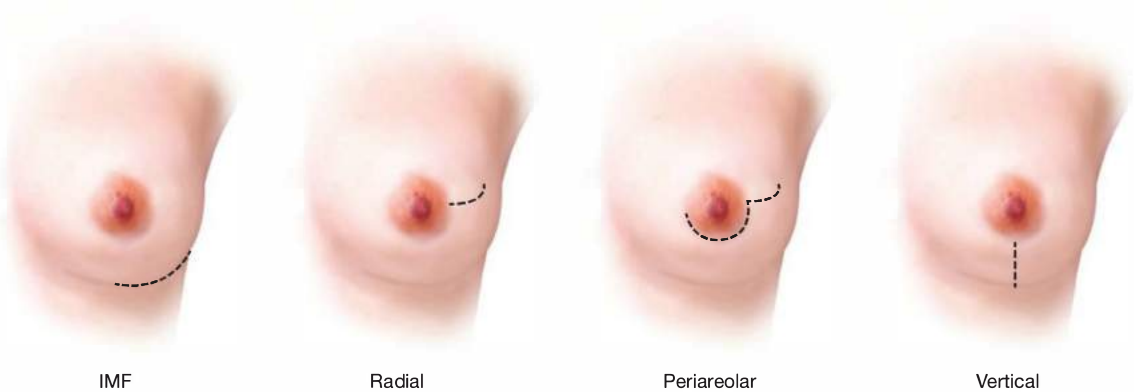

FIG 12 ● Skin incision options for nipple-sparing mastectomy.

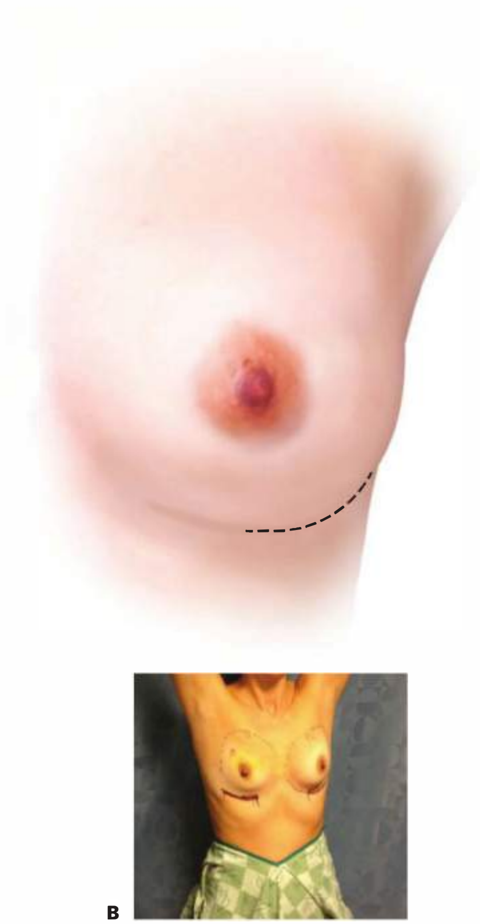

FIG 13 ● **A.** Nipple-sparing mastectomy via inframammary fold skin incision. **B.** Preoperative skin marking for inframammary skin incision. Below medial areola to 9 cm laterally in the inframammary fold.

frozen section (if obtained), the reconstructive surgeon can proceed (FIG 17).

- For patients with ptotic breasts who are not ideal candidates for nipple-sparing mastectomy, we recommend performing a superior circumareolar mastopexy incision with a lateral extension to remove excess skin and achieve a slight lift. Another option for macromastia or significant ptosis is a two-stage procedure suggested by Spear and colleagues[6] where the patient undergoes a primary mammoplasty followed by nipple-sparing mastectomy 3 weeks later (FIG 18).

Analgesia after Mastectomy

- Mastectomy is performed under general anesthesia. In addition to general anesthesia, a long acting local anesthetic may be injected into the borders of the mastectomy wound just below the cut edge of the fascia. Postoperatively, patients are given both an oral narcotic as well as vallium to relax the muscle and prevent muscle spasm and tightness.

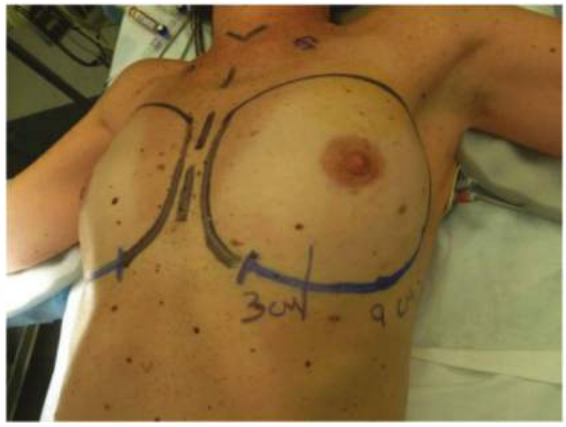

FIG 14 ● Extended incision for more exposure if necessary.

FIG 15 ● Gentle upward traction of the nipple by the first assistant to create plane behind the nipple.

FIG 16 ● Inside of nipple area appears lighter compared to the surrounding tissue.

FIG 17 ● Expansion of the tissue expander after a nipple-sparing mastectomy with immediate reconstruction.

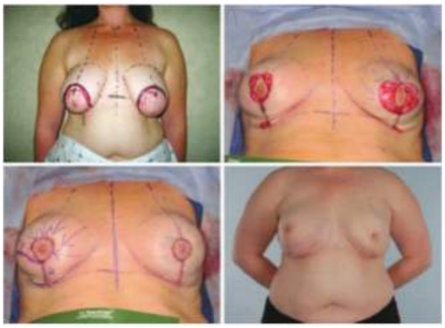

FIG 18 ● Staged nipple-sparing mastectomy following reduction for macromastia or ptotic breasts. (Photo courtesy of Spear S, Rottman S, Seiboth L, et al. Breast reconstruction using a staged nipple-sparing mastectomy following mastopexy or reduction. *Plast Reconstr Surg*. 2012;129:572–581.)

PEARLS AND PITFALLS

Possible Pitfalls of Skin-Sparing Mastectomy	Pearls
Flap necrosis	■ Identify fascial plan below subcutaneous tissue; stay just above this line to create flap. ■ Maintain even traction/countertraction in order to create even flaps. ■ Preserve the subcutaneous venous plexus and the 2nd intercostal perforator to prevent flap necrosis. ■ Avoid denuding the skin.
Nipple necrosis	■ Do not denude the nipple. ■ Avoid too much traction on the nipple for prolonged periods of time. ■ Avoid cautery under the nipple.
Infection	■ Treat reconstructive patients with preoperative IV antibiotics and postoperative oral antibiotics until the drains are removed. ■ Irrigate thoroughly with normal saline after the mastectomy is performed. ■ Obtain careful hemostasis.

POSTOPERATIVE CARE

- Patients who undergo implant reconstruction are admitted as an inpatient overnight.
- Patients who undergo flap reconstruction are admitted longer depending on the type of flap reconstruction.
- They are maintained on oral first-generation cephalosporin until the Jackson-Pratt (JP) drains are removed.
- The patients are discharged with a surgical bra and the JP drains attached to the bra.
- They may resume showering after 48 hours and are taught how to empty and record the drain output.
- The patient returns in 1 week to have the drains removed if she is draining less than 30 cc per day from each drain and to discuss the pathology report.
- Patients are then referred to medical oncology for adjuvant treatment and a radiation oncologist if indicated.
- When the breast is removed, the sensory innervations to the skin are also removed, resulting in loss of sensation. This resulting band of numbness gets narrower over time but never completely resolves.
- Following mastectomy, patients are seen in follow-up by the breast surgeon every 6 months for 5 years to examine the skin for recurrent disease, then yearly thereafter.
- An instruction book of postmastectomy stretching exercises is given to the patient after the drains are removed to increase mobility and prevent frozen shoulder. For patients who develop decreased mobility after surgery, they are referred to a specially trained physical therapist.

OUTCOMES

- Include functional and prosthetic survivorship data, as applicable.

FIG 19 • Nipple and flap necrosis after nipple-sparing mastectomy via inframammary skin incision.

FIG 20 • Inferior flap necrosis after skin-sparing mastectomy with deep inferior epigastric perforator (DIEP) flap reconstruction.

COMPLICATIONS

- Skin flap necrosis (**FIGS 19** and **20**)
- Nipple necrosis
- Infection
- Seroma
- Hematoma

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5. Petit JY, Veronesi U, Orecchia R, et al. Risk factors associated with recurrence after nipple-sparing mastectomy for invasive and intraepithelial neoplasia. *Ann Oncol*. 2012;23;2053–2058.
6. Spear S, Rottman S, Seiboth L, et al. Breast reconstruction using a staged nipple-sparing mastectomy following mastopexy or reduction. *Plast Reconstr Surg*. 2012;129:572–581.

Chapter 12

Modified Radical Mastectomy

Tiffany A. Torstenson Judy C. Boughey

DEFINITION

- Modified radical mastectomy (MRM) is a surgical procedure that removes all breast tissue and lymphatic-bearing tissue in the axilla. This operation removes the nipple–areolar complex, skin envelope, and level I and II axillary nodes but spares the pectoralis major muscle. It can also be termed as a total mastectomy with an axillary lymph node dissection.

PATIENT HISTORY AND PHYSICAL FINDINGS

- There has been a huge evolution in types of the mastectomy over the years. We have moved away from the radical mastectomy to more cosmetic pleasing procedures such as simple mastectomy, skin-sparing mastectomy, and nipple-sparing mastectomy. In mastectomy patients with node-positive disease, axillary lymph node dissection is often recommended.
- Patients undergoing an MRM usually have documented lymph node metastases diagnosed preoperatively or surgically and either elect to have a mastectomy or require a mastectomy (i.e., are not candidates for breast-conserving therapy). Patients diagnosed with inflammatory breast cancer should also undergo an MRM after induction chemotherapy according to National Comprehensive Cancer Network (NCCN) guidelines.[1]
- It is crucial to decide from the beginning if these patients are operable candidates and whether neoadjuvant therapy should be considered. A multidisciplinary approach is vital in the treatment success of these patients. Involvement of a medical oncologist and radiation oncologist early in the management of these patients helps treatment planning and to streamline patient care.
- A comprehensive history and physical examination is imperative on the first consultation with these patients. The history should be very detailed and include questions pertaining to medical conditions, medications, surgeries, allergies, and also about any musculoskeletal issues, which could affect operative positioning. It is important to evaluate for any family history of breast or ovarian cancer.
- If there is a strong family history of breast or ovarian cancer, it is essential to offer genetic counseling and possibility of genetic testing.
- Physical examination starts with an inspection of bilateral breasts both with arms at the patient's side and with the arms elevated, noting any asymmetry, nipple retraction, prior scars, or skin changes.
- Palpation of the breasts should always be done both in a sitting and supine position in a circular or vertical pattern. Palpable masses should have bidimensional measurements and should be assessed for chest wall adherence and skin proximity. Any palpable masses that do not correspond to radiologic findings require further testing and tissue biopsy.
- A thorough examination of the lymph node basins should be performed, including the axillary, cervical, supraclavicular, and infraclavicular nodes. If there is adenopathy on palpation, patients should undergo an in-office or radiologic ultrasound. Any suspicious nodes on imaging should undergo a fine needle aspiration or core needle biopsy.
- Imaging and pathologic diagnoses should be shared and explained to the patient. It is helpful to map out the incisions for the patients to see preoperatively. Explain to patients the need for either neoadjuvant or adjuvant chemotherapy as well as likely need for postmastectomy radiation in patients with node-positive disease.
- Neoadjuvant chemotherapy has been shown to be equivalent to adjuvant chemotherapy in terms of survival and can increase rates of breast-conserving therapy.
- Postmastectomy radiation in node-positive disease decreases rates of locoregional recurrence and increases disease-free and breast cancer–specific survival.
- Inquire if patients are seeking immediate reconstruction or desire to go flat chested. If postmastectomy radiation is recommended, patients may not be candidates for immediate reconstruction.
- Allocate enough time to spend with these patients in order to answer all their questions, and be empathetic to their needs during this emotional time. Keep interruptions with pagers and cell phones to a minimum.

IMAGING AND OTHER DIAGNOSTIC STUDIES

- Breast imaging plays a vital role in the screening and diagnostic workup for breast cancer. Imaging can define the extent of the disease and help assess for any abnormalities in the contralateral breast. It is also used as a monitor for local recurrence in patients postoperatively.
- Mammography is the initial imaging test in the breast cancer workup. Mammograms are very sensitive in detecting abnormalities and have been shown to decrease breast cancer mortality approximately by 30%. Screening mammograms should begin yearly in women who are 40 years of age and asymptomatic.[2]
- Diagnostic mammograms should be obtained in any patient being considered for an MRM (**FIG 1**). Spot and magnification views can help aid to focus and distinguish abnormalities. Implant displacement views (Eklund views) should be obtained in women with implants.[2,3] Request films if they were done at an outside institution. An ultrasound should also be performed to further assess the size of the tumor and the proximity of it to the skin and chest wall. Lesions that are suspicious on ultrasound or mammogram should undergo a percutaneous biopsy.
- Axillary ultrasound should be performed in patients with a biopsy-proven invasive cancer. Lymph nodes should be evaluated for their size, shape, and morphology. Suspicious nodes

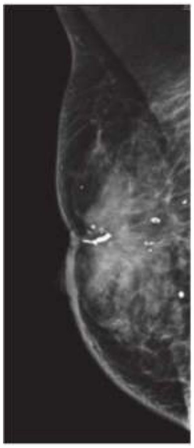


FIG 1 ● Mammogram showing a right invasive ductal carcinoma invading the skin and causing skin retraction.

on imaging or clinically palpable nodes should undergo a fine needle aspiration or core needle biopsy with ultrasound guidance (**FIG 2**). Approximately 31% of axillary metastases are diagnosed with ultrasound-guided biopsy.

- Magnetic resonance imaging (MRI) usage is still controversial but can be used as an additional imaging tool for screening, staging of known breast cancers, and evaluating the contralateral breast. MRIs are highly sensitive tests but lack specificity leading to an increased false-positive rate. Studies have also demonstrated an increased rate of mastectomies in patients undergoing MRIs. The decision to order an MRI should be based on the recommended indications and individualized.
- According to NCCN guidelines, positron emission tomography (PET) scans can be used to evaluate for distant metastasis in patients with stage IIIA breast cancer, but this is a category 2B recommendation. Systemic staging is not recommended for patients with early stage breast cancer in the absence of symptoms.[1]
- When a suspicious lesion is identified on imaging, a tissue biopsy is needed to decipher between a benign and malignant process. Percutaneous biopsy is preferred over an excisional biopsy, which can lead to unnecessary surgeries for benign entities. Core needle biopsy is preferred to evaluate histology and differentiate in situ from invasive disease. Most lesions in the breast will need to undergo a core needle biopsy using ultrasound or stereotactic guidance. MRI-guided core needle biopsy can also be performed when lesions are not detected on ultrasound or mammography but these are more technically challenging. If cancer is identified, there should be a detailed pathologic assessment, including subtype and hormone receptor status. In cases with morphologically abnormal lymph nodes on ultrasound, fine needle aspiration biopsy or core biopsy of lymph nodes should be used.

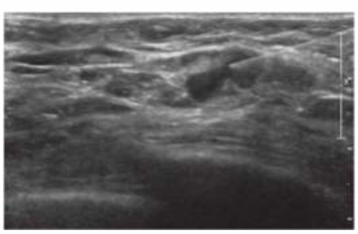


FIG 2 ● Ultrasound-guided fine needle aspiration of an axillary lymph node that revealed metastatic carcinoma in a male breast cancer patient who underwent an MRM.

- After any percutaneous biopsy, a marking clip should always be placed. This is extremely important in patients receiving neoadjuvant chemotherapy.

SURGICAL MANAGEMENT

Preoperative Planning

- Preoperatively, patients can be considered for regional anesthesia at the surgeon's and anesthesiologist's discretion. Paravertebral blocks (PVBs) are increasing in popularity for breast surgery and are more commonly favored over epidural blocks. They can be performed as single- or multiple-level injections or as a continuous catheter infusion. PVBs have been shown to shorten recovery times and length of hospital stays, decrease opiate usage, and decrease the incidence of vomiting. It is also hypothesized this type of regional anesthesia may protect the immune system and decrease metastasis.[4]
- PVBs are preferred over epidural blocks because they induce less hypotension, less urinary retention, are technically easy to learn, and have less severe side effects. Patients who are coagulopathic or who have musculoskeletal deformities such as kyphosis or scoliosis should not be considered for a PVB.[5,6]
- Potential complications associated with a PVB are pneumothorax, vascular penetrance, sepsis, and hematoma. Pneumothoraces are more common with multiple-level injections in comparison to single-level injections. Patients can either be seated with the spine in a kyphotic curve or placed in a lateral decubitus position (**FIG 3**). The local anesthetic is injected in the paravertebral space where the thoracic spinal nerves emerge.
- Ultrasound can also help guide the correct placement of the local anesthetic. Patient comfort improves when an ultrasound is used, and the pneumothorax rate decreases due to the direct visualization of the pleura.
- Before patients enter the operating theater, they should be site marked in the preoperative area to ensure the correct side is being operated on. Radiologic imaging should be thoroughly reviewed prior to the procedure to ensure the location of the tumor and the proximity of it to the skin.
- Prophylactic antibiotics have been shown to reduce postoperative infections and should be administered prior to incision.[7] Most surgeons prefer to avoid the use of paralytics during an MRM in order to aid identification of important motor nerves, but excessive handling of these nerves is discouraged to prevent axonal injury.

FIG 3 ● When performing a PVB, the patient can be seated with the spine positioned in a kyphotic curve. (Modified from Hebl JR, Lennon RL. *Mayo Clinic Atlas of Regional Anesthesia and Ultrasound-Guided Nerve Blockade*. Rochester, MN and New York, NY: Mayo Clinic Scientific Press and Oxford University Press; 2010. Used with permission of Mayo Foundation for Medical Education and Research. All rights reserved.)

FIG 4 ● Positioning and draping of a patient for an MRM. (Modified from Donohue JH, Van Heerden J, Monson JRT, eds. *Atlas of Surgical Oncology*. Cambridge, MA: Blackwell Science; 1995. Used with permission of Mayo Foundation for Medical Education and Research. All rights reserved.)

FIG 5 ● The contralateral arm should contain the IV and blood pressure cuff.

- Prophylactic anticoagulants for prevention of venous thromboembolism (VTE), such as subcutaneous heparin, should be considered on a case-by-case basis. Sequential compression devices should be placed prior to initiation of general anesthesia for VTE prevention.

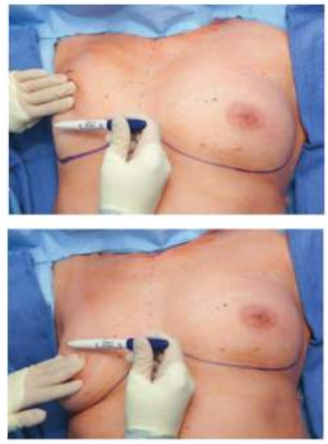
Positioning

- Correct positioning of patients undergoing an MRM is vitally important. Patients should be in a supine position with the side of the MRM close to the edge of the operating table. The endotracheal tube should be positioned toward the contralateral side of the mouth from the side of the MRM. Arms should not be abducted greater than 90 degrees to prevent injury to the brachial plexus. Arms should be placed on padded arm boards and positioned in a way that pressure points are alleviated. It is often helpful, particularly with bulky adenopathy, to prepare the ipsilateral arm into the field and wrap it with a sterile stockinette and Kerlix wrap (**FIG 4**). This allows for relaxation of the pectoralis muscles and easier access to the level II and III axillary nodes.
- The arm should be secured to the arm board. Blood pressure cuffs and intravenous (IV) lines should be placed in the contralateral upper extremity (**FIG 5**). Allow enough room between the operating table and anesthesiologist cart to allow an assistant to stand above the arm.
- Surgical preparation should include the breast and axilla and extend across the midline, inferiorly onto the abdomen, superiorly to the neck and the upper arm, and laterally to the level of the operating table. Draping should ensure preservation of a sterile field with exposure of the whole breast and axilla (**FIG 6**).

FIG 6 ● Draping should ensure preservation of a sterile field with exposure of the whole breast and axilla.

INCISION PLACEMENT

- There are many options for incisions for a total mastectomy that are based on the tumor location. In an MRM, it is important to have an incision that provides good exposure to the axilla and reduces skin redundancy. The incision should include the skin overlying the tumor in cases where the tumor is close to the skin and a 1- to 2-cm margin around the tumor and include the previous biopsy site.
- The classic Stewart incision is a transverse elliptical incision, provides access to the axilla, and is the preferred incision of many plastic surgeons for patients seeking delayed reconstruction (**FIG 7**).
- When mapping the incision, it is important to make sure there will be adequate skin for a tension-free closure without excess skin for redundancy (**FIG 8A,B**). Most of these patients will be receiving postmastectomy radiation, which can lead to incision breakdown, and this is increased when incisions are under tension. The boundaries of the breast (clavicle superiorly, inframammary fold inferiorly, sternum medially, and midaxillary line laterally) define the extent of the flap dissection.
- Measuring the length of the planned superior incision and inferior incision to ensure that these are equal in length can help guide adjustments to allow equal length skin flaps.



A

B

FIG 8 ● **A,B.** Measuring the distance from the superior to the inferior incision with a marking pen will help provide a tension-free closure and reduce skin redundancy.

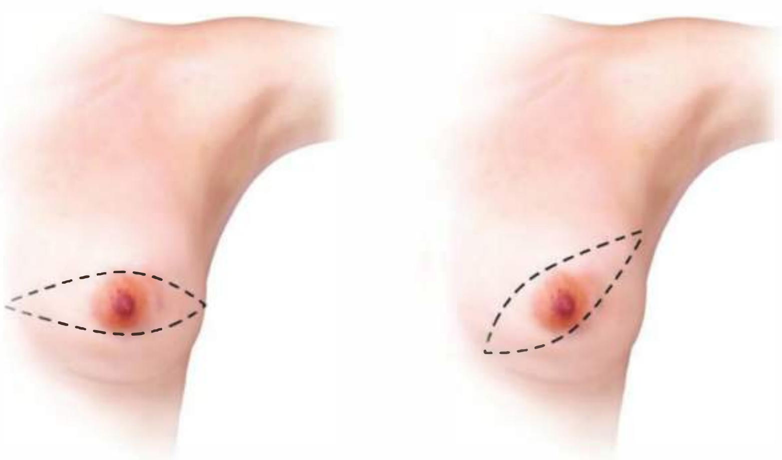


FIG 7 ● The two most common and preferred incisions for an MRM, which provide good axillary exposure. **Left:** Stewart incision. **Right:** Modified Stewart incision. (Modified from Donohue JH, Van Heerden J, Monson JRT, eds. *Atlas of Surgical Oncology*. Cambridge, MA: Blackwell Science; 1995. Used with permission of Mayo Foundation for Medical Education and Research. All rights reserved.)

SKIN INCISION AND CREATION OF FLAPS

- Once the skin incision has been mapped out on the breast, a scalpel is used to cut through the skin and dermis. A small edge of tissue is raised below the dermal layer to develop the flap (**FIG 9**). Skin hooks are used to provide traction for flap elevation, and these should be replaced with deeper retractors or lighted retractors when the dissection flaps are extended (**FIG 10**). Traction of the contralateral hand of the surgeon with a sponge also provides necessary tension for appropriate plane dissection. Flap dissection can be done sharply or with electrocautery, but electrocautery will provide better hemostasis during the dissection.
- The goal of flap elevation is to remove all the breast tissue while maintaining vascular supply to the flaps. The dissection plane should be developed between the breast tissue and subcutaneous fat. Frequently, there will be an avascular plane that can help guide in the dissection. It is important to keep traction on the breast to assist in finding the correct plane, and intermittent flap palpation should be performed to determine the correct thickness of the flaps. Flap thickness will vary among patients and is dependent on the patient's body habitus.

FIG 9 ● Raise an area of tissue under the dermis to begin the flap dissection. Using a sponge in the opposite hand can help provide traction, which will help in the flap creation.

FIG 11 ● The superior flap dissection is extended up to the clavicle where the underlying muscle can then be exposed.

- The superior flap should be extended up to the inferior border of the clavicle, and the medial flap should be dissected to the sternal border (FIG 11). When creating the medial flap, careful attention should be directed to the medial perforators. These perforators should be preserved where feasible to maintain vascular supply to the flap. When these need to be sacrificed, clips or suture ligation should be used to assure hemostasis. The lateral flap should be extended to the latissimus dorsi and the inferior flap should be dissected to the inframammary fold (FIG 12). It is important to avoid excess traction as the dissection is extended to avoid flap ischemia.

FIG 10 ● Joseph retractors or skin hooks are used at the beginning of the flap dissection. These should be switched out for deeper retractors as the dissection is extended.

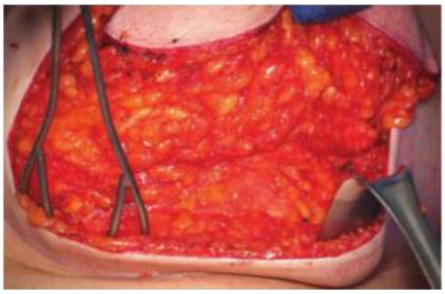


FIG 12 ● The inferior flap dissection is carried to the inframammary fold.

DISSECTION FROM THE PECTORAL MUSCLES

- When the flaps are completed to the appropriate landmarks, the breast tissue is dissected off the pectoralis muscle taking the pectoral fascia with the breast tissue using the electrocautery. The dissection should be started superiorly at the level of the clavicle. Traction should be applied with the contralateral hand to visualize the dissection plane (FIG 13).
- The dissection should continue inferiorly and in a medial to lateral fashion to follow the muscle fibers. The fascia surrounding the muscle should be dissected off with the breast in order to prevent local recurrence.[8,9] Careful attention should be provided to preserve the serratus anterior muscle fascia laterally and inferiorly and the rectus sheath fascia inferiorly. The axillary tail of the breast should remain attached in order to keep the breast and axillary contents as one pathologic specimen and also to guide the axillary dissection.

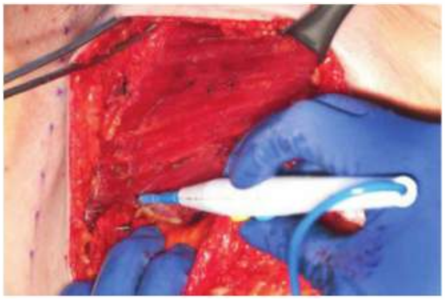


FIG 13 ● Dissection of the breast tissue off the pectoralis major muscle should be done with electrocautery in a medial to lateral fashion taking the pectoralis major muscle fascia with the specimen.

AXILLARY DISSECTION

- The axilla has a pyramidal shape and is located between the upper arm and thoracic chest wall. It is bounded superiorly by the axillary vein, anteriorly by the pectoralis muscle, medially by the serratus anterior muscle, and posterolaterally by the latissimus dorsi.
- The axilla can be reached when the breast tissue is positioned laterally and the dissection is continued under the pectoralis major muscle (**FIG 14**). The clavipectoral fascia should be incised along the edge of the pectoralis major muscle, which will free up the pectoralis major and minor muscle from the nodal tissue (**FIG 15**). Close attention should be paid to identify the medial pectoral neurovascular bundle. It sweeps laterally along the pectoralis minor, and care should be taken to preserve the bundle. The inferior border of the dissection should extend to the 4th or 5th rib to ensure that level I nodes are included in the specimen.[10]
- Once the axillary fat pad is encountered, the subcutaneous fat appears darker and is glistening. Once the axillary space is entered, it is vitally important to identify landmarks to guide your dissection and to prevent neurovascular injury. This ALND describes a lateral to medial approach to the axillary lymph node dissection. A medial to lateral approach is described in Part 5, Chapter 28.
- The first vital structure to identify is the thoracodorsal bundle, and this is facilitated by visualizing the latissimus dorsi laterally (**FIG 16**). The thoracodorsal nerve inserts approximately 4 cm inferior to the axillary vein, and the bundle can be followed superiorly to its posterior insertion on the axillary vein (**FIG 17**).
- The next step is to identify the axillary vein. Richardson retractors should be used at this time to provide exposure to the vein by retracting the pectoral muscles (**FIG 18**). The axillary vein can be easily identified using

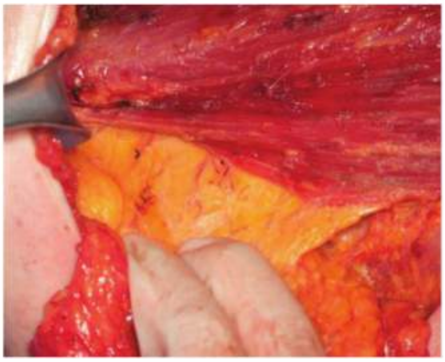


FIG 14 ● The axilla can be reached when the breast tissue is positioned laterally and the dissection is continued under the pectoralis major muscle, where the clavipectoral fascia is exposed.

FIG 15 ● The axillary fat pad is entered when the clavipectoral fascia is incised.

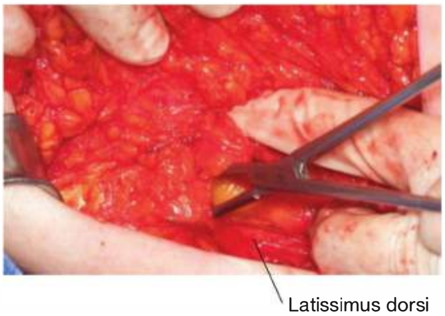


FIG 16 ● Dissect laterally to identify the latissimus dorsi muscle and enter axilla just anterior to latissimus dorsi to find the thoracodorsal bundle.

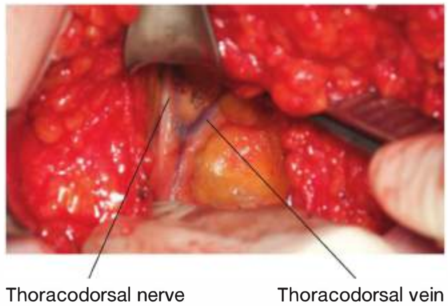


FIG 17 ● The thoracodorsal bundle.

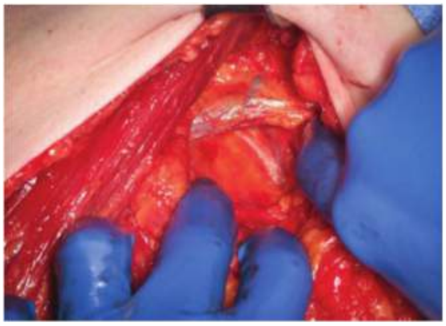


FIG 18 ● The Richardson retractor is used to expose the axillary vein by retracting the pectoral muscles. The thoracodorsal bundle is seen posterior to the axillary vein.

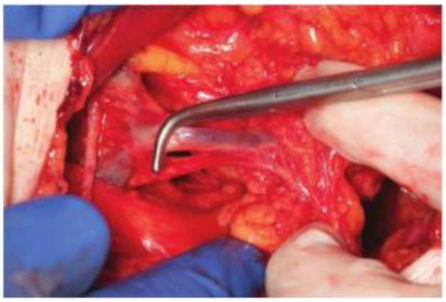


FIG 19 ● The thoracoepigastric vein is the only superficial tributary of the axillary vein and should be ligated with clips or ties.

blunt dissection of the axillary fat once the clavipectoral fascia has been divided. Once the vein is identified, the dissection should continue inferiorly to it. The nodal tissue superior to the axillary vein should be preserved to reduce lymphedema and brachial plexus injury. The thoracoepigastric vein is the only superficial tributary of the axillary vein and should be ligated with clips or ties (**FIG 19**). Before any ligation of this branch is performed, care must be taken to not mistake this vein for the thoracodorsal vein, which lies deep to it. All other lymphatic channels should be clipped and divided using scissors, and superficial branches of the axillary vein should be divided sharply between clips or sutures.

- Level II nodes are located underneath the pectoralis muscle, and level III nodes are located medial to the muscle. Level III nodes are rarely involved in most breast cancer metastasis and are not included in the traditional axillary lymph node dissection.[11] To gain access to the level II nodes, the Richardson retractor should retract the pectoral muscles medially. When placing the retractor deep under the muscles, pay careful attention to the medial pectoral bundle to prevent damage to these structures (**FIG 20A,B**). The dissection should continue to extend medially along the axillary vein, and the lymphatic tissue on the chest wall should be retracted inferolaterally. This tissue should be dissected off the chest wall with ties or clips to prevent lymphatic leaks.
- The long thoracic nerve lies along the chest wall and is superficial to the investing fascia of the serratus anterior muscle (**FIG 21**). This nerve can be difficult to identify, and palpation of this nerve can help to recognize it. The nerve feels like a string of spaghetti when running a finger along the serratus anterior muscle. Care should be taken to not retract the nerve off the chest wall with the specimen. If this nerve is inadvertently injured, it will cause patients to have a winged scapula. Dissection of the lymphatic tissue close to the nerve should be done with sharp dissection and not electrocautery.

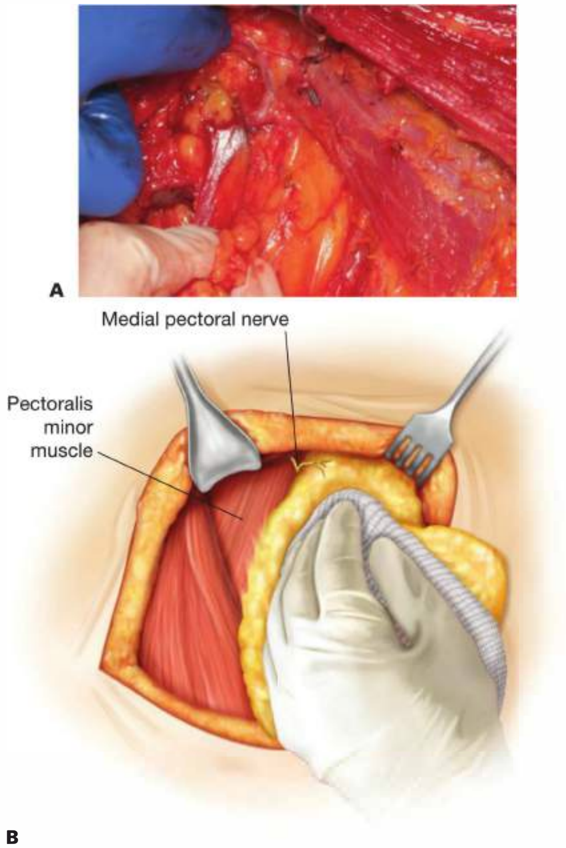


FIG 20 ● **A,B.** When placing the retractor deep under the muscles, pay careful attention to the medial pectoral bundle to prevent damage to these structures. The medial pectoral nerve wraps around the underside of the pectoralis minor muscle. (Part **B** modified from Donohue JH, Van Heerden J, Monson JRT, eds. *Atlas of Surgical Oncology*. Cambridge, MA: Blackwell Science; 1995. Used with permission of Mayo Foundation for Medical Education and Research. All rights reserved.)

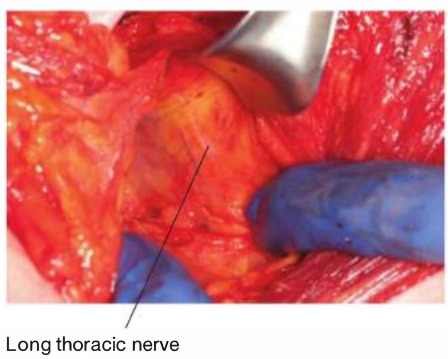


FIG 21 ● The long thoracic nerve lies along the chest wall and is superficial to the investing fascia of the serratus anterior muscle. Care should be taken to not pull the nerve laterally during the axillary dissection. The nerve can be difficult to identify and sometimes will only be felt on palpation. Running a finger along the lateral chest wall can aid in identifying the nerve.

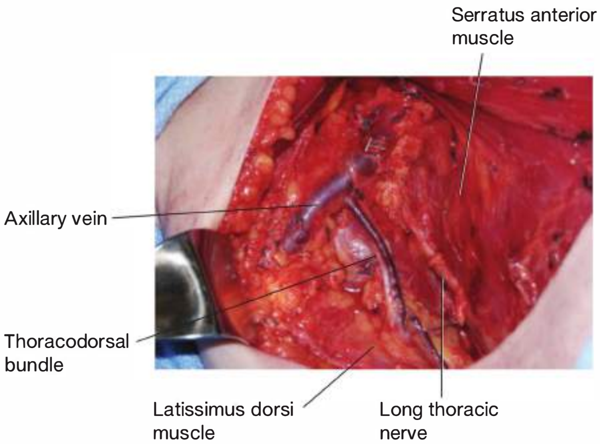


FIG 22 • The axilla after removal of level I and II lymph nodes, with thoracodorsal bundle and long thoracic nerve and axillary vein intact.

- The thoracodorsal bundle is found lateral to the long thoracic nerve. The lymphatic tissue between the two nerves should be dissected and removed. The thoracodorsal bundle should be skeletonized. Any lymphatic channels or superficial branches should be clipped or suture ligated. The branches of the thoracodorsal vein and artery entering the chest medially should be preserved where possible (**FIG 22**).
- Attempts should also be made to try to preserve the intercostobrachial nerves, but if the path of the nerve is directly through the specimen, it can be ligated (**FIG 23**). Patients should know that the intercostobrachial nerves may need to be sacrificed preoperatively, and explain to them that ligating the nerve will cause loss of sensation to their upper inner arm.
- The breast and attached nodal tissue should be excised en bloc by dividing the remaining lateral pedicle. The specimen should be sent to pathology with sutures placed for orientation (**FIG 24**).

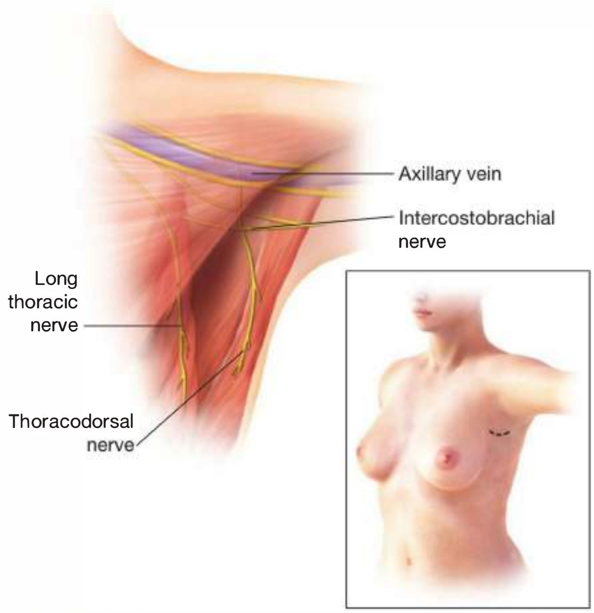


FIG 23 • Schematic drawing of the relationship of the axillary nerves to each other. The intercostobrachial nerves should be preserved if possible. (Modified from and used with permission of Mayo Foundation for Medical Education Research. All rights reserved.)

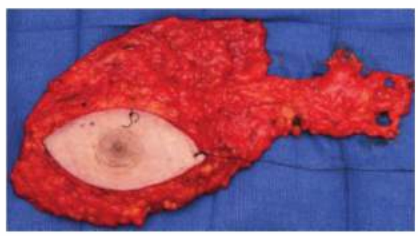


FIG 24 • Suture orientation should be done before the specimen is passed off to pathology. A short stitch should be placed superiorly and a long stitch laterally.

DRAIN PLACEMENT

- Two closed suction drains should be placed to prevent seroma formation. Studies have shown two drains are superior in comparison to one drain placed.[12] One drain should be placed over the pectoralis major muscle and the other drain should be placed in the axillary space (**FIG 25A,B**). The drains should be sutured in place with a monofilament suture and dressed appropriately based on surgical preference.

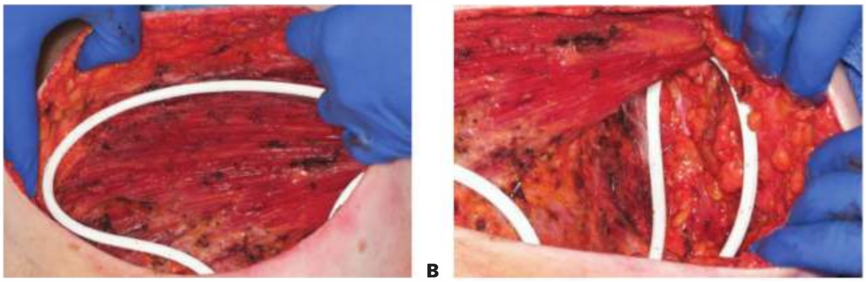


FIG 25 ● **A.** One drain should be placed over the pectoralis major muscle, **(B)** and the other should be placed in the axillary space. The drains should be secured to the skin.

CLOSURE

- A cosmetically pleasing closure is important for psychologic reasons. The goal is to provide a closure that will cause the chest to have a very flat appearance without excess skin redundancy.
- If the skin edges are traumatized, they should be excised with scissors or scalpel. Many times, dog ears appear at the medial and lateral edges of the incision. These should be excised to make the incision have a smoother and flatter appearance. The dermal layer should be closed with an inverted interrupted closure using absorbable suture. INSORB, an absorbable suture stapler, can also be used to close the dermal layer and is a faster alternative to traditional suture closure. The skin should be approximated with an absorbable 4-0 monofilament suture in a running subcuticular closure (**FIG 26**).

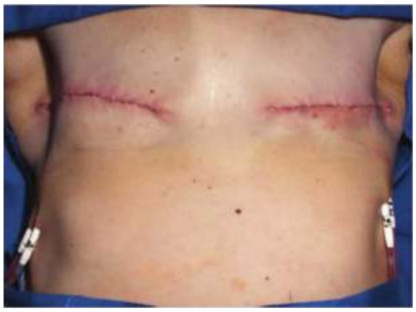


FIG 26 ● A cosmetic closure with a flat-appearing chest wall without skin redundancy is the goal.

PEARLS AND PITFALLS

Indications	■ A comprehensive history and physical examination should be undertaken, as well as review of the radiographic images of the breast and axilla and pathology from all biopsies. Patients with node-positive disease either not amenable to breast conservation or electing mastectomy are candidates for modified radical mastectomy, which encompasses a simple mastectomy together with an axillary lymph node dissection. ■ Once a cancer diagnosis is made, multidisciplinary coordination is essential for successful treatment planning.
Incision placement	■ When choosing an incision for a modified radical mastectomy, the goal is to provide great exposure to the axilla and a good cosmetic outcome. ■ The incision should include a 1- to 2-cm margin around the tumor (if close to the skin) and include the previous biopsy site. ■ The classic Stewart incision is the preferred incision for a modified radical mastectomy providing the necessary exposure and cosmetic outcome.
Flap dissection	■ Flaps should be extended to the borders of the breast tissue. Careful attention needs to be paid to ensure all the breast tissue is resected and the vascular supply to the remaining skin flaps is preserved to avoid flap ischemia.
Axillary lymph node dissection	■ Careful identification of vital structures and the axillary borders will define the dissection. ■ Close attention needs to be paid to the preservation of the axillary vein, thoracodorsal bundle, and long thoracic nerve during the dissection.

Closure	■ The goal is to reduce skin redundancy and create a smooth flat incision. Avoid medial and lateral dog ears. Two closed suction drains should be placed to avoid seroma.
Rehabilitation	■ Patients should have access to counseling or therapy to help in coping with issues of body image. Patients who do not desire reconstruction should also be set up to be fitted for a breast prosthesis. ■ All patients should meet with a lymphedema specialist to coordinate an exercise plan and be provided with compression garments if needed.

POSTOPERATIVE CARE

- Patients after an MRM should be placed in a breast binder or an Ace wrap following their surgery (**FIG 27**). This will provide good compression to prevent development of any hematoma. Steri-Strips or Xeroform dressing can be placed directly over the incisions. Fluffs or Kerlix gauze can be placed over the incision to act as a barrier between the incision and binder.
- Patients who have undergone an MRM will face a variety of rehabilitation issues pertaining to lymphedema, body image, and sexual dysfunction. It is important to have all these concerns addressed preoperatively, during their hospital stay, or at follow-up appointments. The most dreaded complication of having an axillary lymph node dissection is lymphedema. All patients should be scheduled to meet with a lymphedema therapist approximately 2 weeks from their surgery or after drain removal. The therapists can help educate patients on lymphedema and how to prevent the complication and provide them with exercises to avoid restricted shoulder range of motion.
- Patients who have undergone MRM without reconstruction should be referred to be fitted for a breast prosthesis after the drains are removed and the swelling has gone down.

OUTCOMES

- Patients who undergo an MRM are at risk for developing secondary lymphedema. This is one of the most dreaded fears of many breast cancer survivors, and many women are not educated on this complication preoperatively.
- Many patients undergoing an MRM will require postmastectomy radiation. The addition of radiation after a nodal dissection can substantially increase the risk of development of lymphedema to over 40%. Successful diagnosis and treatment of patients suffering from lymphedema should focus on risk-reducing therapies and lifelong self-directed care.[13,14]
- Survival outcomes in patients undergoing MRM are not based solely on the operative procedure but dependent on the tumor stage, nodal stage, and tumor biology. Studies have shown in node-positive patients that the number of positive lymph nodes, patient age, tumor grade, and race are significant variables to affect survival.[15]

FIG 27 ● Patients should be wrapped in an Ace binder or a breast binder to provide compression. The drains should be in view to monitor output and consistency.

COMPLICATIONS

- Seroma
- Wound infection
- Hematoma
- Wound dehiscence
- Flap necrosis
- Positive margins
- Brachial plexus injury
- Nerve injury
- Winged scapula
- Axillary vein thrombosis
- Lymphedema

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Chapter 13

Techniques for Correcting Lumpectomy Defects

Julie E. Park Jonathan Bank David H. Song

DEFINITION

- Breast conservation therapy (BCT), the combination of lumpectomy and breast radiation, allows women with breast cancer to avoid mastectomy without compromising outcome. Although the majority of women will have an excellent cosmetic outcome, some women will develop asymmetry from volume loss and postradiation contour deformity and nipple–areolar complex (NAC) deviation. Several techniques exist for correcting lumpectomy defects to allow for oncologically sound and aesthetically acceptable BCT.

PATIENT HISTORY AND PHYSICAL FINDINGS

- In some situations, the plastic surgeon is asked to evaluate the patient prior to lumpectomy in order to plan for an immediate correction. In other situations, the patient is referred to plastic surgery after radiation therapy for correction of postradiation contour deformity and NAC deviation.
- It is important to discuss with the patient her expectations; specifically, whether she would accept a smaller breast.
- Does the patient have symptomatic macromastia and would she benefit from, or be interested in, breast reduction?
- Does the patient smoke? This might impact nipple perfusion.
- A thorough breast examination should take note of the breast size and any preexisting asymmetry. Any previous scars or contour deformities should be noted, especially in women who have already completed BCT.
- It is also important to document the position of the nipple, including any ptosis, and the distance from the sternal notch.
- For patients anticipated to have a significant deformity from BCT, a multidisciplinary approach is critical to achieving the optimal cosmetic outcome. Communication with the surgical oncologist is critical to both identifying appropriate patients, planning the site and expected volume of resection, and coordinating schedules. It is important to identify with the radiation oncologist if the patient will require a "boost," as this will limit how much tissue can be rearranged. In cases of wire-localized lumpectomy, marks should be placed prior to wire placement and this should be coordinated with the breast radiologist.

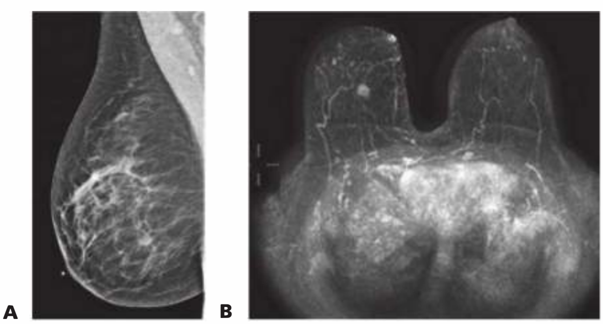

FIG 1 ● Mammogram **(A)** and MRI **(B)** of patient with 1.1 × 1.0 × 0.8 cm right-sided breast cancer at 5 o'clock position.

IMAGING AND OTHER DIAGNOSTIC STUDIES

- Almost all patients who have undergone BCT should have had bilateral mammography as part of the workup (**FIG 1A**), and some women may have had magnetic resonance imaging (MRI) (**FIG 1B**).

SURGICAL MANAGEMENT

Preoperative Planning

- The goals of correcting lumpectomy defects include obliterating any dead space, supporting the NAC and maintaining adequate perfusion, and resecting any excess skin.
- There are two main options for reconstructing a lumpectomy defect. ***Volume displacement*** techniques use parenchymal remodeling (volume shrinkage). ***Volume replacement*** techniques use both local and distant tissue to preserve volume.
- After reviewing the preoperative imaging and discussing with the surgical oncologist, the next question is whether given the size and location of the tumor, will there be sufficient tissue in the breast to rearrange and obliterate dead space without losing too much volume?
  - Yes—volume displacement: reduction, mastopexy, or intrinsic breast flaps
  - No—volume replacement: local rotational flaps
    - Thoracodorsal artery perforator (TAP) or muscle-sparing latissimus dorsi (MSLD) flap
    - Lateral intercostal artery perforator (LICAP) flap

Positioning

- The patient is positioned supine with the arms secured to the arm boards at the side to allow for sitting the patient up during the surgery (**FIG 2**). The arms should be place on padded arm boards and positioned in a way that pressure points are alleviated.

FIG 2 ● Positioning of a patient with both arms abducted, padded, and secured, enabling seating the patient during surgery to assess for symmetry of reconstruction.

FREESTYLE INTRINSIC BREAST FLAPS

- For some defects, dermatoglandular flaps can be created to fill small defects. Depending on the location, even small defects can lead to unfavorable cosmetic results, particularly a significant concavity at the site of the lumpectomy after radiation. This can occur when there is minimal tissue between the skin and underlying muscle.
- The principle of intrinsic breast flaps is to focus on perfusion and support to the NAC and to obliterate the dead space.
- The lumpectomy cavity is examined to evaluate how much dead space there is and the remainder of the breast is assessed for where there is extra tissue (**FIG 4A**). An intrinsic breast flap is created by dissecting between the skin and breast parenchyma and between the breast parenchyma and pectoralis (**FIG 4B**). The flaps are based either on axial blood supply from perforators originating from the internal mammary artery or from the intercostal vessels. As these vessels are not typically identified in the dissection, the flaps should be created as random pattern flaps, adhering to the principles of creating broad-based flaps that are not too lengthy as to put the distal tip of the flap at risk of ischemia. The flap is then advanced and secured to fill the lumpectomy cavity and to maintain support to NAC (**FIG 4C**).
- Any excess skin is resected and the wound is closed.

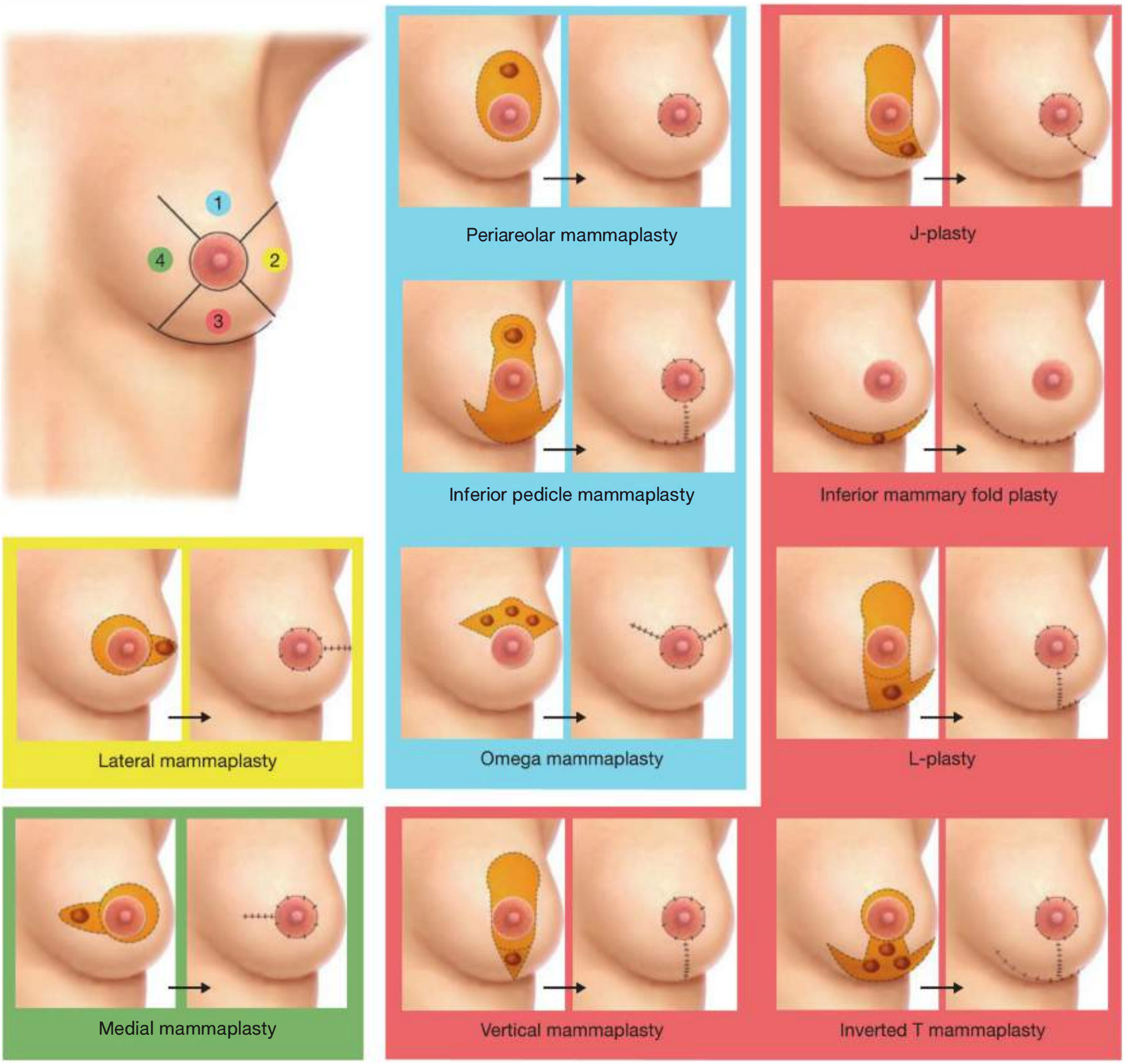

FIG 3 ● There are multiple options for skin incisions for resections depending on the location of the defect, size of the defect, and size of the breast.

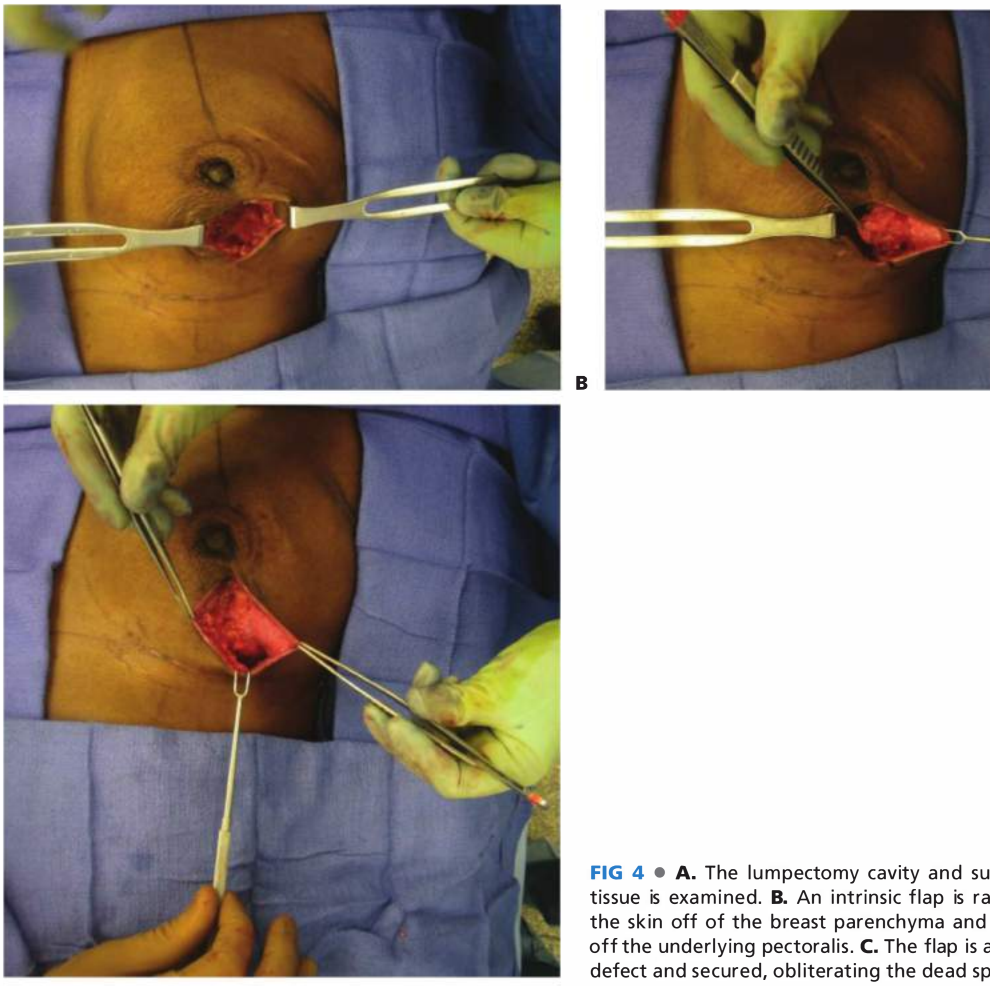

FIG 4 ● **A.** The lumpectomy cavity and surrounding breast tissue is examined. **B.** An intrinsic flap is raised by elevating the skin off of the breast parenchyma and the breast tissue off the underlying pectoralis. **C.** The flap is advanced into the defect and secured, obliterating the dead space.

INFERIOR POLE LUMPECTOMY DEFECTS—THE VERTICAL MAMMAPLASTY TECHNIQUE

Preoperative Marking

- This approach is an option for patients with lumpectomy defects from approximately 4 o'clock to 8 o'clock positions.
- For patients with appropriately sized breasts, a vertical reduction pattern is marked out on the breast (**FIG 5**). Alternatively, an inverted T pattern can be used.
- With the patient in the upright position, landmarks are drawn—sternal notch, midline, and breast meridians. The new position of NAC is marked out, along with any excess skin as follows: the breast mobilized laterally, vertical line drawn medially, then the breast mobilized medially, vertical line drawn laterally. The vertical components connected with curved line 2 to 4 cm above

FIG 5 ● A vertical reduction pattern.

the inframammary fold (IMF). A mosque-shaped marking is drawn for inset of NAC.

Assess Lumpectomy Defect and Nipple–Areolar Complex

- In the operating room, the prior lumpectomy cavity is opened and the seroma evacuated. As there will no longer be a seroma to guide radiation, it is a good idea to place several small clips at the boundaries of the lumpectomy defect.
- Confirm perfusion and support to NAC and make sure that the lumpectomy cavity is not undermining the NAC. If it is, you need to plan on supporting it with intrinsic breast tissue. If this is not possible, a free nipple graft (FNG) will be needed: The NAC is excised as a full-thickness skin graft, defatted, replaced on a well-vascularized bed in the appropriate position on the breast mound, and secured in place with a bolster dressing.

Convert to Vertical Reduction

- Additional (i.e., more than the lumpectomy) breast tissue is resected as needed to allow for an acceptable final shape. Undermining of the breast off of the pectoralis is usually confined to inferior breast. Tissue is resected medial and lateral to vertical incision to allow "rounding off" of the breast. The parenchyma is approximated centrally (approximating the medial and lateral remaining portions of the breast—the medial and lateral "pillars").
- Skin closure—excessed gathered in subcuticular closure. A small horizontal excision is made along the IMF if needed to further reduce the skin.
- This approach will result in volume loss, so a contralateral reduction will be needed in the future, approximately 3 to 6 months after radiation therapy has been completed.

VOLUME REPLACEMENT PEDICLED FLAPS

- For patients with larger defects for which displacement techniques would not work, replacement techniques may be necessary. Pedicled flaps are recommended. Free tissue transfer is not initially recommended in this situation, as it eliminates the use of a flap in the future should the patient have a local recurrence or new tumor and require a mastectomy. Free flaps should only be considered if pedicled flaps are not feasible or fail.
- Flaps can be raised from the axillary and back region (thoracodorsal, intercostal) or from the upper abdomen (superior epigastric). The two most common types of pedicled flaps are (**FIG 6**) as follows:
  - Thoracodorsal artery perforator (TAP) flap, which is based on the perforators from the descending or the horizontal branches of the thoracodorsal vessels. This is most suitable for superior defects.
  - LICAP flap, which is based on perforators arising from the costal groove. This is a good alternative to the TAP flap for lateral and inferior breast defects.
  - Defects in the medial quadrant can be approached via an anterior intercostal artery perforator (AICAP) flap, which is supplied by perforators originating from the muscular segment, or the superior epigastric artery perforator (SEAP) flap, based on perforators from the superior epigastric. These are not described here.

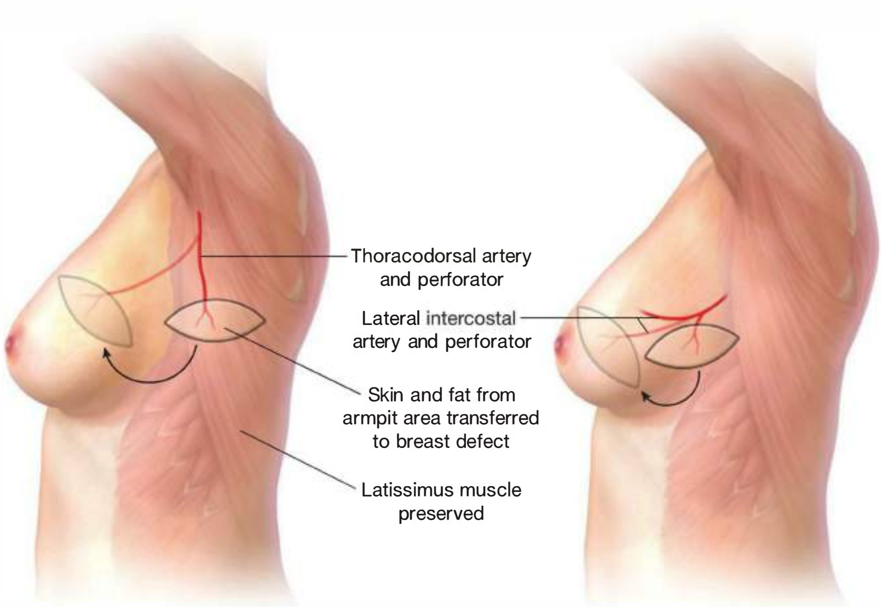

FIG 6 ● The TAP and LICAP flaps.

SUPERIOR-LATERAL LUMPECTOMY DEFECTS—THE THORACODORSAL ARTERY PERFORATOR FLAP OR MUSCLE-SPARING LATISSIMUS DORSI FLAP

Preoperative Marking

- Preoperatively, the patient should be marked in the supine and upright position. Several anatomic landmarks should be identified and marked.
    - The borders of the breast, including the IMF, should be marked. The ideal position of the NAC should be drawn using the contralateral breast as a template. This will need to be adjusted accordingly if there is a plan to either lift or reduce the contralateral breast.
    - Identify and mark the tip of scapula and the anterior edge of the latissimus dorsi muscle.
    - A ***pinch test*** should then be performed to determine the amount of redundant skin in order to determine the size of flap.
- The perforator will determine the viability of the flap and knowing its location will reduce operating time and complications. The perforator emerges approximately 8 to 10 cm from the posterior axillary crease and 2 cm posterior to anterior border of the latissimus (**FIG 7**). This can be confirmed and the perforator marked in the preoperative area with a Doppler ultrasound device.
- Based on this exam, the surgeon should anticipate how to orient the flap.
    - Horizontal—"bra line"
    - Obliquely—line of relaxed skin tension
    - Vertically—along anterior edge of latissimus

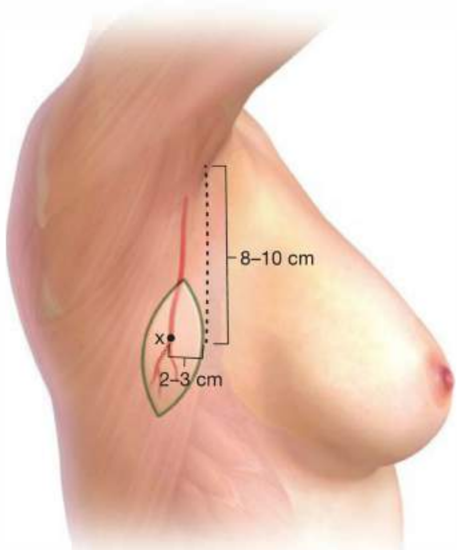

FIG 7 ● The patient is placed in the lateral decubitus position to locate the perforators and design the flap. The *dotted line* is the anterior border of the latissimus dorsi muscle. "X" marks the main perforator artery for the flap, located 2 to 3 cm from the anterior margin of latissimus and 8 to 10 cm from the posterior axillary crease.

Intraoperative Assessment and Creation of Lateral Tunnel

- The patient should be placed on a beanbag. Initially, the patient will be supine. Both breasts are sterilely prepped into the field.
- The prior cavity should be opened and the seroma evacuated. At this point, multiple small clips are placed to mark all the boundaries of the lumpectomy defect. These are important for radiation oncology to know where the lumpectomy cavity was, as there will no longer be a seroma for guidance.
- The NAC should be examined to confirm perfusion and support. It is important to make sure the lumpectomy is not undermining the NAC. Otherwise, this will require support with intrinsic breast tissue. If there is insufficient tissue for perfusion, an FNG may be necessary.
- Assess the total volume of tissue that will be needed to fill the space.
- A tunnel is then created from the lumpectomy cavity to the anterior edge of the latissimus muscle.
- Once the latissimus muscle is identified, the skin edges are temporarily reapproximated with skin staples and the wound is covered with a large sterile occlusive dressing (i.e., Ioban).

Flap Creation

- The patient is repositioned in the lateral decubitus position. All pressure points are appropriately padded and the operative field is again sterilely prepped and draped.
- The perforating vessels are identified using a handheld pencil Doppler. Once the perforators have been identified, the flap position is adjusted as necessary.
- The skin of the flap is incised with a scalpel, beveling so as to capture as much sub–Scarpa's fat as needed. Dissection is then carried down to the muscle.
- Dissect from the midline anteriorly until the perforators are identified (**FIG 8**). The latissimus dorsi fascia should be included with the flap. Complete dissection from anterior to midline is necessary to isolate the perforators.

FIG 8 ● The latissimus dorsi muscle is completely dissected from anterior to midline in order to identify the perforators.

- At this point, it becomes necessary to decide between a TAP flap and an MSLD flap based on the perfusion of the tissues, especially the venous drainage.
  - For a TAP flap, just one perforator is isolated. The muscle is then split and the descending branch of the thoracodorsal artery is dissected to the takeoff point of the transverse branch of the thoracodorsal.
  - For an MSLD flap, multiple perforators within 1 to 3 cm of the anterior edge of the latissimus need to be captured. Harvest the descending branch of the thoracodorsal artery at the takeoff point of the transverse branch.
- Once the flap has been created (**FIG 9**), a drain is placed and the skin is reapproximated. Sterile dressings are applied.

Flap Insertion

- The patient is repositioned supine, with the arms secured to the arm boards to that the table can be flexed and the two breasts compared with the patient in the upright position.
- The flap is inset in order to fill the volume defect. It is important that the NAC be supported.
- It is often necessary to de-epithelialize the skin, but a small skin island should be maintained in order to monitor the flap. The patient should be monitored in the hospital for 1 to 2 days postoperatively (**FIG 10**).

FIG 9 ● Once the flap has been elevated, a drain is placed and the skin is reapproximated. The patient is then repositioned supine.

FIG 10 ● After a poor outcome with a superior lateral lumpectomy **(A–C)**, the defect was corrected using a TAP **(D–F)**.

LATERAL LUMPECTOMY DEFECTS—THE LATERAL INTERCOSTAL ARTERY PERFORATOR FLAP

Preoperative Markings

- The borders of the breast, including the IMF, should be marked. The ideal position of the NAC should be drawn, using the contralateral breast as a template. This will need to be adjusted accordingly if there is a plan to either lift or reduce the contralateral breast.
- Identify and mark at least 5 cm posterior to axillary line at the level of the future defect. (This marking is posterior to the LICAP and thus will ensure inclusion of the perforator in the flap.)
- Mark perforator with handheld pencil Doppler.

Intraoperative Assessment

- The patient is placed supine with a beanbag on the table. Both breasts are prepped and draped into the field.
- The prior lumpectomy cavity is opened and the seroma is evacuated. Multiple small clips are placed to mark all the boundaries of the lumpectomy defect. These are important for radiation oncology to know where the lumpectomy cavity was, as there will no longer be a seroma for guidance.
- Assess the total volume of tissue that will be needed to fill the space.
- The NAC should be examined to confirm perfusion and support. It is important to make sure the lumpectomy is not undermining the NAC. Otherwise, this will require support with intrinsic breast tissue.
- The skin is then temporarily closed with staples and covered with a large sterile occlusive dressing (i.e., Ioban).

Locate Perforators

- The patient is repositioned in the decubitus position. All pressure points are carefully padded and the patient is sterilely prepped and draped.
- A handheld pencil Doppler is used to locate the perforators. It may be necessary to adjust the flap position based on the location of the perforators.

Make Skin Incision

- An elliptical incision starting approximately 5 cm posterior to the axillary fold is created at the level of the defect.
- Bevel to capture as much of the sub–Scarpa's fat as needed, and then the incision is deepened to expose the latissimus dorsi muscle.

Identify Perforators

- The dissection is carried from the midline in the anterior direction until the perforators are found. The smaller posterior branch of the lateral cutaneous branch will be identified at the anterior border of the latissimus and this can be traced to find the larger anterior branch (FIG 11).
- The latissimus dorsi muscle belly is retracted and a pedicle of 3 to 5 cm is obtained. This is adequate to reach a defect over the lateral or superior part of the breast. The fascia should be harvested into the flap as well.
- A Jackson-Pratt (JP) drain is placed, the incision closed, and the donor site is dressed.

Rotate the Flap Anteriorly and Inset

- The patient is repositioned supine with the arms secured to the arm boards so that the table can be flexed and the breasts compared with the patient sitting upright. The patient is again prepped and draped.
- The flap is now inset in order to fill the volume defect (FIG 12). It is important to support the NAC as needed.
- A good portion of the skin may need to be de-epithelialized, but it is important to leave a skin island in order to monitor the flap (FIG 13). The patient should be monitored for 1 to 2 days postoperatively.

FIG 11 ● The smaller posterior branch of the lateral cutaneous branch will be identified at the anterior border of the latissimus and this can be traced to find the larger anterior branch.

A

B

FIG 12 ● The LICAP flap is now inset in order to fill the volume defect.

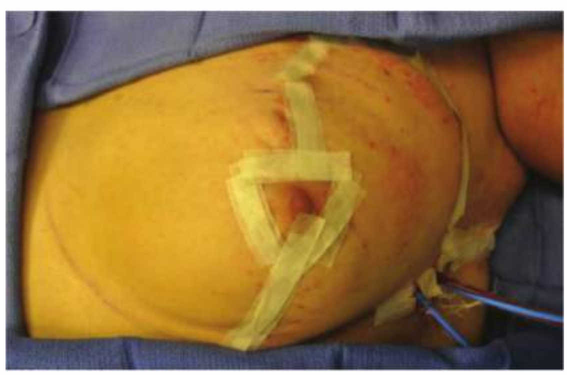

FIG 13 ● After the flap is inset, the skin is de-epithelialized except for a small skin island and the skin is then reapproximated.

CENTRAL LUMPECTOMY INCLUDING THE NIPPLE–AREOLAR COMPLEX

Preoperative Marking

- With the patient in the upright position, the new position of NAC is marked out, along with any excess skin.
- An inferior pedicle reduction pattern is marked out (**FIG 14**).

Assess Lumpectomy Defect and Nipple–Areolar Complex

- In the operating room, the prior lumpectomy cavity is opened and the seroma evacuated. As there will no longer be a seroma to guide radiation, it is a good idea to place several small clips at the boundaries of the lumpectomy defect.

Convert Reduction with Inferior Pedicle

- An inferior pedicle is designed to convert this to a reduction (**FIG 15**).
- A neoareola is created by leaving a skin paddle on the pedicle that will fill in the previous NAC when the pedicle is advanced superiorly.
- An inferior pedicle is created and advanced superiorly. Blood supply emanates from pectoral perforators from thoracoacromial artery. The pedicle design has a 3:1 ratio of length:width with a 30-cm maximal length.

FIG 14 ● An inferior pedicle reduction pattern.

FIG 15 ● After the lumpectomy and NAC have been removed, an inferior pedicle reduction pattern is designed.

FIG 16 ● A neoareola has been created by leaving a skin paddle on the pedicle and brought out through the new NAC space.

- The skin paddle is brought out in the previous NAC space.
- The excess skin and tissue is excised and the remaining skin is reapproximated (**FIG 16**).

Creation of New Nipple–Areolar Complex

- Three to 6 months after radiation therapy is completed, the patient returns to the operating room for nipple reconstruction as per standard techniques for total breast reconstruction (see Part 5, Chapter 20). They will also require a contralateral symmetry procedure at that time (**FIG 17**).

FIG 17 ● After the patient has undergone nipple–areolar reconstruction and contralateral reduction.

PEARLS AND PITFALLS

Timing 6 to 8 weeks to radiation therapy from lumpectomy	■ Evaluate patient prior to lumpectomy. ■ Schedule cases simultaneously. ■ Discuss incision location with oncologic surgeon.
Adjust for postradiation contractures	■ Likely will have a superior lift—do not err on placement of nipple being too high.
Not as much time for resolution of inferior dog ear	■ Excise as needed.
Delay contralateral reduction if possible.	■ Keeps healthy breast tissue out of the field of radiation
Postlumpectomy edema affecting venous perfusion, especially of NAC	■ Good breast support after lumpectomy ■ Convert to FNG as needed.
Will lumpectomy resection allow for NAC pedicle?	■ FNG as needed
Unsure about volume?	■ Evaluate the lumpectomy during first surgery.

POSTOPERATIVE CARE

- Monitor any flaps for at least 1 to 2 days in the hospital.
- Surgical support bra
- Immediate response to any wound dehiscence or breakdown to avoid delay to radiation therapy
- Consider drain placement to limit postoperative edema (limited time to get patient to radiation therapy)

COMPLICATIONS

- Fat necrosis
- Wound healing complications
- Potential delay to radiation therapy

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Chapter 14

Direct-to-Implant Breast Reconstruction

Amy S. Colwell

DEFINITION

- Mastectomy is increasingly performed for breast cancer treatment or risk reduction in high-risk patients. The goal of breast reconstruction is to rebuild the breast and restore a sense of normalcy.

ANATOMY

- The breast glandular tissue extends to the clavicle superiorly, the inframammary fold (IMF) inferiorly, sternum medially, and latissimus dorsi laterally (**FIG 1**). With a skin-sparing or nipple-sparing mastectomy, the glandular tissue is removed and the skin is spared, thus making direct-to-implant breast reconstruction possible. In implant-based breast reconstruction, a space is created underneath the pectoralis muscle, and the serratus anterior is sometimes used to help define the lateral border of the reconstructed breast (**FIG 2**).

NATURAL HISTORY

- Mastectomy offers potential cure in breast cancer patients and prevention for those at high risk for cancer. Immediate breast reconstruction offers an improvement in health-related quality of life and patient satisfaction for women choosing mastectomy as part of their treatment plan.[1–3]

PATIENT HISTORY AND PHYSICAL FINDINGS

- Patient selection in immediate direct-to-implant breast reconstruction is one of the keys to success. A history is obtained to check for comorbidities that are known risk factors for increased complications including smoking, diabetes, body mass index (BMI), and previous breast radiation. On physical exam, the breast is assessed for skin quality, size, scars from previous procedures, symmetry, position of the IMF, and nipple position if a nipple-sparing mastectomy is being considered.

DIFFERENTIAL SURGICAL TREATMENT OPTIONS

- Two-stage tissue expander–implant reconstruction
- Autologous reconstruction using tissue from the body including the abdomen (TRAM, transverse rectus abdominis myocutaneous; DIEP, deep inferior epigastric perforator; SIEA [superficial inferior epigastric artery] flaps), buttocks (SGAP, superior gluteal artery perforator; IGAP [inferior gluteal artery perforator] flaps), thighs (TUG [transverse upper gracilis] flap), and back (latissimus dorsi)
- Fat transfer
- No, or delayed, reconstruction

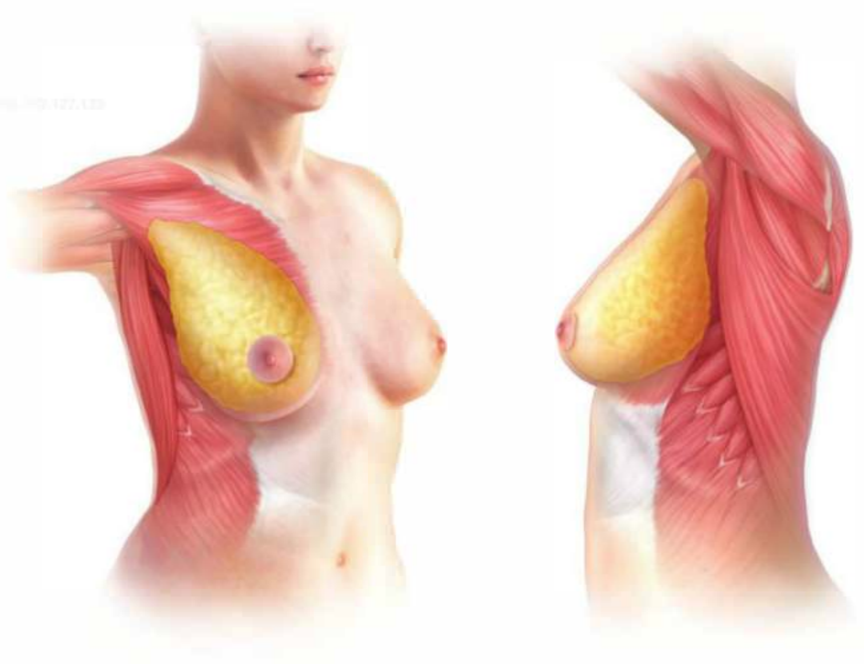


FIG 1 ● The anatomic boundaries of the breast are the clavicle, sternum, inframammary fold, and latissimus dorsi.

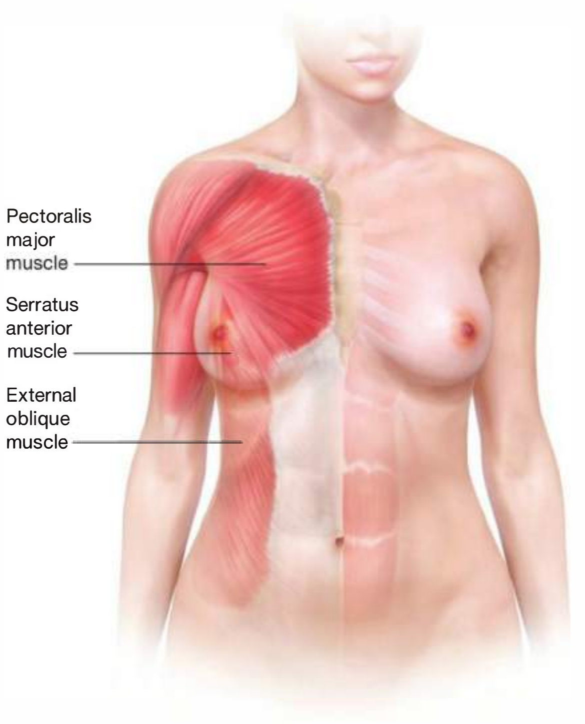


FIG 2 • A plane is created under the pectoralis muscle for implant placement. The pectoralis thus covers the implant superior and medially. The serratus muscle is sometimes elevated for lateral coverage or support.

NONOPERATIVE MANAGEMENT

- Breast reconstruction is a choice, and patients undergoing mastectomy may not elect to pursue reconstruction. If no reconstruction is planned, the breast skin is closed and the chest remains flat in contour. If desired, external breast prostheses are available for women to wear in their clothing to give the appearance of a breast.

SURGICAL MANAGEMENT

- The goals of reconstruction are considered in determining if the reconstruction is designed to augment, reduce, or maintain the current breast size. In general, if a woman wants a significant increase in breast size, this is more safely done in two stages using a tissue expander followed by exchange to implant in a second surgery (see Part 5, Chapter 15). For single-stage implant reconstruction, the implant is placed directly in a partial subpectoral pocket in order to allow superior soft tissue coverage with muscle in the cleavage area of the breast and to help prevent contracture around the implant.[4] The implant is subcutaneous inferiorly, which allows a more natural teardrop shape, and is typically supported by a surgical acellular dermal matrix (ADM) or mesh. Currently, the most common ADM is AlloDerm (human dermis, LifeCell, Branchburg, NJ), but a variety of ADM or mesh material derived from human dermis, porcine dermis, bovine pericardium, fetal bovine dermis, silk, titanium, and Vicryl exist.

Preoperative Planning

- With immediate implant reconstruction, a foreign body (implant) is placed into a skin envelope that has been partially devascularized with the mastectomy. Therefore, sterility is an important component of preoperative planning and operative management. The patient sits upright and is marked prior to the procedure. Important landmarks include the IMF position, its relation to the IMF on the contralateral breast, and the lateral border of the breast. The mastectomy portion of the procedure is performed first followed by the reconstruction.

Positioning

- The patient is positioned supine with the arms secured on arm boards at the side, angled approximately 80 to 85 degrees from the operating table (**FIG 3**). This allows access to the axillary lymph nodes for sampling during the mastectomy. Both breasts are prepped and draped into the field.

Approach

- The mastectomy and reconstruction may be performed using various incisions. If a nipple-sparing approach is chosen, the safest option is to use a radial lateral incision extending from the areola toward the axilla without a full-thickness incision around the nipple. The incision that maximizes cosmesis is an inferolateral or standard IMF incision under the breast.[5] For skin-sparing mastectomies, the incision is made around the areola and extended laterally if needed for access. For larger breasts, a skin-reducing pattern is designed to remove excess skin in a vertical or horizontal direction. The inverted T/Wise/anchor skin pattern is typically avoided (secondary to higher risk of skin necrosis and complications). The pectoralis muscle is partially released inferiorly to accommodate the implant size and allow more natural breast shape. The challenge of direct-to-implant breast reconstruction is in replacement of the breast volume with an implant that closely matches the breast base diameter but without placing undue stress on the breast skin envelope. If this cannot be achieved in one stage, a two-stage approach is used with a tissue expander intermediary step.

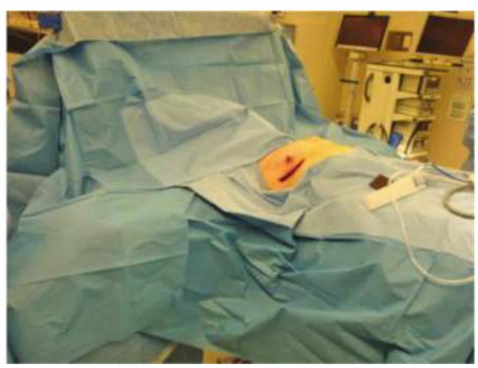


FIG 3 • The patient is positioned supine with arms out on arm boards at approximately 80 to 85 degrees from the operating room table. Care is taken to secure the arms firmly as the back of the operating room table will be raised to a sitting position to check implant placement in the breast pocket while the patient is under anesthesia.

DIRECT-TO-IMPLANT BREAST RECONSTRUCTION WITH PARTIAL PECTORALIS MUSCLE COVERAGE AND ACELLULAR DERMAL MATRIX

- Following mastectomy, the skin is reprepped using a chlorhexidine scrub, and new sterile drapes are placed over the mastectomy drapes. The patient is paralyzed in order to allow easier dissection and pocket creation under the pectoralis muscle. The color of the skin and thickness of the skin flaps are observed to determine if the patient is a candidate for direct-to-implant reconstruction. If there are ischemic changes to the skin marked by pink or blue discoloration, or if the skin flaps are very thin with areas of dermis exposed on the undersurface, it is unlikely that the skin will be able to support the additional stress and weight of a full-size implant at the time of mastectomy. If the skin color is good and the skin flaps have a uniform marbling of subcutaneous fat on the undersurface, then the patient is a candidate for direct-to-implant reconstruction.

Pectoralis Muscle Release

- Using the same access incision used for the mastectomy, the pectoralis muscle is raised from lateral to medial in the loose areolar tissue plane underneath the muscle until the medial origin on the sternum is reached. The pectoralis muscle is then detached from its origin on the external oblique aponeurosis and rectus sheath inferiorly. Dissection continues to the medial muscle origin on the sternum at approximately the 4 o'clock or 8 o'clock position on the chest wall (**FIG 4**) using electrocautery. Inadequate medial release will lead to lateral malposition of the implant. The remaining pectoralis attachment to the sternum is preserved. If necessary, the muscle may be released further to the 3 o'clock or 9 o'clock position on the chest wall to facilitate medial positioning, but this also results in greater pectoralis muscle retraction and thus less muscle coverage over the implant. The pectoralis muscle becomes the superior and medial border of the implant pocket.

Pocket Creation

- Although the pectoralis muscle serves as the superior and medial pocket borders, the inferior and lateral pocket borders are formed by the ADM. The ADM is washed and rehydrated according to the manufacturer. The ADM is then first stitched to the medial border of the released pectoralis muscle (**FIG 5**). If the IMF is intact inferiorly, the ADM is sewn to the IMF using simple buried interrupted sutures. If the IMF is not intact, the ADM is sewn to the chest wall at the desired location for the IMF using a permanent suture (0 Ethibond). Care is taken to leave the ADM loose medially in preparation for accommodating an implant. Laterally, the ADM is sewn to the chest wall at the lateral border of the breast as marked preoperatively or to a raised edge of serratus muscle if the ADM is insufficient in horizontal length. Once the pocket has been created, the base diameter is measured with a ruler to help determine implant choice. A sizer is then placed into the subpectoral, sub-ADM pocket and one or two sutures are placed from the pectoralis muscle to the ADM to keep the sizer in place in the pocket. The skin is stapled shut and the patient is sat upright on the operating room table. The breast reconstruction is observed with different sizer volumes to help determine if it is safe to place an implant, to determine volume, and to assess pocket dimensions.
- The pocket is copiously irrigated with a triple-antibiotic solution of cefazolin, gentamicin, and bacitracin. The surgeon's gloves are changed and the implant is inserted

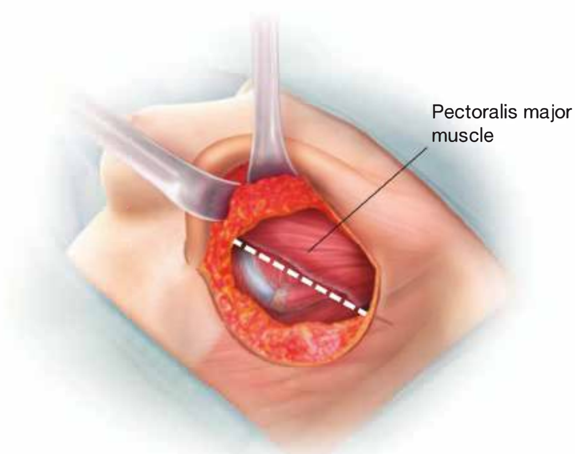


FIG 4 ● The pectoralis muscle is released from its insertion inferiorly to the 4 o'clock or 8 o'clock position on the chest wall to allow medial placement of the implant.

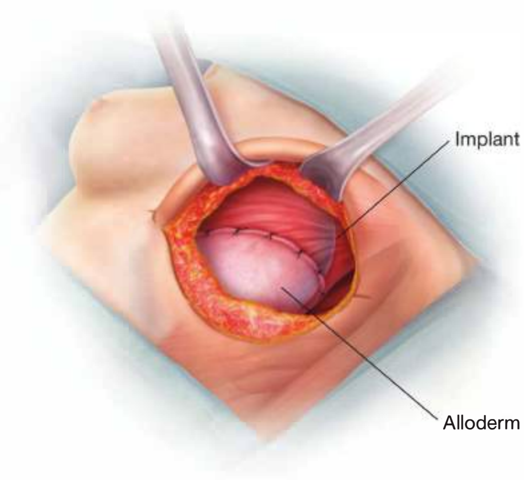


FIG 5 ● To create the inferior and lateral portions of the implant pocket, an ADM or scaffold is sewn to the IMF or chest wall inferiorly and laterally. The implant is placed inside the pocket and then the pectoralis-ADM pocket is closed using absorbable sutures.

into the newly created pectoralis-ADM pocket. The pocket is closed using figure-of-eight or horizontal mattress absorbable sutures (2-0 Vicryl) (FIG 6A,B). Two closed suction drains are placed with one inside the ADM pocket along the IMF and the other outside the pocket in the axilla. The skin edges are trimmed and closed in two layers. Incisions are sealed with surgical glue (Dermabond) and covered with a clear semipermeable dressing (Tegaderm). A chlorhexidine-impregnated sponge (Biopatch) can be used around the drains. If desired, Microfoam tape can be placed laterally and inferiorly to help support the implant position.

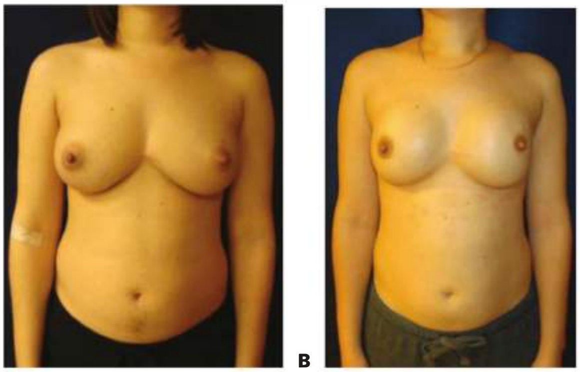
A B


FIG 6 ● This 34-year-old female developed breast cancer and had bilateral nipple-sparing mastectomy procedures through inferolateral IMF incisions with single-stage direct-to-implant reconstructions. **A.** Preoperative photo, **(B)** postoperative photo.

DIRECT-TO-IMPLANT BREAST RECONSTRUCTION WITH TOTAL MUSCLE COVERAGE

- Direct-to-implant breast reconstruction with total muscle coverage of the implant is uncommonly performed due to limitations in achievable volume and less desirable implant shape and position. In select patients with small breast volumes, it can be performed by elevating the pectoralis muscle from lateral to the medial sternal origin. The pectoralis may be partially released inferiorly by dissecting through the rectus abdominis fascia centrally to help avoid superior malposition. A serratus flap is raised laterally to form the lateral borders of the implant pocket. Once the implant is placed, the pectoralis-serratus pocket is closed using absorbable sutures.

PEARLS AND PITFALLS

Lateral malposition of implant	■ Check placement of lateral sutures and determine if lateral border should be medialized to shift implant position. If appropriate, check base diameter of implant to ensure proper fit into pocket. Make sure pectoralis muscle is appropriately released to sternal origin medially and to the 4 o'clock or 8 o'clock position on the chest wall.
Asymmetry of IMF positions	■ Preoperative marks should determine if the IMF position is similar on the breasts. If asymmetric, a decision is typically made to change the IMF position on one breast to match the other breast. Inferior suture placement is checked on both sides for bilateral reconstruction to make sure both are sewn to similar positions on the chest wall or IMF.
Lateralization of nipples on nipple-sparing mastectomy	■ For large breasts, medial positioning of implants may result in lateralization of the nipples. A preoperative discussion with the patient sets expectations and determines whether it would be better to pursue a skin-sparing mastectomy as an alternative. A radial inferior incision yields better nipple position in these breasts but places greater tension on the skin, thus making single-stage reconstruction less likely.
Implant choice	■ For skin-sparing mastectomies, a moderate plus profile implant best matches goals for projection and breast base diameter in most patients. For nipple-sparing mastectomies, a moderate profile implant is used more often to help centralize the nipple.
Learning curve	■ There is a learning curve for surgeons using this technique that is primarily related to the ability to assess the perfusion of the breast skin flap. If the limits of perfusion are surpassed, the result is skin necrosis. Experience with the technique, experience with the breast surgeon, and novel devices to assess skin perfusion decrease the complication rate for this technique.
Fat transfer	■ Fat transfer is increasingly used in implant-based breast reconstruction to fill in defects around the implant. This is not recommended at the time of immediate breast reconstruction with implants, but may be safely done in a second procedure.

POSTOPERATIVE CARE

- The patient stays in the hospital for one or two nights. Prior to discharge, a loose-fitting surgical bra is placed. Care is taken to avoid a tight or constricting dressing or bra that may compromise the blood flow of the mastectomy skin flaps. Patients are seen weekly until drains are removed. Criteria for drain removal is less than 30 mL per day. If skin necrosis develops, it is treated aggressively with sharp debridement and closure. For smooth round implants, gentle medial massage of the implants is started 4 weeks postoperatively to help prevent implant contracture.

OUTCOMES

- Immediate breast reconstruction following mastectomy leads to improved psychosocial outcomes and patient satisfaction compared to patients who decide not to have reconstruction.

COMPLICATIONS

- Total complications following direct-to-implant reconstruction are 3% to 15%.[6,7] The explant rate ranges from 1% to 4%. The most common complication is skin necrosis. Other complications include infection, seroma, hematoma, nipple necrosis, implant malposition, and deep venous thrombosis. The most common late complication is capsular contracture.

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Chapter **15**

Two-Stage Implant Breast Reconstruction

Eric G. Halvorson

DEFINITION

- Two-stage implant breast reconstruction is performed in either the immediate or delayed setting following mastectomy.
- The advantages of two-stage implant reconstruction (compared to autologous reconstruction) include shorter operation, lack of donor site, shorter hospital stay, shorter recovery, patient control over final volume, and a "perkier" result.
- The disadvantages of two-stage implant reconstruction include multiple postoperative office visits for expansions, discomfort associated with the expansion process, a second (albeit outpatient) surgery, and the permanent risks of implants (capsular contracture, rupture, rippling, infection, malposition, and exposure).

PATIENT HISTORY AND PHYSICAL FINDINGS

- It may be beneficial for the initial consultation to occur separate from multidisciplinary clinic visits focused on cancer care. Patients presenting to the plastic surgeon after such visits are often overloaded with information and overwhelmed by all the options and information related to reconstruction. It is critical to determine the patient's goals for reconstruction and to ascertain their preferences with respect to breast size, breast shape, willingness to accept surgical risk, willingness to accept donor site morbidity, operative length, hospital stay, recovery process, postoperative follow-up protocol, secondary surgeries, and long-term complications.
- Having a clinic nurse well versed in reconstructive options to meet with patients and show them patient photographs is an incredibly helpful prelude to the physician–patient consultation.
- Physical examination of the breasts is performed to evaluate any masses and whether or not skin involvement or peau d'orange is present. The overall size and degree of ptosis is noted. Patients with significant ptosis will typically require skin excision. If performed as an inverted "T" or Wise pattern, there is significant risk for mastectomy flap necrosis. Alternatively, one can perform a generous horizontal ellipse, vertical ellipse, or two-stage Wise pattern excision with the vertical closure first and a horizontal excision at the inframammary fold (IMF) 3 to 6 months later.
- The breast width, height, and projection is measured in centimeters. These measurements are used for selecting a tissue expander (as described in the following text).

SURGICAL MANAGEMENT

- Ideal candidates for two-stage implant reconstruction are thin, nonsmokers undergoing bilateral mastectomy who have not, and will not, receive radiotherapy. Smokers are prone to mastectomy flap necrosis and infection. Radiotherapy increases the risk of infection, implant exposure, and capsular contracture. Previously radiated skin will not expand well.
- Although obesity increases the risk of complication for any type of reconstruction, heavier patients tend to have better cosmetic results with autologous reconstruction than with implants, as it can be difficult to match the opposite breast after a unilateral mastectomy or give adequate volume/ptosis after a bilateral mastectomy.
- Patients with very large breasts who require skin removal during mastectomy are at risk for mastectomy flap necrosis and tend to require secondary procedures to address residual excess skin. These patients often have ample donor sites for autologous reconstruction, which may be a better option. Patients with small breasts who want them to be larger can achieve that goal through expansion. Patients who have minimal ptosis and want their breasts to be slightly smaller are candidates for single-stage implant reconstruction.

Preoperative Planning and Implant Selection

- Good communication with the breast surgeon is important to ensure oncologic goals are maintained and that reconstruction is appropriately staged. Patients with advanced disease, requirement for immediate postoperative adjuvant therapy, unstable social environment, and/or uncertainty regarding goals for reconstruction may be better served by delayed reconstruction.
- Prior to mastectomy, the patient must be marked in the standing position. The IMF is marked on each side and the midline is drawn between the sternal notch and xiphoid process. The overall outline of the breasts is marked. Although a transverse ellipse around the nipple–areolar complex (NAC) is commonly used for the mastectomy incision, the author's preference is an oblique ellipse parallel to the pectoralis major fibers (**FIG 1**). This renders the medial scar less visible

FIG 1 ● This patient will be used for the majority of photographs in this chapter. She is a woman in her late 20s with genetic predisposition (*BRCA* gene) undergoing bilateral prophylactic mastectomy and two-stage implant reconstruction. Preoperative markings for the mastectomy are shown, demonstrating the oblique ellipses for incision preferred by the author.

in clothing, allows for better subincisional muscular coverage, and facilitates a stair-step approach during the exchange procedure (as described in the following text).

- Tissue expanders are selected preoperatively based on the width of the patient's breast. There are many different tissue expanders to choose from, but most are textured and anatomic, providing lower pole projection. Some are taller than they are wide, some are wider than they are tall, and some are semicircular or crescentic and focus on lower pole expansion. Most have integrated metal ports that are located with magnets, although a remote port is useful when placing the expander under a thick flap (such as a latissimus dorsi flap in an obese patient). In such patients, finding the port with a magnet can be difficult and a long needle is required, placing the expander at risk for rupture.
- Intraoperatively, a ruler is used to measure the width of the surgically created implant pocket, which ultimately determines the expander to be used. Alternatively, one can create a pocket wide enough to accommodate the desired expander. The author's preference is to measure the surgically created pocket based on native patient anatomy and choose an expander that is 1 cm narrower in width.
- Prior to the exchange procedure, the patient is again marked in the standing position. The midline is marked and asymmetries in implant position are noted. The ideal contour for the final implants is marked.
- Final implants are selected primarily based on volume, although width should be taken into consideration. A full discussion of implant types is beyond the scope of this chapter. The majority of surgeons use smooth, round, high-profile implants for reconstructive purposes, although textured anatomic silicone implants may gain popularity if or when they gain U.S. Food and Drug Administration (FDA) approval. Patients with very wide chests may require a moderate-profile implant that will have a larger base diameter for a given volume (although less projection). A comparison of saline versus silicone implants is also beyond the scope of this chapter, but suffice it to say that the issue is controversial. The author's preference is to offer both types to patients noting the following advantages and disadvantages for each implant type:
  - Saline
    - Advantages: Implant rupture is immediately detected; removal of a ruptured implant is simple and quick.
    - Disadvantages: Reexpansion may be required if implant ruptures and is not replaced expeditiously; firmer than silicone, although this difference is diminished when good soft tissue coverage is present; higher potential for rippling if underfilled.
  - Silicone
    - Advantages: Softer, more "natural" feel
    - Disadvantages: Rupture is often clinically silent until extracapsular rupture and silicone granuloma formation is present, removal of a ruptured implant is a difficult operation that often involves removal of native tissue thus compromising subsequent reconstruction, and monitoring for silent implant rupture using magnetic resonance imaging (MRI) is not proven and has a definite risk of false positives and unnecessary surgeries.

Positioning

- Patients are placed in the supine position under a general anesthetic with arms padded circumferentially and abducted at 80 degrees. Following mastectomy, the patient is positioned such that the sternum is parallel to the floor.

TISSUE EXPANDER PLACEMENT

First Step—Wound Assessment

- Following mastectomy, the wounds are irrigated and hemostasis is obtained. The mastectomy flaps are evaluated by examining their thickness and assessing color and capillary refill. Areas where dermis is exposed internally should be carefully evaluated externally. Areas where the external skin is pale without capillary refill should be considered for debridement. Laser-assisted indocyanine-green fluoroscopy has been promoted to assess mastectomy flap perfusion; however, guidelines for its use and interpretation have not been firmly established.[1]
- Use of tumescent solution by the extirpative surgeon makes assessment of mastectomy flaps difficult and has been shown in some studies to be associated with a higher rate of mastectomy flap necrosis.[2–4]
- When there is significant concern for mastectomy flap necrosis, or if debridement of questionable tissue will lead to closure under tension or an open wound, then aborting reconstruction is strongly advised.
- If necessary, the IMF can be recreated with interrupted suture; however, the position of the inferior edge of the expander will ultimately determine the IMF, which can be adjusted further during an exchange procedure if desired. Some surgeons try to establish the native IMF during this initial procedure (which may make the exchange procedure simpler), whereas others intentionally place the expander lower than the IMF to increase lower pole expansion and projection (which requires recreation of the IMF with suture during the exchange procedure). The author's preference is to preserve the native IMF when performing single-stage implant reconstruction, when placing a significant initial fill volume in the expander, or when the IMF is already low. When performing delayed two-stage implant reconstruction or when placing minimal initial fill volume in the expander, placing the implant below the IMF will preferentially expand the lower pole and permit the surgeon to create minimal ptosis at the exchange procedure (as described in the following text).

Second Step—Creation of Implant Pocket

- The tissue expander cannot be covered by the mastectomy flaps alone, which are thin and offer poor soft tissue coverage. Ideally, the surgeon should provide complete musculofascial coverage with the pectoralis major and serratus anterior muscles (**FIG 2**), or use an acellular dermal allograft (ADA) or other product in addition to the pectoralis major muscle.

FIG 2 ● Following mastectomy, the pectoralis major and serratus anterior muscles are visualized as these are the muscles used for expander coverage. If these muscles have been affected by mastectomy, using an ADA in their place is considered.

- The lateral edge of the pectoralis major muscle is pinched between the surgeon's index finger and thumb and pulled away from the chest, revealing a loose areolar plane between the pectoralis major and minor muscles. Dissection in this plane commences with Bovie cautery, but once the subpectoral space is entered, much of the superior and medial implant pocket can be created via blunt digital dissection before using lighted retractors for direct visualization. A lighted retractor is quite helpful to finish medial dissection, as great care must be taken to ligate or cauterize the intercostal perforators of the internal mammary vessels (FIG 3).
- The medial boundary is defined externally by the preoperative markings that define the patient's native breast form. Internally, it is quite common to release the medial and inferomedial origins of the pectoralis major muscle.

FIG 3 ● A lighted retractor is very helpful for both expander placement and the implant exchange procedure. Here, the lighted retractor is shown during creation of the subpectoral pocket superomedially, where dissection proceeds carefully so intercostal perforators can be visualized and carefully ligated if necessary.

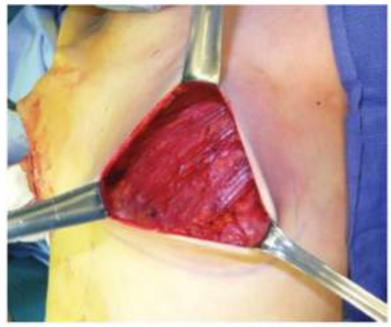

FIG 4 ● The relationship between the most caudal extent of the pectoralis major muscle and the IMF determines whether or not the anterior rectus sheath will be necessary to provide complete submusculofascial coverage of the expander. If the muscle originates at or below the IMF, as shown in this figure, then there is no need to elevate the anterior rectus sheath.

It is important not to release this area excessively, as symmastia can result and is difficult to correct.

- After the subpectoral plane is developed, the inferior insertion of the pectoralis major muscle is examined (FIG 4). If the patient's muscle reaches the IMF, then a submuscular pocket can be created down to the IMF with supple and adequate soft tissue coverage that will respond well to expansion (FIG 5). More commonly, however, the pectoralis major inserts above the IMF. In this scenario, to provide autologous implant coverage inferiorly, one must continue dissection past the pectoralis major insertion and under the anterior rectus sheath until just below the IMF. Transitioning from the subpectoral plane to underneath the anterior rectus sheath is sometimes technically difficult and may result in a few gaps in coverage that can be closed after the pocket is fully created. A lighted retractor is necessary for this portion of the procedure. The anterior rectus sheath is quite stiff and will not expand well unless an incision is made transversely across the sheath just below the IMF, entering the subcutaneous

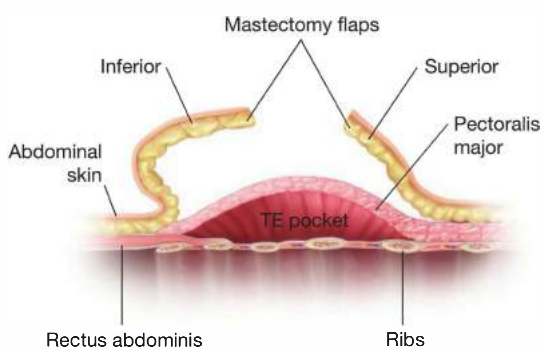

FIG 5 ● Schematic diagram patient anatomy when the pectoralis major originates at or below the IMF. In this case, a submuscular pocket can be created down to the IMF that will be supple and respond well to expansion. TE, tissue expander.

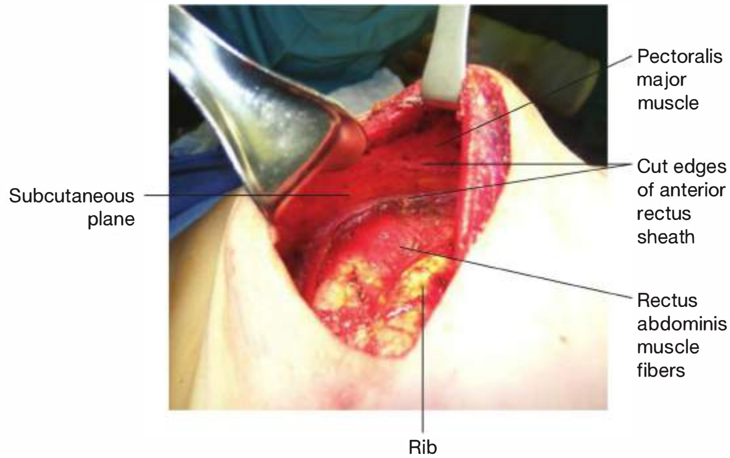

FIG 6 ● At or just below the IMF, the anterior rectus sheath is divided horizontally to enter the subcutaneous plane. If this is not performed, lower pole expansion will be limited by the stiff anterior rectus sheath.

plane (**FIGS 6** and **7**). If the anterior rectus sheath is released above the IMF, one would obviously enter the implant pocket. The goal is to provide complete and supple submusculofascial coverage without gap between the pectoralis major and the IMF. Alternatively, the pectoralis major can be released from the chest wall and a piece of ADA (or other product) can be sewn to the IMF inferiorly and the cut edge of the muscle superiorly.

- Following creation of a subpectoral pocket with or without elevation of the anterior rectus sheath, inferolateral coverage must be provided. Autologous coverage is provided by elevating the serratus anterior fascia if robust, or a partial thickness muscle flap if the fascia is thin or traumatized from the mastectomy. An incision in the serratus anterior is made at the level of, and parallel to, the inferolateral edge of the pectoralis major muscle and a fascial or musculofascial flap is elevated to the anterior axillary line (**FIG 8**). Alternatively, one can determine the width of the implant pocket based on the width of the desired tissue expander and stop lateral dissection when a sufficient pocket width is achieved (usually 1 cm wider than tissue expander). At this point, the inferior and lateral dissections will be complete, but the inferior serratus and superolateral external oblique muscles will still be attached to the chest wall. By retracting inferiorly and laterally, this plane is exposed and the muscles can be elevated off the chest wall to open the inferolateral pocket (**FIG 9**).

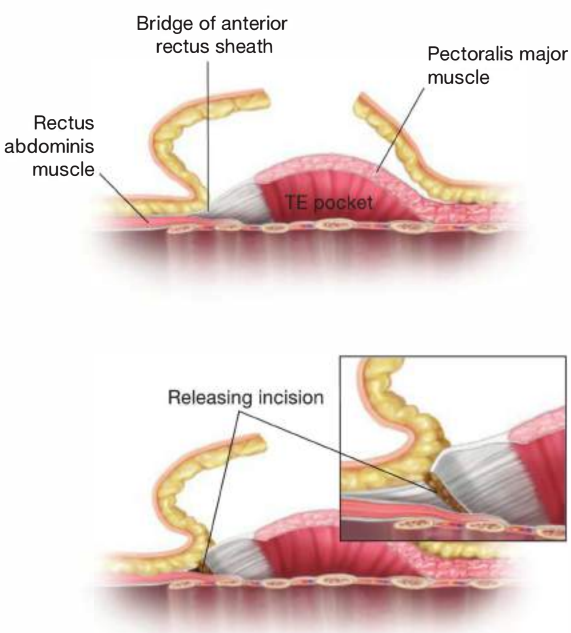

FIG 7 ● Schematic diagram patient anatomy when the pectoralis major muscle originates above the IMF. In this case, the gap between the caudal border of the pectoralis and IMF must be bridged by elevating the anterior rectus sheath. At or just below the IMF, the sheath must be incised horizontally to enter the subcutaneous space; otherwise, the inferior pocket will not expand well. Alternatively, an ADA can be used to bridge this gap. TE, tissue expander.

FIG 8 ● For lateral and inferolateral coverage, a partial-thickness serratus anterior muscle flap is elevated and shown in this photograph. If the fascia is robust and intact, that can be used alone; however, this is seldom the case. An incision in the muscle parallel to the inferolateral edge of the pectoralis major muscle is made and the flap is elevated laterally until the anterior axillary line or sufficiently to create the desired pocket width for the chosen expander.

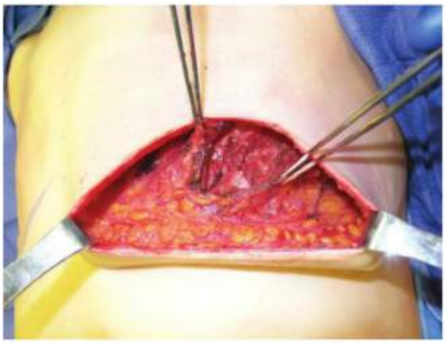

FIG 9 ● Following elevation of the serratus anterior muscle, the inferolateral aspect of the implant pocket will still be adherent to the chest wall. If retractors are placed under the pectoralis major and serratus anterior muscles, this area of adhesion will be exposed and inferolateral dissection will elevate the serratus anterior and external oblique muscles off the chest wall to complete implant pocket dissection.

FIG 11 ● A piece of ADA is prepared appropriately, according to the manufacturer's recommendations, and is sewn in with the epidermis side facing the implant. A 6 × 16 cm piece is usually sufficient. The inferomedial and inferolateral corners of the ADA are trimmed to create a curved inferior border and it is secured to the IMF and lateral pocket using a running 2-0 monofilament slowly absorbing suture. The transition from the IMF to the lateral pocket must be a gentle arc that mimics the opposite side.

- If an ADA is used, the origin of the pectoralis major is taken down starting inferolaterally and extending medially and then superiorly along the sternal origin to approximately the 3rd or 4th rib (**FIG 10**). The ADA will provide inferolateral implant coverage and there is no need to elevate the serratus anterior. In this case, the IMF and anterior axillary line are marked internally and the ADA is sutured along a line that transitions in an arc from the IMF to the anterior axillary line (**FIG 11**). Alternatively, one can mark the lateral mammary fold based on the width of the desired tissue expander and suture the ADA to this line (**FIG 12**). One can tailor the surgically created IMF to match the contralateral native IMF during unilateral reconstruction. If performing bilateral reconstruction, then it is imperative to create symmetric IMFs.
- The advantages of using an ADA are that it avoids any morbidity associated with elevation of the rectus sheath and serratus anterior, it allows for a greater initial fill volume (and thus fewer postoperative expansions), it allows precise control of the IMF, it may reduce operative time, and it may preserve lower pole fullness. Disadvantages include cost and an increased incidence of seroma, infection, and reconstructive failure in patients with risk factors such as obesity, smoking, and/or radiation.[5] Although some surgeons use an ADA routinely and others do not, the author's preference is to use ADA selectively (**FIG 13**). If the anterior rectus sheath or serratus anterior have been affected by the mastectomy and will not provide adequate coverage, ADA is an option, provided the patient does not have risk factors such as prior radiation, obesity, or smoking. In patients who have excess skin, it is advantageous to take advantage of this by placing a higher initial fill volume and an ADA will allow the surgeon to do this (again, provided the patient does not have the risk factors mentioned earlier). When the pectoralis major does not extend down to the IMF in a patient with some excess skin and no risk factors, ADA is a good option. However, in a patient without skin excess, who desires small breasts, and in whom very little initial fill volume will be placed, submusculofascial coverage is provided without ADA.

FIG 10 ● If an ADA is used, the pectoralis major muscle is elevated from the chest wall by dividing its inferior and inferomedial origin.

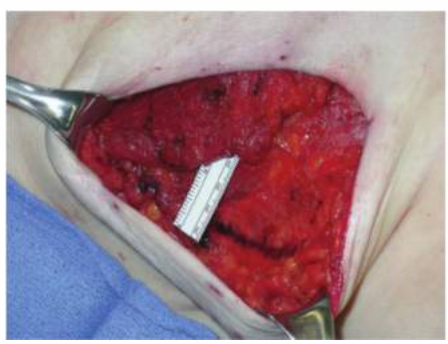

FIG 12 ● A ruler is used to measure the width of the surgically created pocket. The proper pocket width can be determined either by patient anatomy (e.g., the anterior axillary line) or the dimensions of the expander desired.

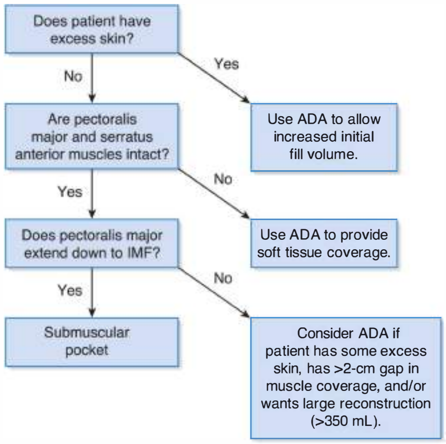

FIG 13 ● Algorithm to determine when to use ADA. IMF, inframammary fold.

Third Step—Preparation of Tissue Expander

- Tissue expanders come with air in them to prevent the inner shell from sticking to itself. There are usually markings for orientation, but it is helpful to draw a vertical line on the expander with a marking pen to assist with positioning the expander in the pocket. A needle (usually 23 gauge) is inserted into the port and all air is removed. The most commonly used tissue expanders are anatomic (creating lower pole expansion) and thus they are textured (to prevent rotation). There is typically more shell inferiorly, and while deflating the expander, it is important to fold excess shell inward as opposed to folding it upward and on to itself, where it might cover the port and get punctured (**FIG 14**).
- The author's preference is to place 60 to 180 mL of sterile saline in the tissue expander prior to placement, which allows the anterior shell to move away from the rigid backing. It is important to control positioning of this backing as it is what determines final expander position.

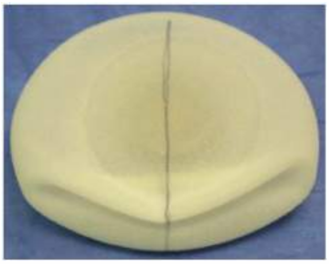

FIG 14 ● The tissue expander is marked with a vertical line for orientation. All air is removed with the excess inferior implant folded inward as shown to avoid puncturing the inferior implant while placing needles for expansion in clinic postoperatively. A minimum of 60 mL of saline is instilled, dyed with methylene blue. This allows for quick identification of inadvertent implant rupture during wound closure and also allows the clinic staff to confirm placement of the filling needle during subsequent expansions.

- It is extremely helpful to put 1 mL of methylene blue in 1 L of injectable saline and use this for the initial expander fluid. If the expander is punctured during closure, it will be evident due to the dye. Additionally, during expansions in clinic, the blue dye will confirm when the port is accessed.

Fourth Step—Placement of Tissue Expander and Closure

- The pectoralis is retracted away from the chest wall and the expander is placed into the pocket taking great care to orient it correctly. It is important to note the rigid backing of the expander and place the caudal edge at the IMF or below if desired. Be sure to unfold all edges of the expander. If performing bilateral reconstruction, symmetry in expander placement should be confirmed by palpating the expander ports on each side and ensuring symmetric horizontal and vertical positioning. If an expander requires adjustment in positioning, it is critical to grasp the rigid backing of the implant and then adjust the position. If only the ports or anterior shell are adjusted, this usually has no effect on the position of the backing, which determines implant position once fully inflated.
- The inferolateral edge of the pectoralis major muscle is sutured to the anteromedial edge of the serratus anterior muscle with running absorbable 2-0 braided suture, closing the pocket. A small opening is left superolaterally to allow egress of fluid. Alternatively, if an ADA is used, the pectoralis major muscle is sewn to the ADA with interrupted figure-of-eight braided absorbable 2-0 suture (**FIG 15**).
- The author's preference is to inflate the tissue expander with sterile saline as much as the soft tissue (muscle/skin) will allow without undue tension. This is typically 180 to 240 mL. It is important to do this prior to skin closure, as placing the needle through the muscle will occasionally cause bleeding, which can be controlled directly. Otherwise, a hematoma could expand in the subcutaneous space without notice until the patient is

FIG 15 ● The inferolateral edge of the pectoralis major is sewn to the superomedial edge of the serratus anterior with a running 2-0 absorbable polyfilament suture to cover the implant. If an ADA is used, the pectoralis major is sewn to the edge of the ADA with interrupted figure-of-eight 2-0 absorbable polyfilament suture, as shown.

out of surgery. In cases where there is significant concern regarding the cutaneous circulation, then only 0 to 60 mL of inflation is advisable.

- Two closed suction drains are placed in the subcutaneous space. One is oriented superiorly and the other inferiorly. The skin is closed with interrupted 3-0 absorbable monofilament suture for the dermis and a running 4-0 absorbable monofilament suture for subcuticular closure (**FIG 16**). The author's preference is to use skin glue alone as a dressing, without placement of a surgical bra, which applies pressure to the tenuous mastectomy flaps and is an impediment to physical examination.
- Antibiotics are continued parenterally for at least 24 hours postoperatively and transitioned to oral antibiotics for a week, as withholding postoperative antibiotics has been shown to be associated with an unacceptable rate of implant infection.[6] Drains are removed when output is less than 30 mL per 24 hours and expansion is begun typically 2 weeks postoperatively. Expansion can continue on a weekly basis, adding as much fluid as the patient will tolerate without discomfort (usually 60 to 120 mL). Once expansion is complete according to patient preference and surgeon's satisfaction, the author's preference is to perform one additional overexpansion, which can provide some additional tissue to create minimal ptosis at the exchange procedure at least 1 month later (as described in the following text).

FIG 16 ● The patient is shown following placement of tissue expanders and closure over two closed suction drains. Internal absorbable sutures are used, with skin glue as the only dressing. No bra is applied, which might apply pressure to tenuous mastectomy flaps.

IMPLANT EXCHANGE

First Step—Removal of Tissue Expander

- As noted earlier, the patient is marked in the standing position. Asymmetries are noted and the ideal contour for the final implants is marked.
- The mastectomy scars have often widened during expansion and these can be excised. A stair-step approach to the implant pocket is usually performed, so any wound breakdown in one layer does not expose the suture line of the other layer. If the scar is oriented obliquely (**FIG 17**), 2 to 4 cm of superomedial skin elevation will expose the pectoralis major, which can be incised parallel to the muscle fibers (**FIGS 18** and **19**). If a transverse approach was used, then superolateral and inferomedial skin elevation is required to expose the pectoralis major and allow for an incision parallel to the muscle fibers.
- The implant pocket is entered and the capsule is bluntly separated from the expander, which is removed. If the expander is too large, it can be ruptured with a needle or scalpel to assist in removal. If there was any doubt about the final expander volume, it can be measured at this point.

FIG 17 ● The patient is shown prior to the exchange procedure, 1 month following the last expansion in clinic. She has been expanded to 600 mL and desires 550 mL implants.

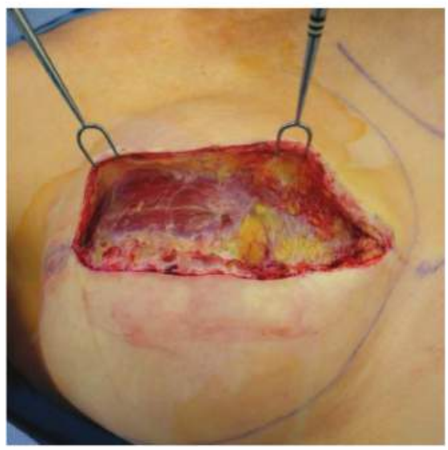

FIG 18 ● If the oblique incision is used for mastectomy, it is easy at the exchange procedure to elevate a superomedial flap exposing the pectoralis major muscle where it tends to be thicker. This will allow a "stair-step" approach to the implant pocket. Any wound healing issue at one level will not expose the suture line at the other level.

Second Step—Creation of Implant Pocket

- Ideally, the expanders can be removed and the permanent implants placed without further intervention; however, this is almost never the case. Superior and superomedial capsulotomy is often required to soften the transition from the chest wall to the implant (**FIG 20**). The pocket may need to be medialized, lateralized, elevated, or displaced inferiorly.

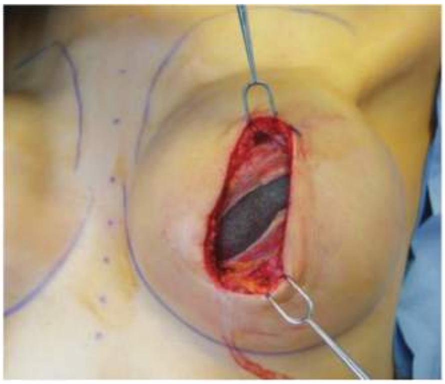

FIG 19 ● A muscular incision is made parallel to the pectoralis major muscle fibers to access the implant pocket. The capsule is also incised with cautery and the expander is bluntly separated from the capsule.

FIG 21 ● The patient is positioned upright with both upper extremities well padded and secured to arm boards abducted less than 90 degrees.

These can all be accomplished through capsulotomy. If the final implant is roughly the same width as the expander, then a corresponding capsulorrhaphy at the opposite side of the pocket is necessary using figure-of-eight interrupted 0 absorbable suture. If the implant is wider than the expander, this may not be necessary as the capsulotomy will increase pocket diameter.

- If the expander was placed below the IMF, or if the IMF needs to be elevated, this is accomplished with figure-of-eight interrupted 0 absorbable suture. The patient is sat upright (**FIG 21**) and the inferior mastectomy flap is lifted away from the chest wall. Usually, the old IMF can be visualized and marked (**FIG 22**); otherwise, the desired IMF can be marked. The needle is passed through the capsule and the IMF marking externally is visualized. The needle tip should just catch the deep dermis, resulting in a small indentation when tied. These indentations will resolve in several weeks. After passing the needle through the capsule/dermis, tension can be adjusted by examining the fold externally (**FIG 23**) and elevating it

FIG 22 ● When the inferior mastectomy flap is elevated gently from the chest wall, the patient's original IMF is still visible and can be marked for recreation of the native IMF. A higher or lower IMF can also be created.

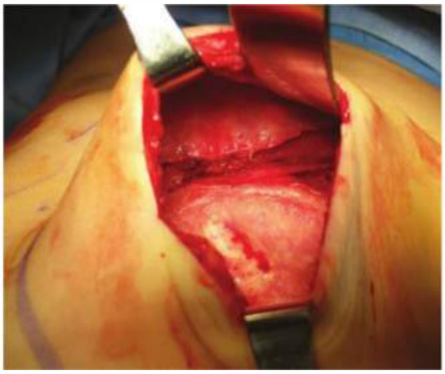

FIG 20 ● A superomedial and superior capsulotomy is made just above the chest wall using a lighted retractor. This will soften the transition from chest wall to implant and allow for more implant mobility within the pocket.

FIG 23 ● A suture is placed in the center of the IMF, through the capsule and just catching the deep dermis. The suture is pulled upward and the level of the IMF adjusted as desired to recreate a sharp and well-defined IMF. Once held in appropriate position, internal inspection will reveal where a suture should be placed on the chest wall. To minimize pain, suturing to the ribs should be avoided if possible. If the lower portion of the expander was placed at the IMF and good lower pole expansion and a crisp IMF in good position has resulted, then this maneuver is unnecessary.

FIG 24 ● The IMF has been reestablished with multiple figure-of-eight capsulorrhaphy sutures, starting in the center of the IMF and proceeding medially and laterally until an adequate IMF is recreated. A temporary implant sizer is helpful to assess the reconstructed IMF during this process.

FIG 26 ● A horizontal capsulotomy approximately half way up the inferior mastectomy flap is performed to further expand the lower pole and create minimal ptosis. Multiple radial capsulotomies (perpendicular to the horizontal capsulotomy and extending from the IMF to the incision) will further expand the lower pole.

as desired. Internal inspection with the suture still under tension will indicate where the corresponding suture throw in the chest wall must be made. Suturing into the rib should be avoided, as this results in pain. The first suture is placed at the center of the IMF and then one to two sutures are placed medially and laterally until an adequate fold is created (**FIGS 24** and **25**).

- Some surgeons prefer to establish the IMF at the initial operation, potentially with an ADA, which has the added benefit of permitting a higher initial fill volume. A higher initial fill volume has the potential to better preserve lower pole fullness. No time is spent reconstructing the IMF at the exchange procedure. Although this may be a simpler approach, it may result in a blunted IMF. The author's preference is to treat each case individually and surgically create a crisp IMF at the exchange procedure if necessary. For example, patients undergoing delayed reconstruction will benefit from significant lower pole expansion and thus the expander is placed inferior to the desired IMF and the IMF is reconstructed at the exchange procedure. A patient with minimal excess skin and ptosis undergoing immediate reconstruction will benefit from an ADA to maximize the initial fill volume (preserve lower pole fullness), establish the IMF, and avoid inferior capsulorrhaphy at the exchange procedure.
- To further expand the lower pole and create minimal ptosis, capsulotomy of the inferior pocket is then performed. A horizontal capsulotomy half way up the inferior mastectomy flap, at least 4 cm off the chest wall, will expand the lower pole of the pocket (**FIG 26**). Additional radial capsulotomies can be added for further lower pole expansion or elsewhere to create symmetric pockets.

FIG 25 ● Comparison of the left side, where the IMF has been recreated, and the right side, where it has not.

- During pocket creation, it is helpful to have a temporary sizer inflated (with air or saline) to roughly the desired implant volume, which can be placed into the implant pocket to assess position, shape, and volume. This is particularly important in bilateral reconstructions, where two sizers are required to confirm pocket symmetry.

Third Step—Implant Selection and Closure

- When ordering implants for the exchange procedure, it is wise to order implants that are one size smaller and one size larger than the implant size determined by the patient's final expansion volume (prior to final overexpansion). As mentioned earlier, temporary sizers are usually used and can be adjusted to determine an acceptable final implant volume. Inflating the sizer beyond the final expander volume usually results in excessive upper pole fullness, a noticeable step-off between the chest and implant, and tight closure. The chest should transition to the implant smoothly and the breast mound should have slight ptosis.
- When placing saline implants, choose an implant that has the desired volume as the upper end of its volume range. For example, if 380 mL is the desired implant volume, use an implant with a volume range of 360 to 390 mL. This avoids rippling at the expense of making the implant slightly firmer. Some surgeons will in fact overfill the implant by 10% to avoid rippling.
- The pockets are irrigated, hemostasis is obtained, and the final implants are opened. Although many surgeons will reprep the patient, place new drapes, dip retractors in prep solution, and handle the implants with fresh gloves, there is no data to support these practices. The author does not take any special precautions, as the procedure is a clean, sterile procedure. The implants are placed and the muscular closure is performed with a running 2-0 braided absorbable suture. The capsule is not included

FIG 27 ● The implants have been placed and the wounds closed without drains. Skin glue has been applied. The dimpling observed at the IMFs will resolve in several weeks.

in this closure if possible, thus creating an anterior capsulotomy (made upon initial approach to the implant pocket). No drains are placed. The skin is closed with interrupted deep dermal 3-0 monofilament absorbable suture and a running 4-0 subcuticular absorbable suture (**FIG 27**). A skin glue is applied, and a bra is only used if supporting the implant in a particular position is desired.

FIG 28 ● Three months following the exchange procedure, the patient is very happy and interested in nipple reconstruction. The right IMF is 2 cm lower than the left IMF, but the patient does not desire correction. It is important to establish the final implant position prior to nipple reconstruction; otherwise, later implant repositioning will affect how the nipple is positioned on the breast mound. There is minimal step-off from the chest wall to the implants, which is the result of mastectomy and commonly seen in implant reconstruction. This can be corrected with fat grafting—an effective and popular but controversial procedure at this time. The patient did not desire fat grafting.

Additional Procedure—Nipple Reconstruction and Revisions

- When examined with a critical eye, almost all patients have some degree of asymmetry following reconstruction (**FIG 28**). Approximately 30% will request a third procedure to address this asymmetry. Correcting the unfavorable result in implant breast reconstruction is a complex subject, involving techniques to alter implant position, breast shape, implant type, and soft tissue characteristics. Many patients ultimately opt for NAC reconstruction (**FIG 29**) (see Part 5, Chapter 20). In many cases, minor revisions can be performed at the time of NAC reconstruction; however, the nipple should only be created once the breast mound is in its final position, and thus it is not advisable to adjust the implant pocket and create the nipple during the same operation.

FIG 29 ● Options for nipple–areolar complex (NAC) reconstruction include tattoo only, nipple reconstruction with areola tattoo, and nipple reconstruction with areola graft. This patient opted for a "3-D" tattoo performed by a professional tattoo artist that specializes in NAC tattoo (Vinnie Myers in Finksburg, MD—http://www.vinniemyers.com). She is very happy with the aesthetic result, although she has some chronic discomfort lateral to the right breast. It is very common for patients to have some degree of chronic sensory dysfunction following mastectomy. Much of this resolves with time and can improve with therapy and massage; however, every patient should be counseled of this risk. It is also very common for patients with implants to be aware of their presence permanently. No patients think the implants feel just like their native breasts. The implants have dropped slightly, resulting in a more obvious step-off from the chest wall to the implants, and could be corrected with elevation of the implants (which would affect NAC position on the breast mound) or fat grafting.

PEARLS AND PITFALLS

Indications	■ Patients with a history of radiation are poor candidates for implant reconstruction. ■ Risk factors for infection and wound healing complications include smoking, radiation, and obesity.
Incision placement	■ An oblique incision parallel to the pectoralis muscle fibers provides the best cosmesis and easiest approach for the exchange procedure. ■ Excess skin can be excised through a linear incision only, as additional incisions will compromise circulation and risk mastectomy flap necrosis. Secondary procedures are frequently necessary in patients with excess skin.
Expander selection	■ Expanders are selected based on breast width, not volume.

Expander placement	■ Marking the expander assists in correct orientation. ■ Remove all air and place saline dyed with methylene blue to allow detection of implant rupture as well as confirmation of port access for staff performing expansions. ■ Provide at least 24 hours of postoperative antibiotics.
Implant selection	■ Implants are selected based on volume primarily, taking breast width into consideration. High-profile implants are typically used, except in patients with wide chests who benefit from moderate profile, wider implants.
Patient expectation	■ Two-stage implant breast reconstruction is typically a year-long process. ■ Symmetry in the nude is always the goal but is seldom achieved. Symmetry in clothing is the most reasonable expectation.

POSTOPERATIVE CARE

- Following the mastectomy and tissue expander placement, the patient is maintained on antibiotics for at least 24 hours and more commonly for 1 week or until drains are removed. Drains remain in place at least 3 days and then are removed when output is less than 30 mL per day. Only one drain from each side should be removed at a time, as sometimes the output of the second drain will increase after the first drain is removed. The author's preference is to allow patients to shower with drains in place. The patient should be seen within 1 week to evaluate for postoperative infection and/or mastectomy flap necrosis and to remove drains if appropriate. Expansion is begun 2 weeks after surgery and continued on a weekly basis thereafter until the patient and surgeon are happy with the final volume. One additional "overexpansion" is performed and the exchange procedure is scheduled at least 1 month later to allow the tissues to soften.
- Following the exchange procedure, patients may shower after 48 hours. Although the author feels very strongly about giving patients extended postoperative prophylactic antibiotics after mastectomy and expander placement, the exchange procedure is a clean procedure and the mastectomy flaps have been delayed and have robust perfusion. Thus, no postoperative antibiotics are usually given. Although there is little data to support practices such as repreping the patient, changing drapes, changing gloves, or dipping retractors in prep solution, this is commonly performed by surgeons placing implants.

FIG 30 ● This patient is 1 year out from the exchange procedure and 6 months out from NAC reconstruction with local flaps to reconstruct the nipple and areola tattoo. She has a higher body mass index (BMI) and more subcutaneous fat, and the mastectomy did not extend very far superiorly. Thus, she has a smooth transition from the chest wall to the implants.

OUTCOMES

- Patient satisfaction with implant breast reconstruction is high, provided the preoperative consultation appropriately identified the patient's priorities, goals, and preferences with respect to reconstructive options, and realistic expectations were discussed (**FIGS 30** to **32**). Although some studies have indicated that patients undergoing prosthetic reconstruction are less satisfied than those undergoing autologous tissue reconstruction,[7,8] other studies have shown significant improvements in psychosocial outcomes regardless of the type of reconstruction.[9]
- It is common to tell patients undergoing implant reconstruction that, on average, they will require some form of surgery every 10 years. These could be procedures for symmetry, infection, rupture, or capsular contracture. Although some surgeons exchange silicone implants every 10 years to avoid extracapsular ruptures, most only offer surgery if a problem is identified. One study evaluated long-term outcomes of autologous versus implant reconstruction and noted stable survival of 90% of autologous reconstructions

A

B

FIG 31 ● **A,B.** This patient is 6 months out from unilateral reconstruction. She did not desire NAC reconstruction or a contralateral mastopexy for symmetry. She has a very acceptable appearance in a bra.

FIG 32 ● This patient is 9 months out from her exchange procedure. She had prior augmentation mammaplasty and thin soft tissue coverage inferiorly; therefore, an ADA was used to augment soft tissue coverage of the expanders.

versus a gradual decline to 70% survival of implant reconstructions.[10] In general, autologous reconstructions improve or remain stable with time, whereas implant reconstructions tend to worsen slightly over time.

- There is no increased risk of breast cancer recurrence in patients undergoing therapeutic mastectomy and implant reconstruction. Detection of recurrence and outcome when recurrence is detected are not affected by the presence of an implant reconstruction.[11]

COMPLICATIONS

- Bleeding
- Infection
- Injury to surrounding structures (e.g., cutaneous nerves)
- Mastectomy flap necrosis
- Long-term risks of implants: capsular contracture, rupture, rippling, infection, malposition, and exposure
- Asymmetry, imperfect cosmetic result

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Chapter 16

Pedicled Latissimus Dorsi Flap Breast Reconstruction after Mastectomy

Frank Fang Adeyiza O. Momoh

DEFINITION

- The latissimus dorsi myocutaneous flap was originally performed for chest wall reconstruction after radical mastectomy by Iginio Tansini in 1906 but fell out of favor when mastectomies were primarily closed or skin grafted.[1] Although the latissimus flap remained a dependable option for anterior chest wall reconstruction,[2–4] it was not until 1977 when it was first described to reconstruct a true breast mound in combination with a prosthetic implant.[5]
- The latissimus dorsi myocutaneous flap currently remains a viable and frequently used option for breast reconstruction. Typically, patients who required chest wall irradiation and are either unwilling or unable (lack of donor site tissue volume) to undergo one of the other autologous flap options for breast reconstruction will proceed with this option. Furthermore, this flap has found use in the reconstruction of congenital defects such as Poland syndrome in the younger patient population.[6] For the purpose of breast reconstruction, this technique usually requires flap transfer combined with an initial tissue expansion process followed by a subsequent saline- or silicone-filled prosthetic implant placement. Breast reconstruction with a latissimus dorsi myocuataneous flap without an implant is also possible but less commonly used due to flap volume limitations.[7]

ANATOMY

- The latissimus dorsi is a large, flat, triangle-shaped muscle on the back measuring approximately 25 × 35 cm; it mirrors the pectoralis major posteriorly.
- The muscle origin is a broad aponeurosis that spans the lower six thoracic vertebrae (superomedially), supraspinous ligament (central medial region), thoracolumbar fascia (inferomedially), and posterior iliac crest (inferiorly).
- The lateral border of the muscle separates from the serratus anterior as a free potential space until one encounters the small slips of origin from the 10th to 12th ribs, where the latissimus interdigitates with the slips of origin of the external oblique and serratus anterior muscles.
- The superior border of the muscle has an area of adhesion to the region of the inferior angle of the scapula but otherwise contains free potential space with the underlying layer.
- The muscle converges in the axilla to insert on the crest of the lesser tuberosity of the humerus.
- The latissimus dorsi adducts, extends, and rotates the humerus medially (“pull-up,” rowing, or free-style swimming motions).
- The latissimus dorsi flap is a Nahai-Mathes type V myocutaneous flap, meaning that it may survive based solely on either the thoracodorsal artery or the segmental perforators from the intercostal and lumbar arteries.
- The thoracodorsal artery (arising from the subscapular branch off the axillary artery) enters the deep surface of the latissimus dorsi muscle in the posterior axilla approximately 10 cm inferior to the muscle insertion into the humerus and 2.6 cm medial to the lateral border of the muscle (**FIG 1**).
- The artery then divides into the medial (also known as transverse) and the lateral (also known as vertical or descending) branches. The medial branch is located approximately 3.5 cm below and parallel to the superior border. The lateral branch

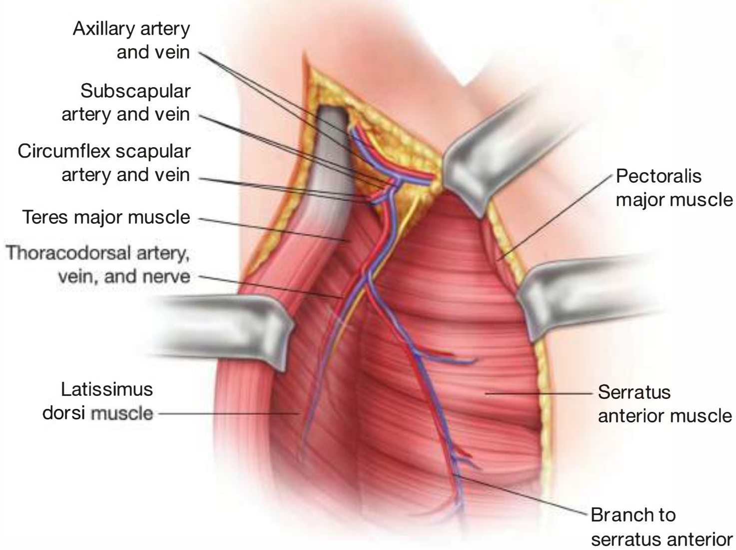

FIG 1 • Vascular anatomy of the thoracodorsal artery and vein.

is located approximately 2.6 cm medial and parallel to the lateral border. The serratus branch (artery to the serratus anterior), which joins the thoracodorsal artery just before its entrance to the latissimus muscle, is a useful landmark as it guides one directly to the thoracodorsal pedicle. There is usually a single vena comitans of the thoracodorsal artery.[8,9]

- The thoracodorsal motor nerve enters the muscle with the vascular pedicle. Cutaneous sensory nerves arise from the intercostal nerves at the midaxillary line and also in the paraspinal region.

PATIENT HISTORY AND PHYSICAL FINDINGS

- A thorough history and physical examination are critical in preparing for reconstruction.
- Pertinent aspects of the history include previous axillary operations (e.g., lymph node dissections or biopsies) and medical conditions that would preclude patients from an operation of moderate length under general anesthesia.
- Certain patients (e.g., paraplegic or wheelchair-dependent individuals who cannot afford even a minimal weakening of shoulder strength) probably should not undergo latissimus dorsi breast reconstruction. The average patient, however, will likely not notice a difference in shoulder function after a period of full recovery.
- A focused exam of the axilla and back for scars that may preclude use of the muscle flap or affect placement of the skin paddle is necessary.
- The presence of a viable and innervated muscle may be confirmed by having the patient activate the muscle by placing the hands on the hips and pushing firmly. However, a vigorous muscle contraction does not necessarily indicate an intact thoracodorsal arterial pedicle, as the nerve is quite separated from the thoracodorsal artery proximal to the branch point from the subscapular artery and could be potentially preserved despite ligation of the thoracodorsal artery.
- A team-based approach involving surgeons, anesthesiologists, primary care physicians, and other specialists such as cardiologists when needed ensures that patients are evaluated as a whole and all key concerns are addressed.

IMAGING AND OTHER DIAGNOSTIC STUDIES

- Preoperative computed tomography (CT) angiography of the donor site (**FIG 2**) is recommended in patients with previous surgical procedures during which the thoracodorsal arterial pedicle may have been sacrificed (e.g., axillary lymph node dissection or modified radical mastectomy).

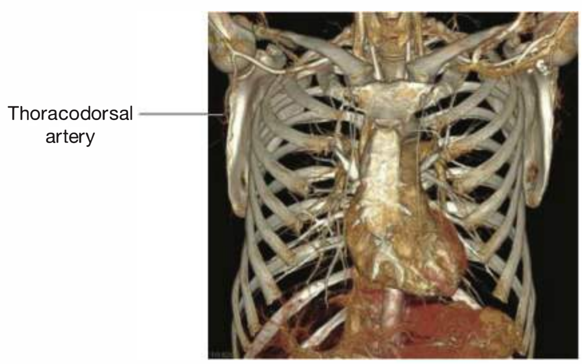

FIG 2 • Preoperative CT angiography of the thoracodorsal vessels.

SURGICAL MANAGEMENT

- In consulting with patients, decisions about the timing of reconstruction (immediately after mastectomy or delayed) and the type of reconstruction are made taking patient factors and tumor characteristics into consideration.
  - Patient factors of significance include the following:
    - Patient preference
    - Smoking history
    - History of previous axillary operations that compromise the vascular pedicle of the donor site
    - Medical comorbidities that would preclude patients from undergoing an operation of moderate length.
  - Tumor characteristics as they relate to the following:
    - The need for postmastectomy radiation therapy
    - The need for close postmastectomy surveillance prior to reconstruction
    - In general, patients known to require postmastectomy radiation therapy are reconstructed in a delayed fashion to avoid the detrimental effects of radiation on flaps. A history of radiation therapy also serves as a relative indication for use of an autologous form of reconstruction, as implant-only reconstructions in the setting of radiation are prone to higher rates of complications and failure.

Preoperative Planning

- Basic labs (chemistry and blood counts)
- All anticoagulant and antiplatelet medications should be stopped a week prior to the operation. Warfarin can be bridged with enoxaparin a week prior.
- Smokers are required to quit for a minimum of 4 weeks prior.
- Patients receive preoperative antibiotics with intraoperative redosing.
- Patients receive deep vein thrombosis (DVT) prophylaxis with use of a pneumatic compression device at the beginning of the case; preoperative subcutaneous heparin is not typically used in our practice.
- A Foley catheter will be needed, given the length of the case.
- A headlight may be helpful in the harvest of the latissimus dorsi muscle.
- A beanbag is needed for lateral decubitus positioning.
- A sterile Doppler probe is helpful to have available in case there is any concern for the location or integrity of the thoracodorsal pedicle during the case.

Positioning

Marking/positioning

- The inframammary fold (IMF), medial limit, and lateral limit of the breast should be marked with the patient upright.
- With the patient in the sitting position, have the patient activate the latissimus muscle (by placing hands on the hips and coughing) and mark anterolateral margin of the muscle.

- Other key landmarks for the limits of the latissimus muscle are the tip of scapula, vertebral column, and posterior iliac crest. They should be marked for additional orientation.
- The pivot point for the flap is the approximate pedicle location: It should be marked 2 to 3 cm medial to lateral border and 9 cm below the apex of the axilla.
- Eight to 10-cm–wide skin paddles can generally be closed primarily (verify adequate skin laxity by pinching). The skin paddle must be placed over the muscular portion of the latissimus, as the vascularity of the skin over the thoracolumbar fascia is notoriously poor. In most patients, it is necessary to stay at least 8 cm superior to the posterior iliac crest to avoid the thoracolumbar fascia (**FIG 3**).
- Verify that the skin paddle has been designed correctly for rotating to the planned anterior position by measuring from the estimated pedicle pivot point to the inferolateral tip of the skin paddle. This distance must equal the distance from the pivot point to the medial limit of your planned mastectomy incision.
- The orientation of the axis of the skin paddle can be varied (**FIG 4**). A horizontally oriented skin paddle allows the scar to be hidden by a bra strap but may limit the size of the paddle harvested.

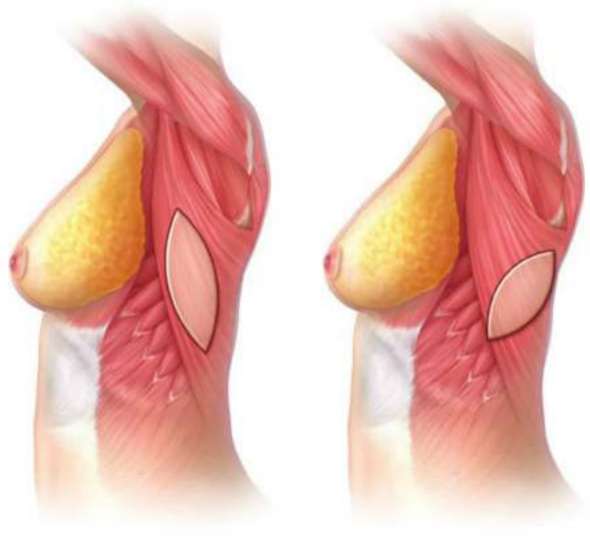

FIG 4 ● Possible orientations of the latissimus dorsi flap skin paddles.

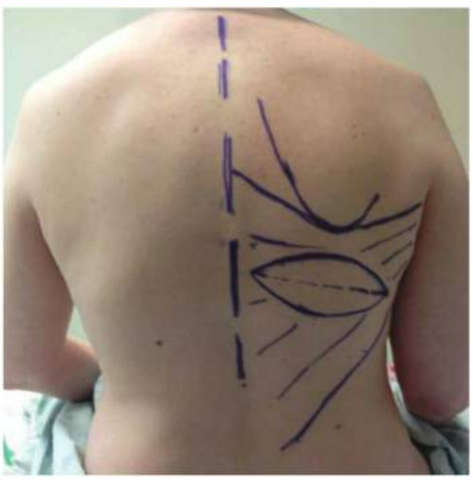

FIG 3 ● Flap markings.

- Measure the breast base width to guide your choice of tissue expander size.
- Patient positioning varies by surgeon. Harvesting a full latissimus dorsi flap requires a lateral decubitus position with a special arm support for the ipsilateral arm and an axillary roll under the contralateral axilla to prevent brachial plexopathy. The lower extremities will also require adequate padding.
- Placing patients in the supine position during the earlier or latter parts of the case is based on surgeon preference and laterality of reconstruction (unilateral vs. bilateral). Bilateral procedures absolutely require position changes.
- The description in the following text will include multiple position changes to make clear the sequence of events for the procedure. This sequence can then be modified.

RECIPIENT SITE PREPARATION (IN EITHER SUPINE OR LATERAL POSITION)

- Develop the recipient site with the patient in supine position: Elevate the skin and subcutaneous flaps off the pectoralis major to recreate the mastectomy defect in cases of delayed reconstruction; for immediate reconstruction, the mastectomy skin flaps are already developed by the breast surgeon.
- Natural borders of the breast should be preserved, including the IMF and skin adherence to the sternum along the midline. A possible exception would be in delayed reconstruction where the inferior dissection can extend approximately 0.5 to 1.0 cm inferior to the IMF to allow the expander to sit at the IMF after the latissimus is inset.
- Limit the lateral dissection, when possible, to the anterior axillary line with the exception of a three to four fingerbreadths tunnel created to allow for transfer of the flap. This tunnel should not violate the IMF.
- The lateral dissection is performed in a suprafascial plane within the tunnel and extends to the lateral border of the latissimus.
- Dissect 2 to 3 cm past the border of the latissimus, on its deep surface, to facilitate flap elevation when the patient is repositioned (**FIG 5**).
- Elevation of the pectoralis major muscle is then performed, disinserting the muscle from its attachments to ribs at the IMF. This disinsertion is terminated at lateral border of the sternum.

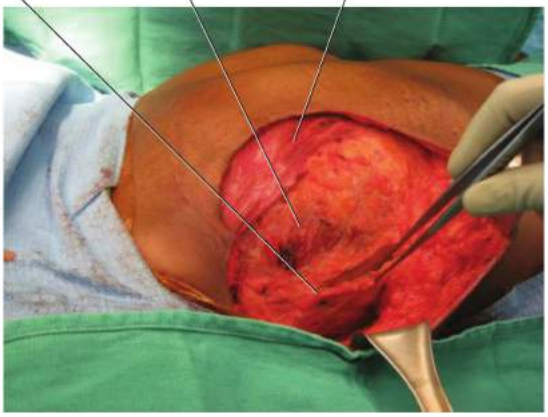

FIG 5 ● View of the chest wall with exposure of the pectoralis major, serratus anterior, and lateral border of the latissimus dorsi muscle.

- The anterior chest surgical site is then packed with moist laparotomy sponges, tucking a sponge laterally under the lateral border of the latissimus. This also helps identify this border of the flap during harvest in the lateral decubitus position. An Ioban sheet is then used to seal the mastectomy defects.

FLAP HARVEST

- The patient is either placed in a lateral decubitus position (**FIG 6**) for a unilateral flap harvest or in a prone position for bilateral flap harvests.
- All position changes require reprepping and redraping of the operative fields.
- The incision is made on the lines of the designed skin paddle. As soon as subcutaneous fat is visualized, the plane of dissection should be beveled outward in a fashion to preserve as many vascular perforators as possible.
- The skin and subcutaneous tissue are elevated off the latissimus muscle until the superior, medial, and inferior limits of the muscle are visualized.

FIG 6 ● Patient positioning (lateral decubitus) for flap harvest.

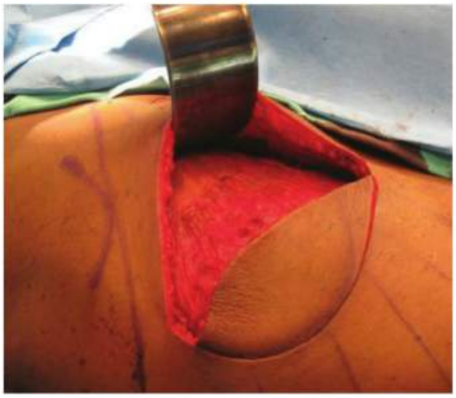

FIG 7 ● Exposure of superficial surface of the muscle during flap harvest.

- Retraction can be a challenging aspect of this step. A Deaver or Harrington retractor and Bovie electrocautery extension are helpful (**FIG 7**).
- Dissection under the lateral edge of the latissimus is now initiated, starting in the area inferolaterally. Note that the anterior edge of the muscle often approaches the midaxillary line.
- Identification of the lateral border of the muscle is easy if elevation is begun while the patient is supine, with placement of a laparotomy sponge under the muscle edge as outlined previously.
- Dissection deep to the latissimus near the pedicle should be done cautiously with electrocautery to minimize the chance for pedicle damage.
- Visualization of the pedicle is not necessary for most pedicled flaps with the exception of flaps requiring

a division of the muscle insertion or flaps requiring denervation.

- Note that the serratus branch artery (**FIG 1**) can guide you from the serratus anterior muscle to the superiorly located thoracodorsal vessels.
- Lateral and medial row segmental pattern perforators to the skin will be encountered in the paraspinal region and should be meticulously cauterized.
- The latissimus muscle is divided medially and inferiorly at the point where the muscle fibers transition into the thoracolumbar fascia.
- Deep to the latissimus muscle, the dissection should be limited to muscle only, leaving behind adipose tissue, as this contains many lymphatic channels; preserving this lymphatic circulation is thought to reduce the risk for seroma.
- The fully elevated flap (**FIG 8**) is then rotated into the previously created lateral chest wall tunnel for passage to the mastectomy defect.
- Placing a large silk stitch on the medial edge of the flap skin paddle is helpful for locating the flap within the tunnel and subsequently for traction to slide the flap through the subcutaneous tunnel.
- A drain tube is placed in back donor site.

FIG 8 ● Elevated latissimus dorsi myocutaneous flap.

- The back donor site is then closed in layers.
- Prior to closure, fibrin sealant such as Tisseel or Evicel can be instilled into the donor site. Although not absolutely necessary, this maneuver is thought to reduce the risk for seroma.
- Dressings in the form of a skin glue product, Steri-Strips, or an ointment are then applied to the suture line.

INSETTING OF THE FLAP

- The patient is repositioned to the supine position.
- The latissimus muscle is advanced into the recipient site. Any restricting bands of tissue near the pedicle pivot point can be carefully lysed to yield better flap rotation and an ideal position of the pedicle.
- Complete skeletonization of the pedicle is not necessary. Disinsertion of the muscle attachments to the humerus can be performed to gain a few additional centimeters of reach.
- Ligation of the thoracodorsal nerve eliminates contraction of the muscle, which can be bothersome to some patients. Most patients, however, do not complain about persistent muscle contractions after transposition of this muscle without sacrificing the motor nerve.
- The latissimus muscle is then inset to the IMF with interrupted absorbable sutures.
- A tissue expander selected based on the patient's chest wall dimensions (primarily breast base width) is then placed in the pocket flanked superiorly by the pectoralis major muscle flap and inferiorly by the latissimus dorsi myocutaneous flap (**FIG 9**).
- Tissue expanders with suture tabs can be used, as they allow the expander to be secured to the chest wall temporarily, preventing migration and optimizing expansion of desired areas of the breast mound.
- The pectoralis major muscle is then approximated to the latissimus with interrupted or running absorbable sutures.
- If there are concerns for tension on the flap, filling of the tissue expander (**FIG 10**) should be delayed.

FIG 9 ● Tissue expander placed behind the pectoralis major (superior) and latissimus dorsi (inferior) muscle flaps within the mastectomy defect.

FIG 10 ● Intraoperative fill of the tissue expander.

- The subcutaneous tunnel opening to the lateral tissue expander pocket can be closed to prevent lateral migration of the implant.
- A drain tube is placed deep to the skin flaps but superficial to the muscle flaps at the inferior pole of the breast, exiting at the lateral chest wall.
- Skin closure is performed in layers with absorbable interrupted deep dermal sutures and a running subcuticular suture (**FIG 11**).
- Dressings in the form of a skin glue product, Steri-Strips, or an ointment are then applied to the suture line.

FIG 11 ● Inset flap skin paddle.

PEARLS AND PITFALLS

Preoperative planning	■ Preoperative CT angiography is worthwhile when axillary lymph node dissection has been performed previously. The thoracodorsal vessels are occasionally ligated during axillary dissections.
Positioning	■ Minimizing the position changes will reduce surgical duration. For instance, a lateral position for both recipient site preparation and donor site harvest followed by supine positioning for the inset and expander placement takes advantage of a single position change.
Freeing the latissimus dorsi	■ Identifying and beginning the dissection underneath the lateral border of the latissimus while the patient is supine allows for an easier flap elevation once the patient is in a lateral position. ■ Disinserting the muscle attachments to the humerus improves the reach of the muscle.
Postoperative seroma	■ Avoid taking out donor site drains too early as seromas are common with this flap elevation.

POSTOPERATIVE CARE

- Patients can be transferred from the operating room (OR) to a postanesthesia care unit (PACU) or directly to a unit with nursing capabilities for flap monitoring.
- Flaps are monitored by physical exams (color, temperature, capillary refill) performed every hour for the first 4 hours and then checks can be spaced out to every 2 hours and 4 hours over subsequent hospital days.
- DVT prophylaxis is the only form of anticoagulation used routinely.
- Diet is advanced from clear liquids to regular on postoperative day 1; there are no restrictions on caffeine.
- Patients are assisted to ambulate beginning on postoperative day 1.
- Foley catheters and intravenous (IV) fluids are discontinued; IV medications/patient-controlled analgesias (PCAs) are converted to orals on postoperative day 1.
- Patients are typically ready for discharge home from postoperative days 2 to 4.
- Surgical drains are discontinued once the output is less than 30 mL for 2 consecutive days.
- Activities are limited and weight-lifting restrictions are in place for 6 weeks postoperative.
- The first postoperative visit is at 1 week following discharge.
- Postoperative results for a left delayed breast reconstruction in an irradiated patient (**FIG 12**).

OUTCOMES

- Breast reconstruction outcomes may be assessed in several ways. Patient satisfaction, shoulder girdle function and reoperation rates are all parameters that have been analyzed in recent literature. An evaluation of patient satisfaction showed that latissimus dorsi breast reconstruction patients are generally satisfied with their decision, with 80% of surveyed patients indicating that they would both recommend the surgery to another person and undergo the surgery again if given the choice. Over 70% of surveyed patients found the size, shape, and scars associated with their reconstructions to be "good" or "excellent." However, contrary to what is previously believed, over one-third of patients questioned reported moderate to severe loss of shoulder force and function. By strict physiometric measurements, there is comparable shoulder range of motion and slight decrease in shoulder strength when compared to preoperative measurements at 1 year postoperatively. This amount of change does not substantially affect the ability to perform daily activities for most patients.[10] Also, reoperation rate was 50% for prosthesis-related problems at a mean follow-up time of 14.9 years.[11]

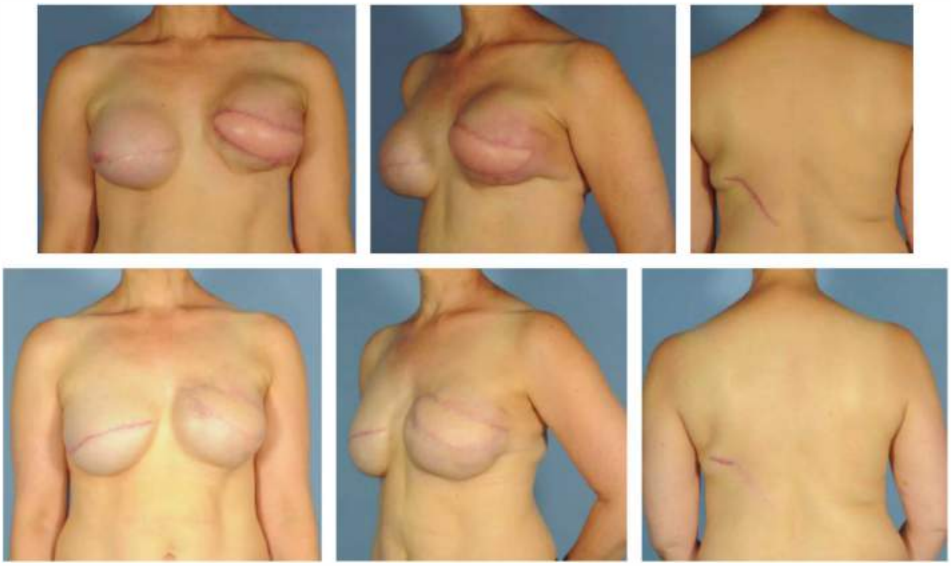

FIG 12 ● A patient with left breast invasive ductal carcinoma who underwent bilateral mastectomies, adjuvant chemotherapy, and left chest wall radiation. *Above*, 4-month postoperative result after completion of tissue expansion. *Below*, 9 months after exchange of the tissue expanders for silicone implants.

- Breast reconstruction patients are typically satisfied in the short term (<5 years) with their choice of reconstruction across implant-based to autologous forms of reconstruction.[12]
- Over the long term (>8 years), satisfaction with abdominal-based flap reconstruction is maintained, whereas satisfaction with implant-based techniques tends to depreciate.[12]
- Studies have also shown greater satisfaction with autologous reconstruction in patients requiring unilateral reconstructions. This is likely the result of better symmetry with the natural contralateral breast.[12]
- Patient satisfaction in bilateral reconstructions has been found to be similar across all techniques provided that the same technique is used on both sides,[12] highlighting again the importance of symmetry.

COMPLICATIONS

Flap-Related Complications

- Infections/implant extrusions—risks for these complications are elevated for implant-only reconstruction of irradiated sites. Autologous tissue transferred to the chest over a prosthesis offers greater resistance to infection or implant extrusion than do prostheses alone on irradiated sites.[13,14]
- Delayed wound healing—this complication typically occurs at the interface between the mastectomy flap and latissimus flap skin paddle. It often is a result of marginal mastectomy flap necrosis from poor skin perfusion, which is more likely in smokers and in the previously radiated breast skin.
- Partial flap loss—an uncommon complication (~3% or less) that is also related to poor perfusion.[15,16] It can be the result of poor skin paddle design. An excision of the necrotic segment is usually required.
- Total flap loss—this is one of the most devastating complications encountered and it occurs in less than 1% of reconstructions.[15,16]
- Capsular contracture—recent studies based on the newest generation implants report approximately 16%.[17]

Donor Site Complications

- Seroma—approximately 9% of latissimus dorsi flap donor sites encounter a seroma.[15,16] Some studies report as high as 34%.[17]
- Delayed wound healing—wound healing problems are encountered often in morbidly obese patients, diabetics, and smokers. These wounds are managed by debridement and dressing changes with healing by secondary intention.

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Chapter 17

Pedicled Transverse Rectus Abdominis Myocutaneous Flap Breast Reconstruction

Dale Collins Vidal   Emily B. Ridgway

DEFINITION

- All patients undergoing mastectomy, or those who have undergone a prior mastectomy, are potential candidates for breast reconstruction. The choice to have breast reconstruction is personal, and the options available for breast reconstruction are affected by an individual's anatomy, weight, prior surgical procedures and radiation, and personal preferences. Each patient is unique and consideration must be made of their current breast size, goal breast size, and anatomic limitations.
- The pedicled transverse rectus abdominis myocutaneous (TRAM) flap was first described by Hartrampf in the 1980s and remains the autologous "workhorse" of breast reconstruction. Diabetic patients, smokers, and patients with an elevated BMI or a pendulous panniculus have higher risk for flap failure.

PATIENT HISTORY AND PHYSICAL FINDINGS

- A complete medical and surgical history is essential.
- Prior comorbidities should be identified and the decision for preoperative anesthesia evaluation should be made.
- Current related history must include cancer stage; *BRCA* status; and prior treatments including lumpectomy, biopsy, neoadjuvant chemotherapy, and radiation.
- Accurate documentation of any prior abdominal, pelvic, cardiac, and groin surgery is necessary in order to evaluate the candidacy for a TRAM flap.
- Current breast size, the patient's goal for breast size, and the amount of abdominal tissue will also guide surgical planning and the need for a contralateral symmetry surgery.
- Risks, benefits, and alternate therapies must also be reviewed with the patient including other autologous options (free and pedicled) and implant-based reconstruction options.

Anatomy

- As with any surgical technique, a thorough working knowledge of the anatomy of the chest and abdominal wall and any variants is essential. The primary blood supply of the breast originates from internal mammary perforating branches. Secondary blood supply is received via perforating arteries from the lateral thoracic, pectoral, thoracic, and lateral intercostal arteries. Many of these vessels are injured during mastectomy and much of the mastectomy flap blood supply is compromised and relies on dermal and subcutaneous vessels running just deep to the dermis.
- The abdominal wall is made of skin, varying thickness of subcutaneous adipose tissue, and an anterior rectus fascia overlying the paired rectus abdominis muscles (**FIG 1**).
- Deep to the muscles is the posterior rectus fascia made up of the transversus fascia and internal oblique muscle fascia above the arcuate line and the transversus fascia below the arcuate line.
- The paired rectus muscles originate from the pubic bone and extend to the cartilage of the 6th, 7th and 8th ribs. The blood supply comes from the dominant deep inferior epigastric artery and the superior epigastric artery (**FIG 2**).

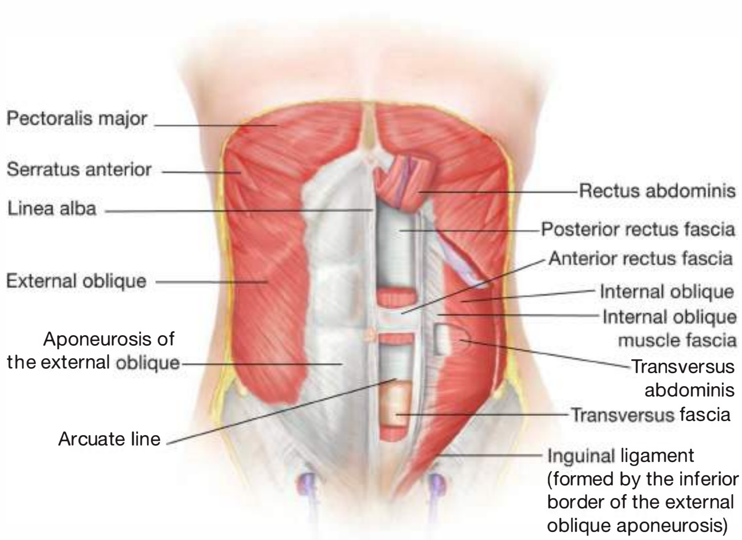

FIG 1 • Abdominal wall musculature.

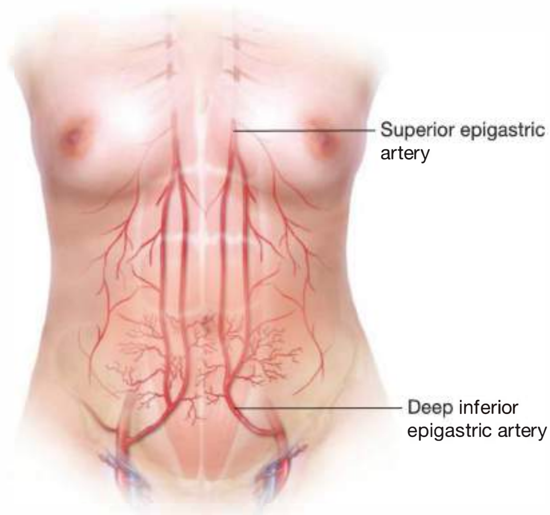

FIG 2 ● Abdominal wall blood supply.

Additional blood supply comes from the posterior perforating vessels accompanying the 8th through 12th intercostal neurovascular bundles.

- Within the muscle, the superior and inferior epigastric arteries may not have direct anastomoses under normal conditions. These connections are made or increased with surgical delay of the deep inferior epigastric artery.
- Musculocutaneous perforators pass through the muscle and anterior rectus fascia (**FIG 3**). They are often gathered in the periumbilical area and in mirrored medial and lateral rows of perforators. The medial and lateral row of perforators on a given side is separated by approximately 1.5 to 2 cm.

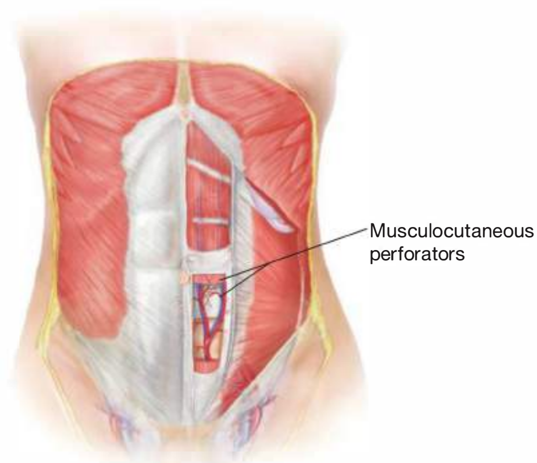

FIG 3 ● Surgical delay is performed to ligate the deep inferior epigastric artery and vein.

In the case of the pedicled TRAM flap, the flap is based on the superior epigastric vessels.

SURGICAL MANAGEMENT

Preoperative Planning

- For high-risk patients, ligation of the inferior epigastric artery (surgical delay) should be considered. Surgical delay of the inferior epigastric artery is performed 10 to 14 days prior to the mastectomy. This is often performed at the time of sentinel lymph node biopsy in order to limit events requiring anesthesia.
- On the day of reconstruction, the patient is marked first in the standing position. At the breast, the inframammary fold (IMF), midline and a line 1 cm off the midline on either side, the lateral breast extension, and proposed or prior mastectomy skin incision approach are marked. The width of the proposed breast reconstruction is measured as this will guide the ideal width of the abdominal flap, which is particularly important in delayed breast reconstruction where there is often a paucity of breast skin (**FIG 4**).
- On the abdomen, the midline is marked and an ellipse of skin including the umbilicus is marked. In our experience, all patients offer at least 13 cm in width of the ellipse and this can be assessed with a pinch test (**FIG 4**).
- The patient is then seated and any further extensions of the incisions are laterally marked to remove any “dog ear.”

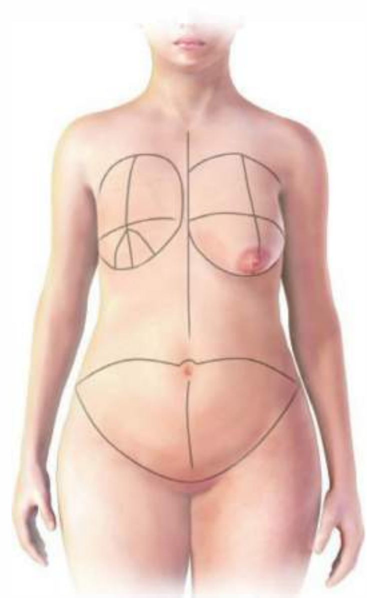

FIG 4 ● Preoperative marking of chest and abdomen in the standing position. Note the lateral dimension of the planned breast should correlate to the height of the planned TRAM flap. The TRAM flap is centered around the site of largest perforators at the periumbilical region.

- Perioperative antibiotics are provided and a Foley catheter and sequential compression device (SCD) boots are placed.
- The flap can be raised while the mastectomy is being performed. No tumescence is used. The superior incision is made first, and the upper abdominal wall is raised to the level of the costochondral cartilages. On the side of the planned reconstruction, a tunnel is made through the IMF into the mastectomy pocket that fits a fist and the planned flap.
- The patient is then flexed and the superior abdominal flap brought down to verify its pending closure and the possible height of the flap to be created. The inferior incision is then made. Beginning laterally on each side, the flap is then elevated with electrocautery above the level of the fascia until the lateral border of the rectus abdominis is seen. At this point, either bipolar or very low cautery is recommended for continuing to complete the identification of both the medial and lateral rows of perforators (**FIG 5**). If a bilateral reconstruction is planned, the midline incision may also be made to help in exposure for dissection (**FIG 6**). No perforators should be sacrificed at this time.
- Once all perforators have been identified, the flap vascularity is assessed. In unilateral reconstruction cases, if one flap has a heartier blood supply, this flap is chosen.
- Methylene blue is then used to mark the planned fascia incisions including each row of perforators and only the intervening fascia. A no.10 blade is used to incise the fascia and sharp dissection around the outside of each medial and lateral perforator under loupe magnification (**FIGS 7** and **8**). The width of this fascia (approximately 2 cm) is also included in the flap superiorly to the level of the costochondral cartilage (**FIG 8**). The underlying rectus muscle is then secured to the anterior rectus fascia and overlying Scarpa's fascia with several 3-0 Vicryl sutures on either side to prevent the flap from being avulsed from the muscle.

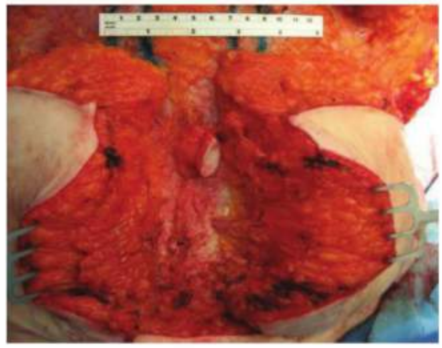

FIG 6 ● If a bilateral reconstruction is planned, the midline incision may also be made to help in exposure for dissection.

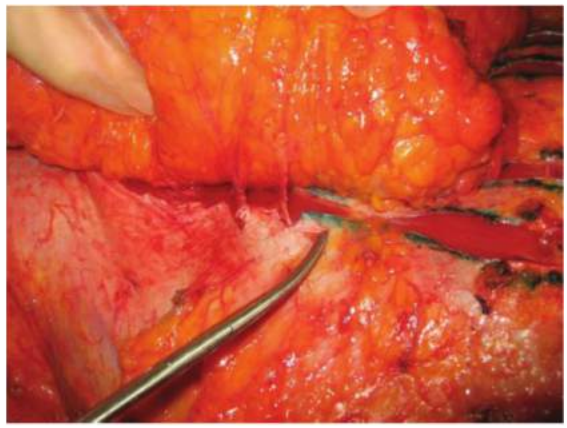

FIG 7 ● Methylene blue is then used to mark the planned fascia incisions including each row of perforators and only the intervening fascia.

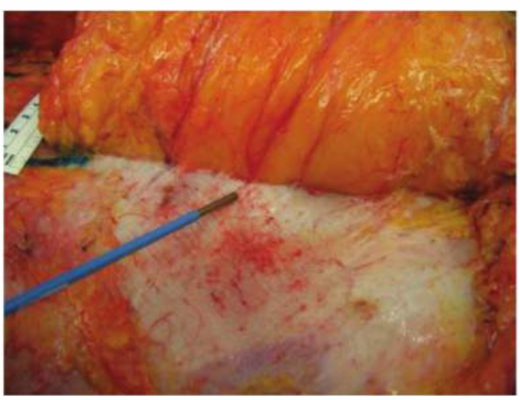

FIG 5 ● Lateral flap elevation: Beginning laterally on each side, the flap is elevated with Bovie cautery above the level of the fascia until the lateral border of the rectus abdominis is seen. At this point, either bipolar or very low cautery is recommended for continuing to complete the identification of both the medial and lateral rows of perforators.

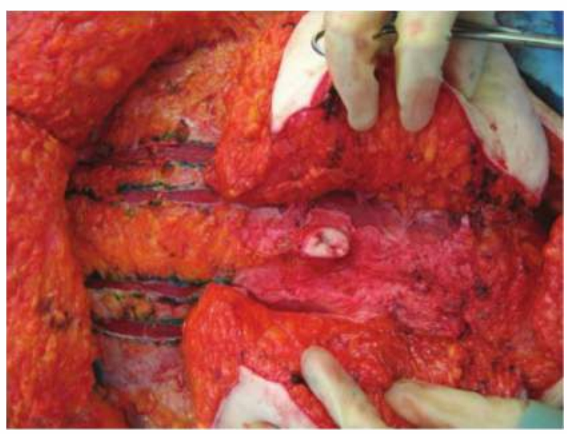

FIG 8 ● Perforator dissection. A no. 10 blade is used to incise the fascia and sharp dissection around the outside of each medial and lateral perforator under loupes magnification.

FIG 9 ● Flap elevation: The width of the fascia within the TRAM (approximately 2 cm) is also included in the flap superiorly to the level of the costochondral cartilage.

- Circumferential muscle dissection is then completed, the deep inferior epigastric artery identified and clipped, and the inferior portion of the muscle divided. The flap is then raised and any posterior perforators and intercostal nerves clipped such that there is no tethering of the flap (**FIG 9**. At the superior border of the fascial dissection, a back cut is made to allow the flap to rotate superiorly without tension or kinking of the blood supply. The flap is then placed within the mastectomy pocket.
- The donor site is then verified for hemostasis particularly at the site of the deep inferior epigastric artery ligation and the narrow gap in the anterior rectus fascia closed with 0-Vicryl and 0-polydioxanone (PDS) sutures (**FIG 10**).

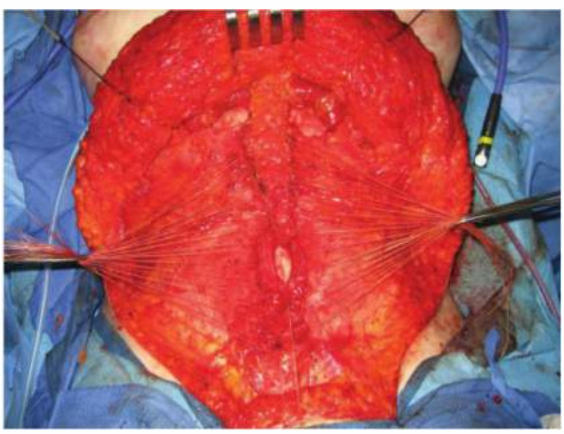

FIG 10 ● Fascia closure: The anterior rectus fascia is closed with interrupted 0-Vicryl and a running 0-PDS suture. The posterior sheath has not been violated. Hemostasis is crucial prior to closure of the fascia.

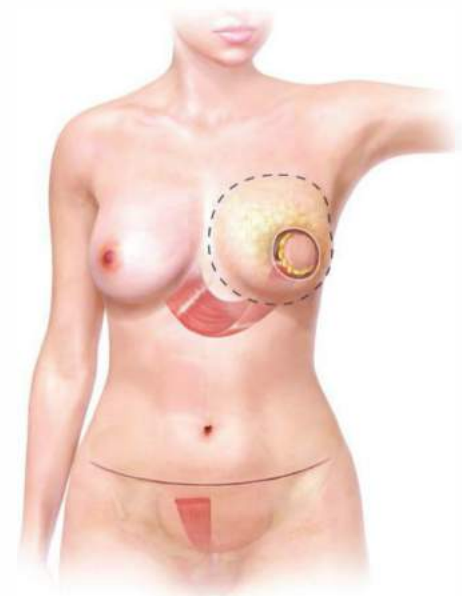

FIG 11 ● Flap placement: The flap is then rotated into the ipsilateral or contralateral mastectomy defect via the prepared tunnel.

In unilateral cases, a plication may be performed on the contralateral side to restore the umbilicus to the midline. This plication and closure should extend from the costochondral margin to the pubic bone to create a smooth desirable abdominal contour. The bed is then flexed and two drains are placed exiting through inferolateral stab incisions. The Scarpa's fascia is then approximated with 0-Vicryl sutures and the dermis closed with buried deep dermal 3-0 Vicryl followed by a subcuticular 4-0 Monocryl and dermal glue.

- By this time, the mastectomy flap can be either clinically assessed or studies used to assess the viability of the mastectomy flaps. The lateral border of the breast can be recreated using dermal to fascia 3-0 Vicryl sutures. Puckering at this time is expected and will resolve. In cases of questionable flap viability, these areas may be excised or the flap inset delayed to allow further debridement of the flaps 3 to 5 days later. In cases where the mastectomy flap is viable, the TRAM flap is de-epithelialized in non–nipple-sparing cases except for the site of the nipple–areolar complex (NAC) or entirely in cases of nipple-sparing mastectomies (**FIG 11**). The flap is then secured medially and superiorly with Vicryl sutures to the pectoralis fascia. A drain is placed running along the IMF and exiting through a lateral stab incision (two drains are placed if axillary lymph node dissection has been performed) and the wound is closed with deep dermal 3-0 Vicryl sutures and a 4-0 Monocryl subcuticular suture followed by dermal glue (**FIG 12**).

FIG 12 ● Immediate tram reconstruction for left skin sparing mastectomy.

PEARLS AND PITFALLS

Preoperative planning	■ A thorough history and physical will identify high-risk factors. ■ Smoking cessation should be strongly encouraged. ■ High-risk patients should be considered for surgical delay. ■ A thorough discussion with the patient regarding goals and reasonable expectations is essential.
Patient marking	■ Careful marking of the patient in the standing and seating positions is essential to a successful TRAM flap.
Intraoperative technique	■ Use either bipolar or very low cautery to avoid injury to the medial and lateral rows of perforators. ■ Carefully assess the mastectomy flap viability. Excise any questionable areas or consider delaying the flap inset.

POSTOPERATIVE CARE

- Awaiting extubation and during transfer of the patient, the bed is kept in the flexed position.
- Routine postoperative care includes removal of the Foley catheter on the night of surgery, SCD boots, and subcutaneous deep vein thrombosis (DVT) prophylaxis beginning 6 hours after the procedure is completed and per the Caprini scale.
- Patients are moved to the chair and ambulated the afternoon of surgery or next morning.
- Incentive spirometry is encouraged hourly.
- No bra is initially placed to prevent compression of the pedicle, and a binder is placed when patient is ambulating but not while in the chair or sitting up in bed again to avoid compression of the pedicle. The binder is recommended for 6 to 8 weeks followed by use of compression undergarments for comfort. A surgical bra without underwire is placed in clinic on the first visit once the mastectomy flap has matured.
- No postoperative antibiotics are given after inset of the flap.
- Patients are discharged between 1 and 3 days after the procedure or on the day of inset if inset has been delayed.

COMPLICATIONS

- The most common complications related to breast reconstruction is mastectomy flap necrosis. Careful inspection and experience with your breast surgeon is critical.
- Partial flap loss or fat necrosis are also possible but have been limited by our requirements of smoking cessation and experience with surgical delay prior to TRAM. Complete flap loss is very unusual.
- Abdominal bulge, hernia, and back pain are also reported complications of TRAM patients.
- DVT and pulmonary embolus are life-threatening complications.

OUTCOMES

- In immediate breast reconstruction cases, common revisions include lateral abdominal dog ear scar revision. If the case was not nipple sparing, this can be performed under local anesthesia at the time of nipple reconstruction.
- Asymmetry can be improved also based on the patient's breast size goal and preoperative size, with contralateral breast reduction or mastopexy.
- Secondary revisions are more common in cases of delayed reconstruction. These can be performed to improve symmetry at the time of nipple reconstruction.
- In all cases, the superior pole may have a paucity of tissue and can be improved with autologous fat grafting. A common secondary procedure includes NAC reconstruction, dog ear revisions, and fat grafting to the superior pole.
- With these revisions, we have found patients to be very satisfied with their outcomes, with a few number of interventions (**FIG 13**).

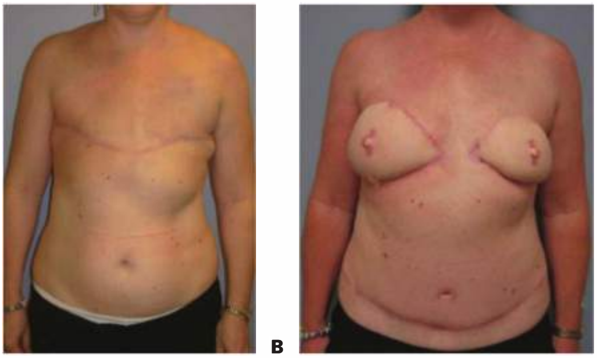

FIG 13 ● **A,B.** Pre- and postoperative images of delayed TRAM flap breast reconstruction.

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Chapter 18

Free Transverse Rectus Abdominis Musculocutaneous Flap Reconstruction after Mastectomy

Maurice Y. Nahabedian   Ketan M. Patel

DEFINITION

- Breast reconstruction using free tissue transfer techniques have become routine procedures following mastectomy.
- The most common free flaps for breast reconstruction include the free transverse rectus abdominis musculocutaneous (TRAM) flap and the deep inferior epigastric perforator (DIEP) flap. Indications for these flaps are primarily based on the availability of sufficient skin and fat at the abdominal donor site.
- There are several decision points to be considered when determining candidacy for a free TRAM or DIEP flap. Many patients are now choosing to have bilateral mastectomy and reconstruction in the setting of unilateral breast cancer or for prevention of breast cancer.
- Once the decision to proceed with an abdominal free flap for breast reconstruction has been made, decisions relating to the type of abdominal flaps are considered and based on patient anatomy and surgical experience.
- Non–muscle-sparing free TRAM flaps are technically easier but are associated with increased donor site morbidity that includes contour abnormalities and weakness. These morbidities are increased when the continuity of the rectus abdominis muscle has been disrupted, such as with the traditional pedicle TRAM and the MS-0 (full width) free TRAM. For these reasons, the full-width free TRAM flap is rarely performed and will not be included in this review.
- Muscle-sparing free TRAM flaps and DIEP flaps are technically more challenging and require a better understanding and appreciation of perforator anatomy and dissection techniques. This chapter will focus on the free TRAM flap, whereas the DIEP flap is covered in Part 5, Chapter 19.
- Muscle-sparing TRAM flap classification[1] (**FIG 1** [top])
  - MS-0: no muscle preservation (traditional TRAM flap)
  - MS-1: medial *or* lateral muscle preservation
  - MS-2: medial *and* lateral muscle preservation (central muscle sacrificed)
  - MS-3: total muscle preservation (DIEP flap)

PATIENT HISTORY AND PHYSICAL FINDINGS

- Many women with moderate to excessive volume are interested in these options because of the abdominoplasty appearance of the abdomen that is usually obtained.
- In women that lack a suitable quantity of abdominal soft tissue, alternative donor site options such as the gluteal or medial thigh region are considered.
- Sufficient donor site volume must be assessed to deliver appropriate breast volume. In some cases of bilateral free flap reconstruction, a hemiabdominal flap may not provide adequate volume and adjuncts such as combining flaps with implants or autologous fat grafting may warrant consideration.
- Prior abdominal surgery or body habitus may necessitate the use of computerized tomographic angiography (CTA) or magnetic resonance angiography (MRA) to assess the patency and location of the perforators and deep inferior epigastric artery and vein.

SURGICAL MANAGEMENT

Preoperative Planning

- A thorough history should focus on comorbidities, smoking history, previous surgeries, and medications that can alter surgical management and affect microvascular reconstruction. (Examples include coagulopathies, previous cardiac bypass surgery, previous abdominal surgery, and antiplatelet medications.)
- Physical exam will uncover hernias and previous abdominal scars. In addition, an assessment of the anterior abdomen for thickness and dimensions will aid in estimating a reconstructed breast volume.
- General complications include bleeding, hematoma, seroma, infection, delayed healing, and injury to surrounding structures.
- Specific complications include a 1% to 3% total flap failure rate,[2] early revisional surgery for microsurgical anastomotic thrombosis, late revisional surgery for contour irregularities, breast asymmetry, poor cosmetic result, and donor site complications that include an abdominal bulge/hernia (3% to 5%),[3] complex scarring, lateral "dog ears," and prolonged pain.
- Average length of surgery can range from 4 to 8 hours for a unilateral reconstruction and 6 to 12 hours for a bilateral reconstruction. Appropriate deep vein thrombosis (DVT) prophylaxis and perioperative antibiotics are routinely used due to the length and extent of surgery.
- The decision to proceed with a free TRAM or DIEP flap is sometimes made preoperatively and other times intraoperatively. Patients with a high body mass index (BMI) (>35) who have an overriding pannus are usually scheduled preoperatively for a muscle-sparing free TRAM flap. In other patients, who are found to lack a dominant perforator intraoperatively, the decision to convert from a DIEP to a free TRAM is made. If one or two dominant perforators are found, a DIEP flap is performed.

Anatomy

- The lower abdominal skin is supplied by perforating vessels from the primary source vessels that include the superior and deep inferior epigastric system.

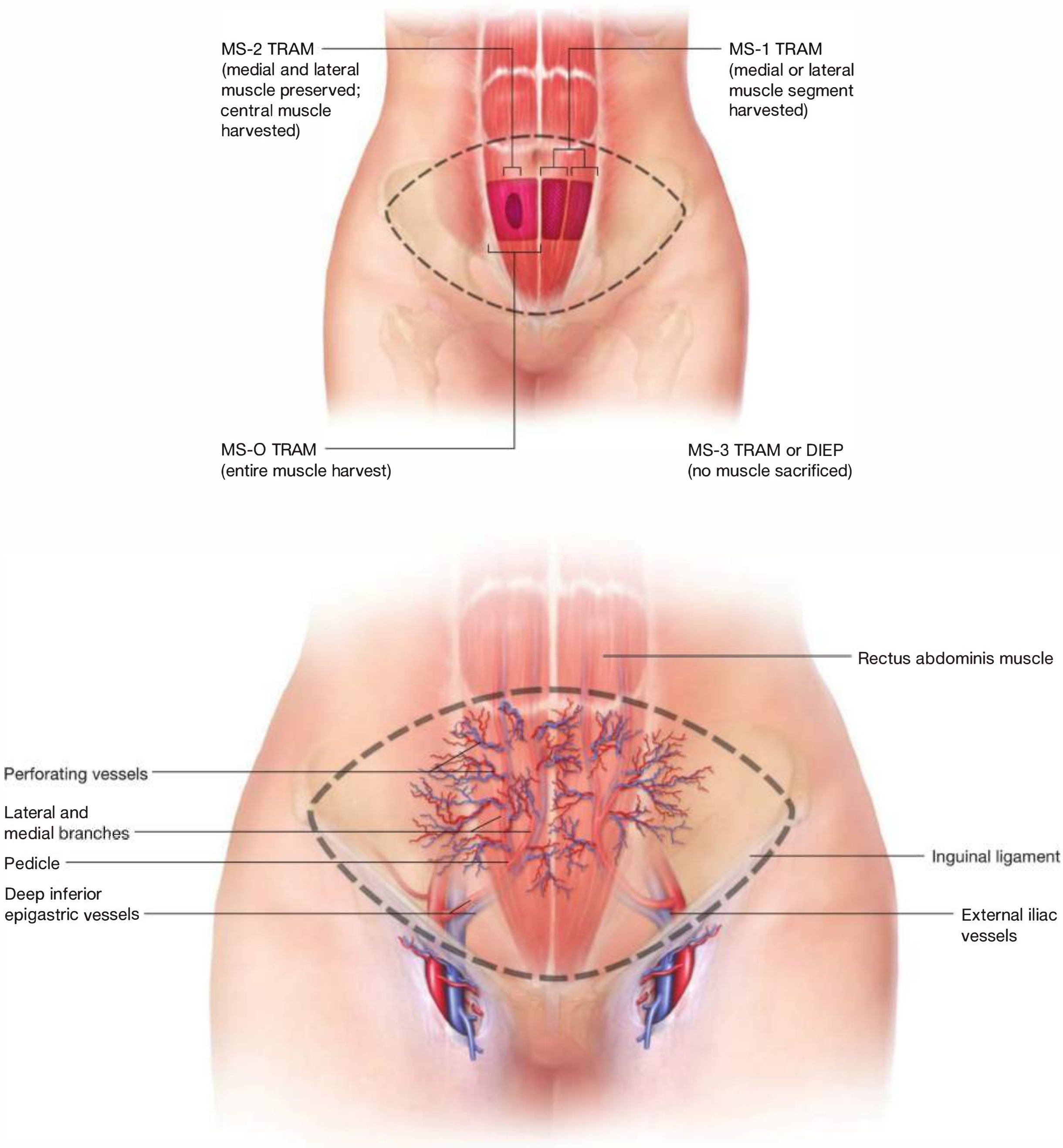

FIG 1 ● The variations of muscle preservation during abdominal flap harvest are shown. A traditional MS-0 represents the entire horizontal segment of rectus harvest. An MS-1 harvest can either spare the medial *or* lateral segments of rectus abdominis muscle as shown. Sparing of the lateral segment of muscle may result in an improved functional benefit as motor innervation to this segment is spared. MS-2 flap harvest spares the medial *and* lateral muscle segments with harvest of a central portion of the muscle. An MS-3 or DIEP flap spares the entire muscle and requires intramuscular perforator dissection.

- Source vessels travel vertically along the fibers of the rectus abdominis muscle on each side of the abdomen and send vertical perforating vessels to the overlying skin and subcutaneous tissue.
- The inferior epigastric system originates from the medial aspect of the external iliac system just superior to the inguinal ligament. The pedicle enters the rectus abdominis muscle on the undersurface from the inferolateral aspect of the muscle at the junction of the lateral and central third of the muscle.
- Two main intramuscular branches are identified: a lateral and medial branch. These branches then send perforating vessels to the overlying skin (**FIG 1** [bottom]).

ABDOMINAL FLAP HARVEST

- The patient is marked in the upright position (**FIG 2**). The anterior superior iliac spine (ASIS) is palpated and marked bilaterally. The upper extent of the abdominal flap is delineated, connecting the two ASIS marks across the abdomen and staying approximately 1 cm above the umbilicus. The lower abdominal line is an estimation that extends from the two ASIS markings in a curvilinear fashion. The inferior limit of this line is the pubic symphysis. The final inferior line is determined in the operating room after the upper skin flap is redraped. The markings for a free TRAM flap and a DIEP flap are identical (**FIG 3**).
- The initial incision is the upper abdominal ellipse. The incision extends to the anterior rectus sheath using electrocautery (**FIG 4**). The upper abdominal adipocutaneous flap is typically undermined to the midpoint between the umbilicus and the xiphoid process.
- The patient is flexed 10 to 30 degrees and the lower abdominal ellipse is definitively delineated and incised. The umbilicus is incised and preserved on its stalk.
- Flap elevation begins from a lateral to medial direction at the level of the anterior rectus sheath. The "safe zone" extends to the lateral edge of the linea semilunaris. Medial to the linea semilunaris, extreme precautions are taken to preserve and avoid injury to perforating vessels from the deep inferior epigastric system (**FIG 5**).
- A decision at this stage must be made to determine if a muscle-sparing free TRAM flap or DIEP flap will be performed. In either case, the lateral innervation to the rectus abdominis muscle is preserved.
- If bilateral free DIEP flaps are to be performed, medial to lateral and lateral to medial perforator dissection is performed (**FIG 6**). This is facilitated using bipolar cautery or monopolar cautery at very low current. Mosquito clamps are used to elevate and divide strands of muscle fibers without injury to the perforators or underlying vasculature.
- With the muscle-sparing free TRAM technique, an island of perforators is defined and the anterior rectus sheath surrounding the island of perforators is incised (**FIG 7**).

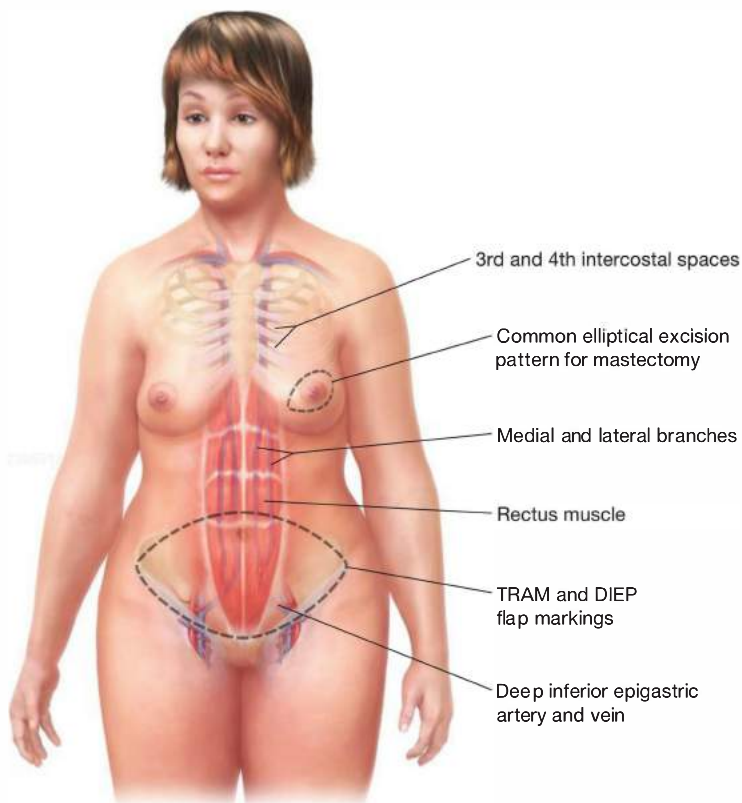

FIG 2 ● An oblique or horizontal ellipse is traditionally performed during a non–nipple-sparing mastectomy. Other configurations that can be used include a periareolar circular pattern or a vertically oriented pattern. Knowledge of the rib anatomy and intercostal spaces will aid in selecting a recipient site for microsurgical anastomosis. A large interspace, usually the 3rd or 4th intercostal space, is usually selected. The internal mammary vessels are located close to the sternocostal junction.

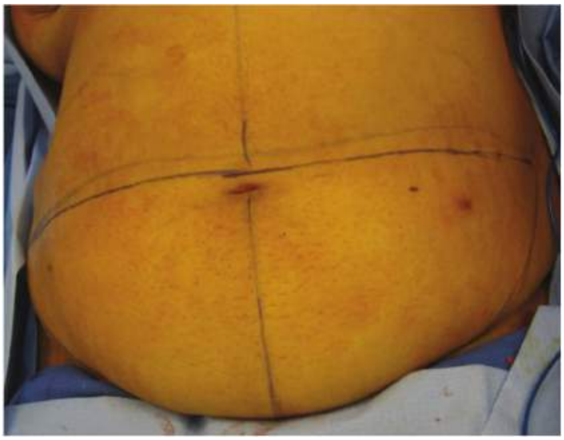

FIG 3 ● The abdomen in supine position is shown. The upper incision is usually located just above the umbilicus. The lower incision is placed in the lower abdominal crease or in a position to allow for donor site closure.

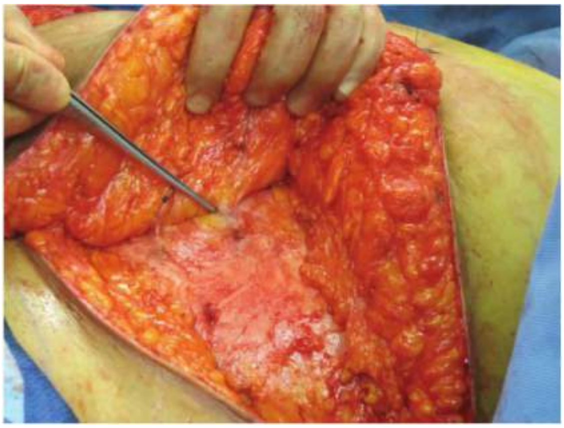

FIG 5 ● Flap elevation begins from the lateral edge. As the rectus sheath is encountered, lateral row perforators can be found piercing the fascia to perfuse the overlying skin and fat.

The medial and lateral sheath is elevated off the muscle and the retrorectus space is defined. The surrounding muscle is divided using monopolar or bipolar cautery.

- The superior portion of the rectus muscle is cauterized and the distal extent of the vascular pedicle is clipped. Palpation beneath the muscle will help identify the pulse and location of the pedicle to ensure that the pedicle is within the muscle segment (**FIG 8**).
- Once this is performed, the flap is solely based on the deep inferior epigastric system and elevated from distal to proximal. Cautery dissection proceeds at low current (**FIG 9**).
- The proximal portion of the pedicle can be visualized travelling toward the lateral edge of the rectus muscle and is dissected using sharp instruments. All side branches are clipped or ligated. Care must be taken to avoid injury to the vessels and intercostal nerves at this stage as diathermic injury may result in vessel thrombosis or neural injury (**FIG 10**).
- Pedicle dissection is continued proximally as deemed necessary for adequate pedicle length. Slightly increased caliber of the deep inferior epigastric artery (DIEA)/deep inferior epigastric vein (DIEV) is seen with more proximal dissection. Approximately 10 to 12 cm may be obtained if dissection is continued to the external iliac vessels.

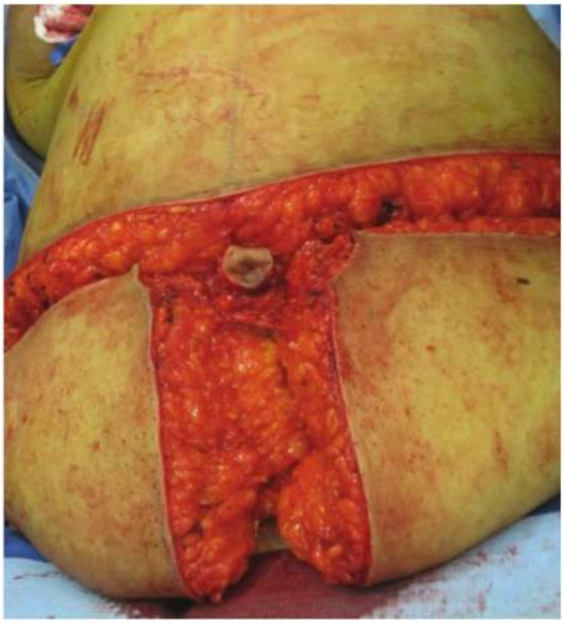

FIG 4 ● The upper incision is performed first. If bilateral reconstruction is being performed, the abdominal flap can be divided down the midline.

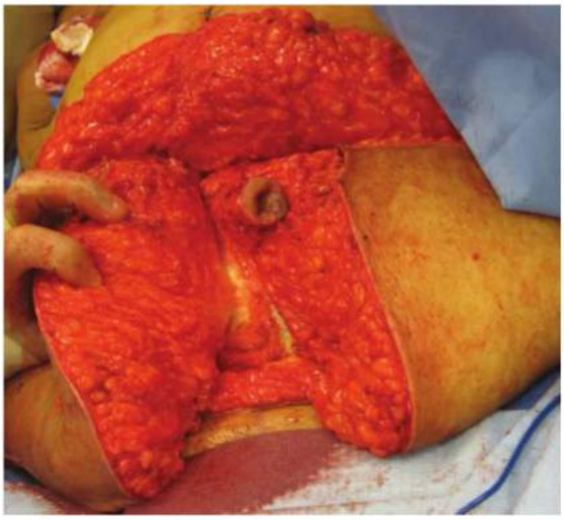

FIG 6 ● Dissection from the medial aspect of the flap is performed until medial row perforators are encountered and/or until safely over the rectus muscle.

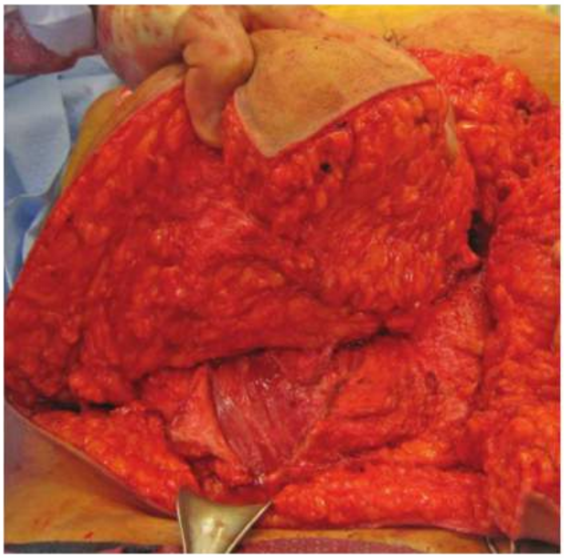

FIG 7 ● When harvesting a muscle-sparing TRAM flap, a fascial island is created around the perforators. The remaining fascia is elevated off of the surrounding muscle for better visualization and dissection.

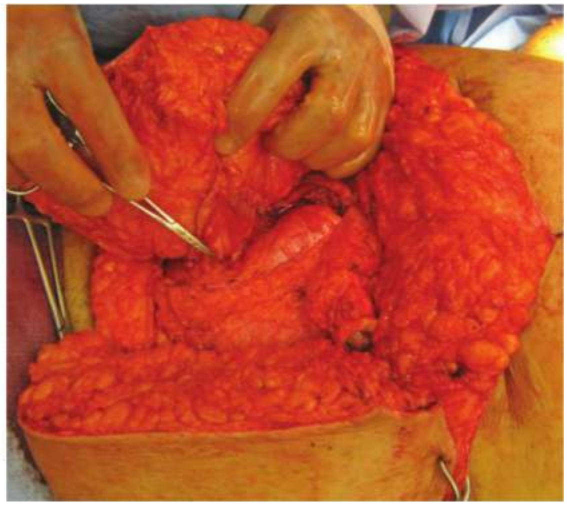

FIG 9 ● Once the muscle cuff is harvested, proximal dissection will reveal the pedicle vessels.

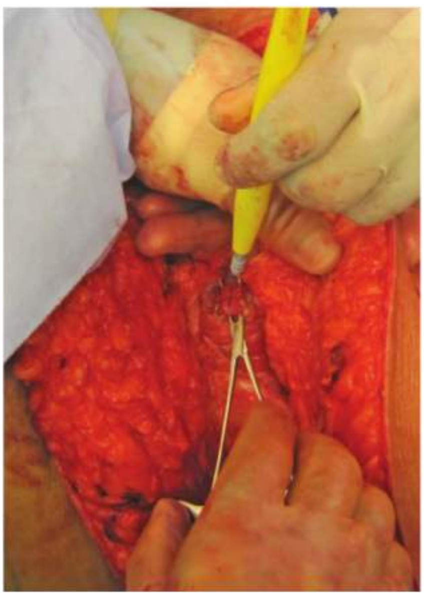

FIG 8 ● Careful dissection of the superior extent of the flap will allow for ligation of the distal pedicle to allow for distal to proximal flap harvest.

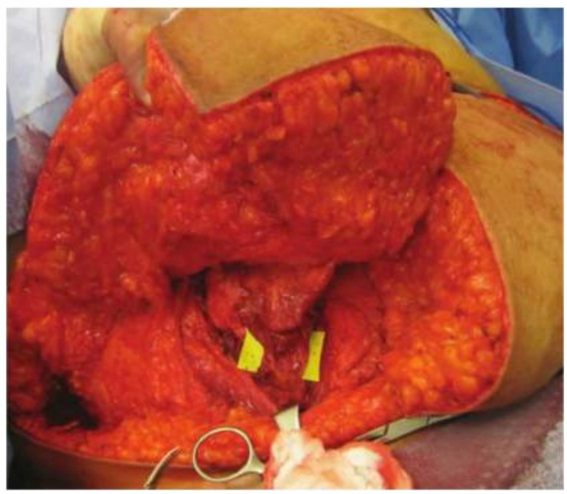

FIG 10 ● Care is taken to avoid injury to the pedicle during retrograde pedicle dissection.

RECIPIENT VESSEL DISSECTION

- The two sets of recipient vessels for free flap breast reconstruction include the internal mammary and thoracodorsal artery and vein. The most commonly used recipient vessels are the internal mammary system.
- The internal mammary vessels run paramedian to the sternum directly beneath the costal cartilage on the left and the right side. The thoracodorsal vessels are posterior in the axillary space and traverse along the anterior surface of the latissimus dorsi muscle.

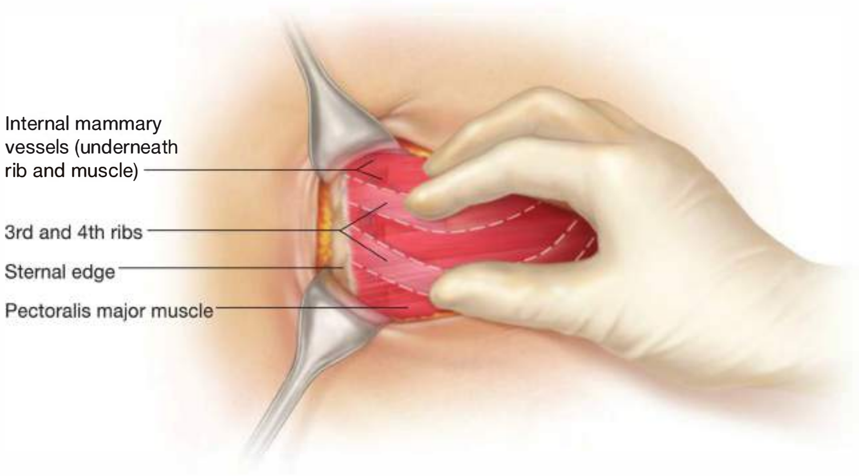

FIG 11 ● Selection of the interspace is usually performed intraoperatively with palpation of the intervening rib segments. Selection of a rib too low can result in a smaller caliber vein and a narrow interspace.

- The exposure technique described is for the internal mammary system. An appropriate intercostal space is chosen that will allow for adequate access for performing microsurgery. This is usually the 3rd or 4th interspace (**FIG 11**).
- The pectoralis major muscle overlying the desired rib is divided along the direction of the fibers using electrocautery. An adequate window is made, allowing for further rib and vessel dissection (**FIG 12**).
- The perichondrium is then removed overlying the costal portion of the rib and dissection proceeds in a subperichondrial fashion (**FIG 13**).
- Doyen surgical instruments are used to release the posterior perichondrium. Caution is taken in this dissection, as inadvertent passage through the posterior perichondrium can result in internal mammary artery and internal mammary vein (IMA/IMV) vessel injury or entry into the pleural space. A rib cutter is then used to isolate and remove a lateral segment of costal cartilage (**FIG 14**).
- Rib removal with a bone rongeur then proceeds from lateral to medial, again avoiding injury to the posterior perichondrium (**FIG 15**).
- Following complete removal of the costal cartilage segment, the posterior perichondrium is divided, elevated, and carefully excised using bipolar cautery and microdissection (**FIG 16**).
- The internal mammary artery and vein are visualized. The vein is usually the medial structure. Occasionally, a vena comitans is present. The recipient vessels are further dissected to clear the perivascular tissue using loupe magnification (**FIG 17**).

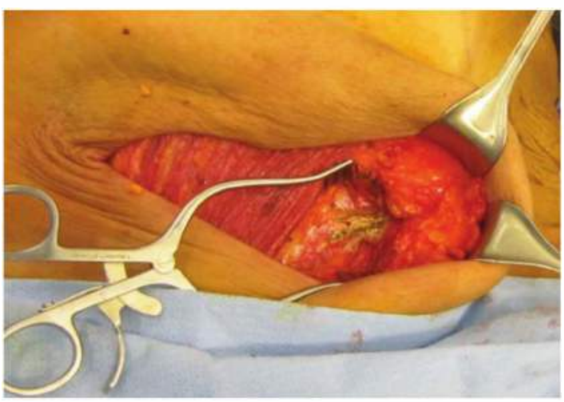

FIG 12 ● Division along the pectoralis major fibers will reveal the desired cartilaginous rib for resection.

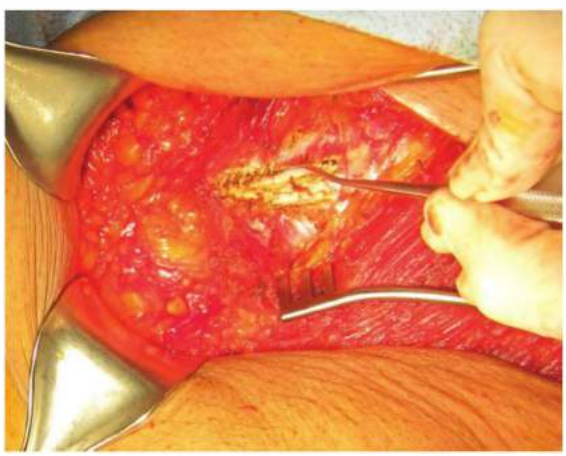

FIG 13 ● The perichondrium is incised and an elevator is used to circumferentially dissect around the rib segment.

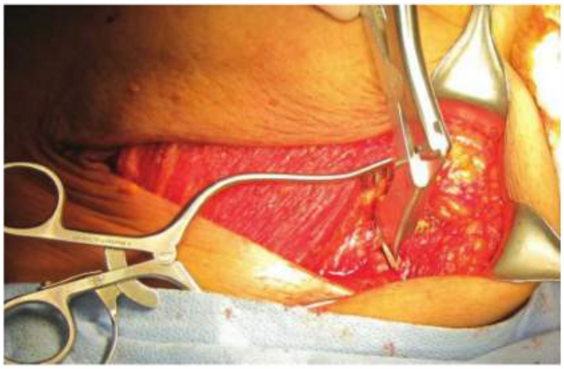

FIG 14 ● A rib cutter is used to remove the cartilaginous segment of rib.

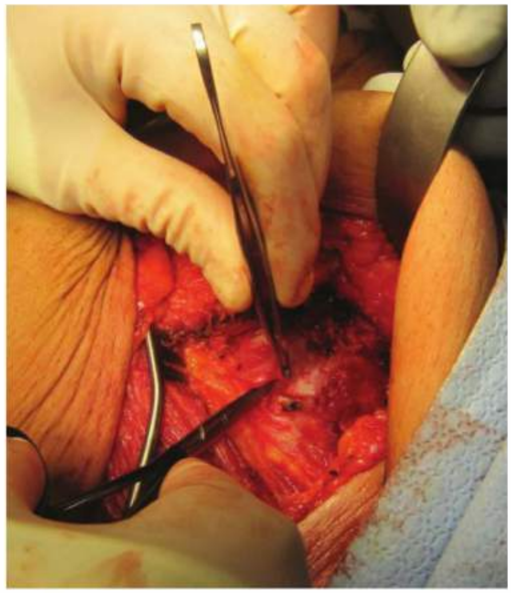

FIG 16 ● Careful dissection is performed to separate the posterior perichondrium from the underlying vessels.

FIG 15 ● A rongeur is used to finish the removal of the cartilaginous portion of rib. Care is taken to avoid injury to the posterior perichondrium as the internal mammary vessels lie deep to this structure.

FIG 17 ● Perivascular dissection is performed in order to prepare the vessels for microanastomosis.

MICROSURGICAL ANASTOMOSIS

- Intravenous heparin is usually administered prior to division of the inferior epigastric vessels.
- The harvested flap is positioned over the chest wall such that the inferior epigastric artery and vein are aligned with the internal mammary artery and vein.
- The medial anastomosis is usually performed first, which is typically the venous anastomosis. This is followed by the lateral or arterial anastomosis.
- The decision to use the vascular coupler (FIG 18) or to perform a hand-sewn anastomosis is based on surgeon preference. If a coupler is chosen, 2.0- to 3.0-mm ring is usually recommended. If a hand-sewn venous anastomosis is chosen, 8-0 or 9-0 sutures are used in an interrupted or continuous fashion. Avoidance of back-wall sutures is critical (FIG 19). Usually 8 to 10 sutures are needed to complete the artery (FIG 20).
- Following completion of the arterial and venous anastomoses, the vascular pedicle must be appropriately positioned on the chest wall to prevent twisting and kinking in order to minimize pedicle-related complications such as thrombosis.
- Positioning of the flap on the chest wall is an important step to recreate the breast contour and shape. Fortunately

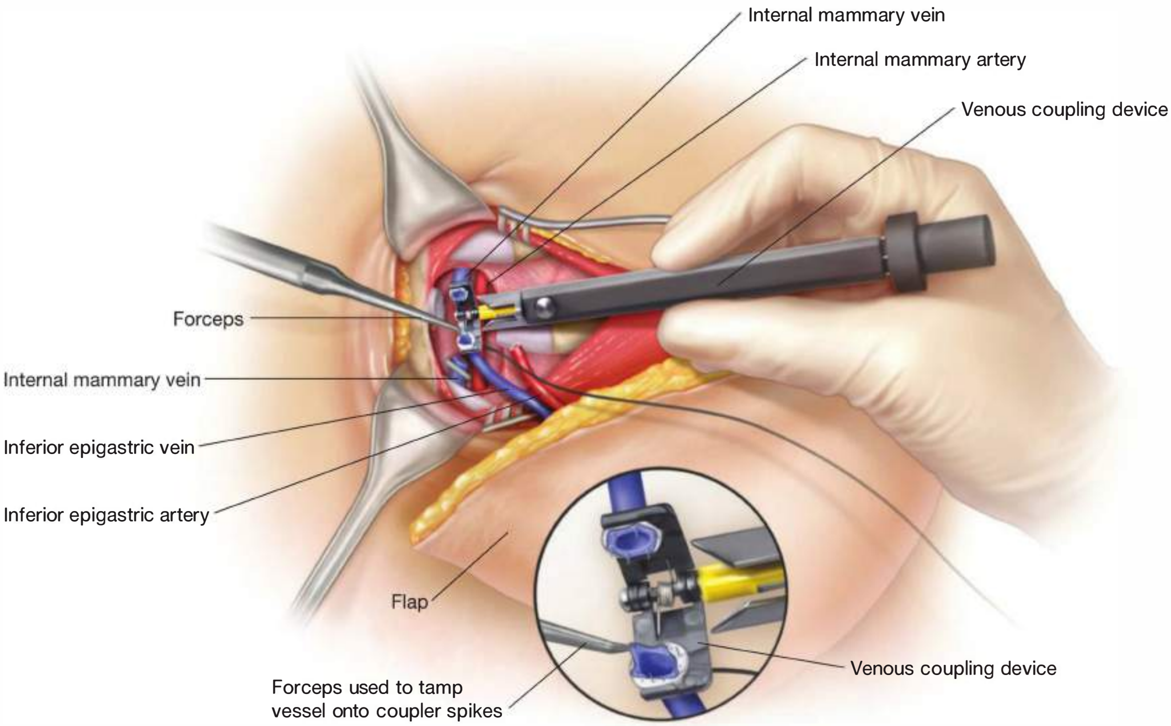

FIG 18 ● When the venous coupler is chosen to perform the venous anastomosis, proper orientation of the coupler device will ensure an efficient anastomosis. Performing the donor vein first will allow for reorientation of the device prior to performing the recipient side. The tamping forceps have a small central hole that allows correct positioning of the vein on the coupler spikes.

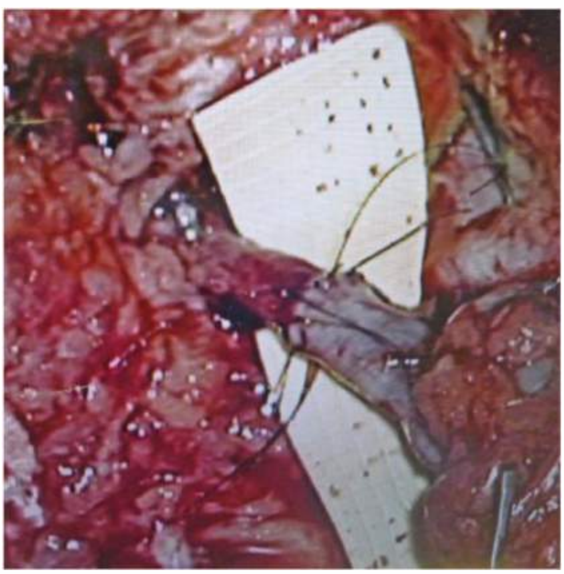

FIG 19 ● The medially located vein is usually anastomosed first with interrupted microsutures.

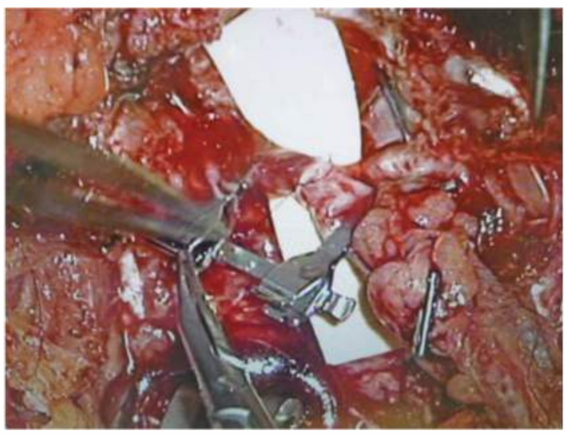

FIG 20 ● Arterial anastomosis is then performed using the same microanastomosis techniques.

with free flaps, there are no points that tether the flap and mobility of the flaps is maintained for optimal shaping.

- The abdominal donor site closure is an important phase of the breast reconstruction. With the DIEP flap, there is no muscle removed and usually no fascia; therefore, the closure consisted of a primary closure using a nonabsorbable monofilament. Reinforcement with a synthetic mesh is rarely necessary. With the muscle-sparing free TRAM, muscle and fascia are removed; therefore, it is sometimes necessary to replace the fascia with a synthetic or biologic mesh. This is more common with bilateral reconstructions compared to unilateral (**FIG 21**).
- Two drains are usually placed in the donor site and one drain in the reconstructed breast.

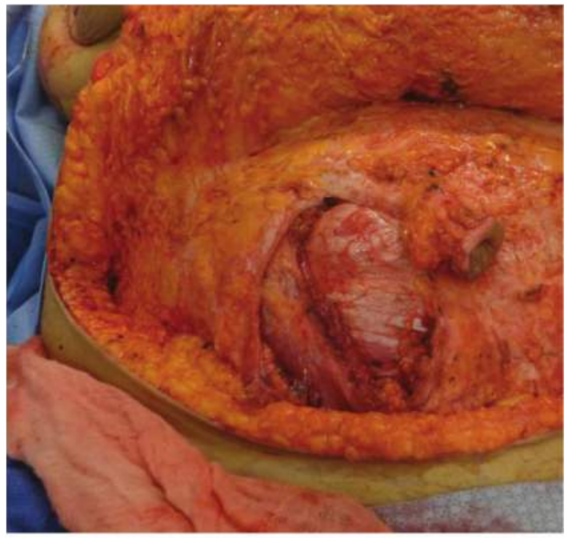

FIG 21 ● The donor defect is shown. When larger segments of anterior rectus sheath are harvested (such as in MS-0 and MS-1 TRAMs), mesh is used to either reinforce the anterior abdominal wall or to replace the anterior fascia.

PEARLS AND PITFALLS

Flap dissection	■ Finger palpation of the pedicle pulse is crucial during muscle-sparing harvest techniques. ■ A longer pedicle will allow for a larger vessel internal diameter that more closely matches the internal mammary vessel diameter.
Microanastomosis techniques	■ Secondary venous drainage may be helpful for larger flaps. ■ Radiated internal mammary vessels are less pliable and may tear more easily when using a venous coupler device.
Flap insetting	■ Excising radiated mastectomy flap skin may prevent tightness of the flap inset and later contour irregularities. ■ Suture tacks in the superior portion of the flap will maintain contour of the superior pole of the breast.

POSTOPERATIVE CARE

- Close flap monitoring occurs in the first 72 hours to ensure flap viability. A strict nursing flap check protocol includes frequent Doppler examination, color, and capillary refill assessments. Tissue oximetry is used on almost all flaps.
- Patients are maintained on postoperative antibiotic therapy for approximately 5 days and aspirin for 1 to 2 weeks to prevent anastomotic thrombosis.
- Ambulation is encouraged on postoperative day 1 or 2.
- Patients usually stay in the hospital for 3 to 4 days following surgery and are discharged home. They are encouraged to shower on postoperative day 3.

OUTCOMES

- The free TRAM reconstruction has been demonstrated to result in high levels of patient satisfaction and quality of life.[4] In long-term evaluation, autologous tissue reconstruction maintains a more natural-appearing breast as compared to implant-based reconstruction.[5]
- Abdominal donor site morbidity is relatively low.[6,7] Bulge/hernia formation may occur in approximately 3% to 5% of patients. In the event that surgical repair is necessary, this is usually achieved with fascial plication and reinforcement with a synthetic mesh.
- The free TRAM and DIEP flaps for breast reconstruction are valuable options for breast reconstruction following mastectomy.
- Free tissue transfer techniques are useful in complex situations such as prior radiation therapy, prosthetic failure, and in overweight and obese patients.
- Microsurgical expertise is necessary to obtain predictable outcomes and a low failure rate.
- Donor site morbidity rates are acceptable. Most women will achieve an "abdominoplasty" appearance of the abdomen following free TRAM and DIEP flap reconstruction.

COMPLICATIONS

- The most relevant complications following microvascular breast reconstruction include anastomotic thrombosis, hematoma, and flap failure. Postoperative flap monitoring is necessary to ensure prompt operative exploration in cases of vascular thrombosis. This is usually accomplished using tissue oximetry or Doppler analysis. Return to the operating room is necessary when there is a disruption in flow. Revision maneuvers include mechanical thrombectomy, tissue plasminogen activator (TPA), and redo anastomosis.

- Donor site morbidities are slightly more common and include contour abnormalities (hernia/bulge), incisional dehiscence, delayed healing, hematoma, and seroma. These complications can be managed conservatively but sometimes require operative intervention.

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Chapter 19

Deep Inferior Epigastric Perforator Flap Breast Reconstruction after Mastectomy

Adeyiza O. Momoh

DEFINITION

- Autologous reconstruction techniques after mastectomy are well-established options for breast reconstruction. Although over the years multiple flap options for reconstruction have been described, abdominal-based flaps continue to be the workhorse for autologous breast reconstruction. Abdominal flaps provide distinct advantages over implant-based reconstruction including a natural contour, superior symmetry and appearance of the reconstructed breast mound, and higher patient satisfaction.[1,2] A secondary benefit of these flaps is the improvement they provide to the abdominal contour. Hartrampf et al.[3] first described the pedicled transverse rectus abdominis myocutaneous (TRAM) flap in 1982, with its benefits of providing a soft, ptotic, aesthetically pleasing reconstruction that closely approximates the natural breast. Technical advancements and the continued quest to improve on flap perfusion and minimize donor site morbidity led to the introduction of the deep inferior epigastric perforator (DIEP) flap by Koshima and Soeda[4] in 1989 with later popularization by Allen and Treece[5] in 1994. The DIEP flap has gained in popularity over the years, and the potential benefits it offers include less abdominal wall weakness, bulging, and hernias.[6–8]

ANATOMY

- The DIEP flap is an adipocutaneous flap based on intramuscular perforators from the deep inferior epigastric artery (DIEA) and deep inferior epigastric vein (DIEV).
- The DIEA and DIEV originate from the external iliac vessels in the groin and course superomedially toward the lateral border of the rectus abdominis muscle.
- Deep to the rectus abdominis muscle, the DIEA and DIEV most commonly bifurcate (type II branching pattern) in the vicinity of the arcuate line and join up with the superior epigastric vessels above the umbilicus.
- Other encountered branching patterns are the type I with no branching and type III with trifurcating vessels (**FIG 1**).
- Perforators to the lower abdominal skin and adipose tissue come off the pedicle at multiple levels and are referred to as medial or lateral rows of perforators, indicating their relative position within the rectus/entry point into the flap.
- Most perforators are found within a 10-cm radius from the umbilicus.
- Zones of perfusion based on fluorescent perfusion studies[9] are illustrated in **FIG 2**—illustration with zones transposed onto rectus/pedicle.
- In general, perfusion of the hemiabdominal flap ipsilateral to the perforators (zones I and II) is stronger than it is to the contralateral abdominal flap across the midline (zones III and IV).
- Medial row perforators have a greater likelihood of perfusing tissue across the midline than do lateral row perforators.
- In contrast, lateral row perforators have a greater likelihood of perfusing the most lateral extent of the ipsilateral hemiabdominal flap than do medial row perforators.
- Medial and lateral rows of perforators communicate via a subdermal plexus.
- There is also communication between DIEA and DIEV system and the superficial inferior epigastric artery (SIEA) and superficial inferior epigastric vein (SIEV) system.
- The SIEV is the dominant outflow vessel for the lower abdomen in many patients.

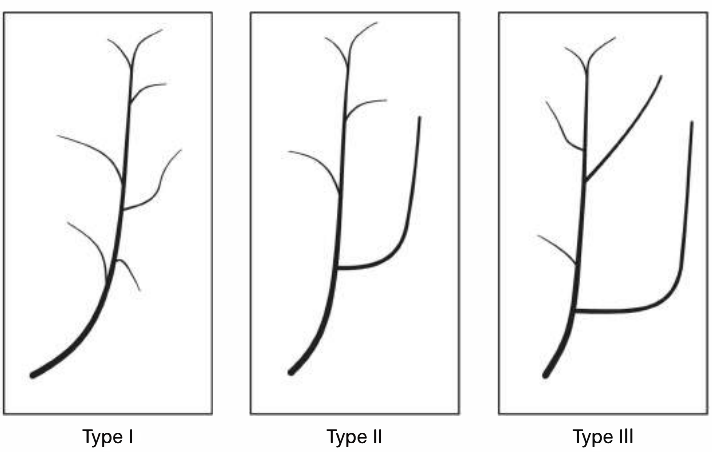


FIG 1 • Type I, type II, and type III vascular branching patterns.

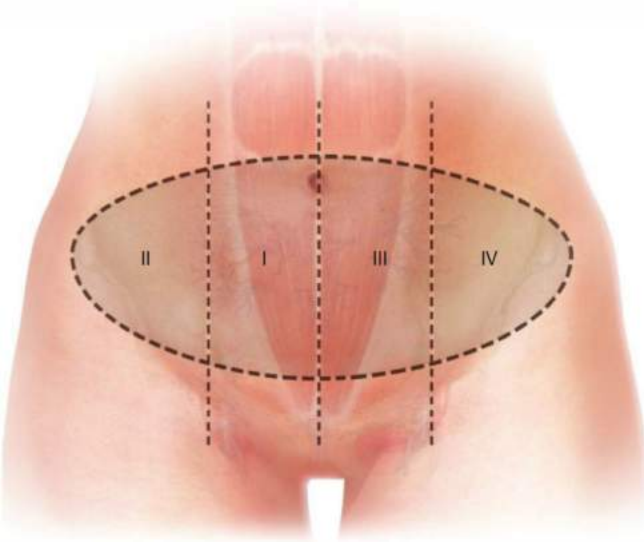


FIG 2 ● Zones of perfusion of the lower abdomen based on fluorescent perfusion studies.

PATIENT HISTORY AND PHYSICAL FINDINGS

- A thorough history and physical examination are critical in preparing for reconstruction.
- Pertinent aspects of the history include previous abdominal or chest wall operations and medical conditions that would preclude patients from a lengthy operation under general anesthesia."
- A focused abdominal examination evaluating the amount of lower abdominal adipose tissue and the location of surgical scars if present
- A team-based approach involving surgeons, anesthesiologists, primary care physicians, and other specialists such as cardiologists, as needed, ensures that patients are evaluated as a whole and all key concerns are addressed.

IMAGING AND OTHER DIAGNOSTIC STUDIES

- Preoperative computed tomography (CT) angiography of the donor site has been advocated in recent years. The preoperative scans provide a road map for flap perforators, with information on perforator location, size, and distribution (FIG 3).
- In patients with long low transverse abdominal incisions, the scans also allow for the assessment of continuity of the flap pedicle beyond the incision.
- Information gathered from scans has been shown to decrease operative times.[10] CT scans, however, are not an absolute requirement for preoperative planning.

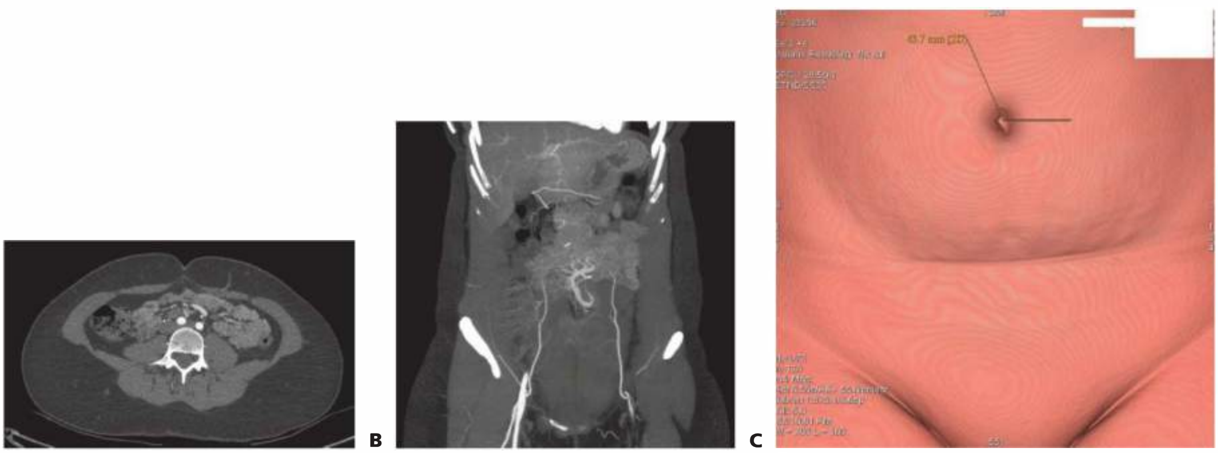


FIG 3 ● **A,B.** Preoperative CT angiography of the lower abdomen. **C.** A 3-D rendering of the abdominal soft tissue. Perforator locations based on axial cuts are transposed to the skin surface to enhance preoperative planning.

SURGICAL MANAGEMENT

- In consulting with patients, decisions about the timing of reconstruction (immediately after mastectomy or delayed) and the type of reconstruction are made, taking patient factors and tumor characteristics into consideration.
  - Patient factors of significance include the following:
    - Patient preference
    - Body habitus or the availability of abdominal donor tissue
    - Body mass index
    - Smoking history
    - History of previous abdominal operations that compromise the vascular pedicle or donor site
    - Medical comorbidities that would preclude patients from undergoing a lengthy operation
  - Tumor characteristics as they relate to the following:
    - The need for postmastectomy radiation therapy or
    - The need for close postmastectomy surveillance prior to reconstruction
    - In general, patients known to require postmastectomy radiation therapy are reconstructed in a delayed fashion to avoid the detrimental effects of radiation on flaps. A history of radiation therapy also serves as a relative indication for use of an autologous form of reconstruction, as implant reconstructions in the setting of radiation are prone to higher rates of complications and failure.

Preoperative Planning

- In addition to basic labs, patients should be type and screened, particularly in cases of bilateral reconstructions.
- All anticoagulant and antiplatelet medications should be stopped a week prior to the operation. Warfarin can be bridged with enoxaparin also a week prior.
- Smokers are required to quit for a minimum of 4 weeks prior.
- Patients receive preoperative antibiotics with intraoperative redosing.
- Patients receive deep vein thrombosis (DVT) prophylaxis with use of a pneumatic compression device and subcutaneous heparin at the beginning of the case.

Positioning

Marking/positioning

- Preoperative markings of the breast and abdomen are performed with the patient in the upright position.
- Key landmarks for the breast marked are the chest midline, inframammary fold, and a periareolar marking in the case of a skin-sparing mastectomy. The breast base width is also measured (**FIG 4A**).
- The upper marking for the abdominal flap is made at or just above the umbilicus with the location of perforators on preoperative imaging, providing some guidance. The breast base width is used to mark the potential vertical height/distance from the upper marking to the lower marking. The lower marking is then made to complete the elliptical pattern (**FIG 4B**).
- Patient positioning in the operating room (OR) is supine and the table is turned 180 degrees from the anesthesiologist, providing better access for two surgical teams (**FIG 5**).

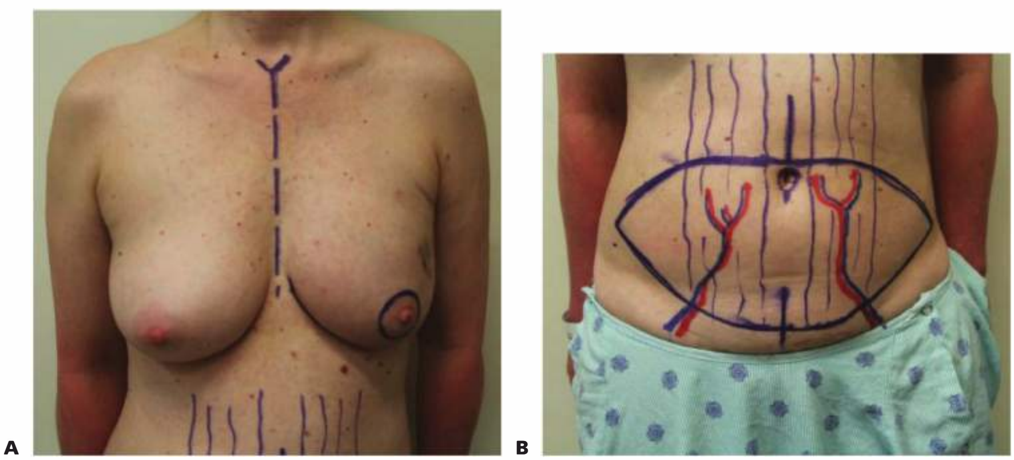


FIG 4 ● **A.** Breast preoperative marking. **B.** Abdominal preoperative marking.

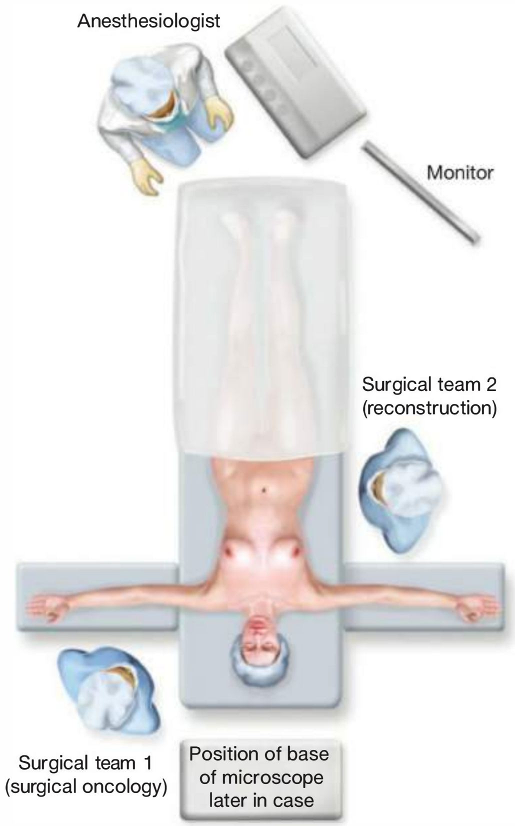


FIG 5 ● Patient positioning in the OR.

FLAP HARVEST

- Skin preparation with clipping is performed as needed.
- The breasts and abdomen are prepped and draped in a sterile fashion.
- The upper abdominal incision is made with a scalpel, and dissection through the adipose tissue down to anterior abdominal wall fascia is performed with electrocautery.
- An adipocutaneous flap is elevated cephalad with the electrocautery, ending at the xiphoid centrally and at the costal margins laterally. Less elevation may be needed in patients with ample skin laxity.
- The OR table is reflexed and the raised upper abdominal flap is transposed downward to assess the ability of this skin edge to meet the lower abdominal markings for closure. The lower abdominal markings are at this time adjusted as needed and the table returned to its original position.
- The lower abdominal incision is made superficially with a scalpel and careful dissection through the adipose tissue is performed, anticipating the presence of the SIEA and SIEV, typically above Scarpa's fascia (**FIG 6**).
- Once the superficial vessels are visualized, a Weitlaner retractor is introduced to provide further exposure and

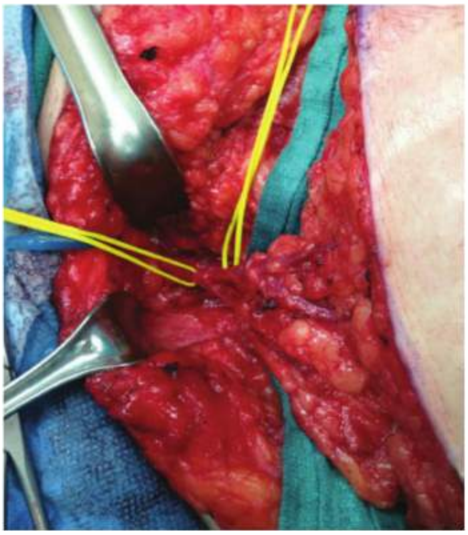


FIG 6 ● Dissection of the SIEV within the lower abdominal incision.

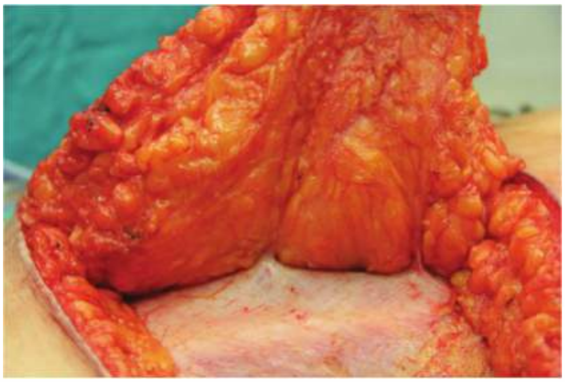


FIG 7 ● The lateral row of perforators visualized with suprafascial flap elevation.

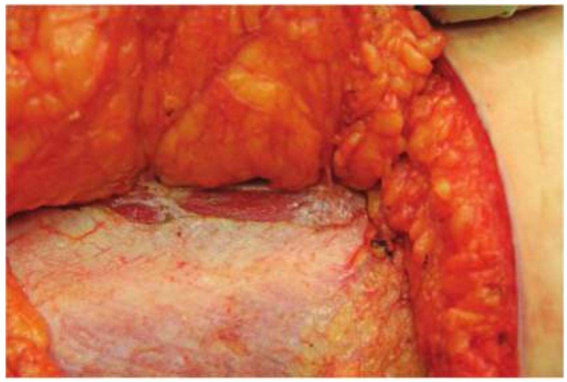


FIG 9 ● Subfascial exposure of flap perforators.

the vessels are dissected out toward the femoral vessels with use of tenotomy scissors and bipolar electrocautery. In patients who are not good candidates for the SIEA flap (SIEA) based on the absence of adequate-sized vessels, the vein is dissected to a length greater than or equal to 5 cm prior to ligating it with hemoclips and dividing it.

- Dissection down to the anterior abdominal wall fascia is then completed with electrocautery.
- Flap elevation is performed in the suprafascial plane from lateral to medial with electrocautery until the lateral row of perforators are encountered just medial to the edge of the rectus fascia (**FIG 7**).
- An incision is made around the umbilicus and along the midline of the flap in bilateral reconstruction cases or in cases with hemiabdominal flaps large enough for a unilateral reconstruction.
- The umbilical stalk is dissected out with blunt-tipped scissors and division of the flap down the midline is completed with electrocautery.
- In unilateral reconstructions that require use of portions of the flap that cross the midline, the umbilicus is dissected out without splitting the flap.
- Suprafascial elevation of the flap from its medial edge is performed with electrocautery until the medial row of perforators are encountered.

FIG 8 ● Perfusion map with laser-assisted indocyanine green fluorescent dye with dark areas indicating poor perfusion.

- Dissection around the perforators is performed with a low-energy electrocautery, and at this time, all perforators are assessed for their size and location within the flap.
- Small perforators (<1.5 mm in diameter) are ligated with hemoclips and one or more perforators within either the medial or lateral row are selected for use.
- Laser-assisted indocyanine green fluorescent dye can be employed at this point to assist with perforator selection. Appropriate-sized Acland clamps are placed on all perforators excluding the few selected and the dye is administered by the anesthesiologist intravenously. Within a few minutes of the dye administration, a real-time perfusion map of the flap is visualized (**FIG 8**).
- Alternatively, capillary refill can be assessed with the Acland clamps in place for a few minutes to determine adequacy of flap perfusion based on the few selected perforators.
- The anterior rectus fascia adjacent to the selected row of perforators is incised with electrocautery in a craniocaudal orientation (**FIG 9**).
- A millimeter cuff of fascia is cut with a tenotomy around the perforator, freeing it from the surrounding anterior rectus fascia.
- Two to 3 mL of heparinized saline is then injected into the rectus muscle adjacent to the individual perforators with an olive-tipped cannula. The heparinized saline used in this fashion hydrodissects the surrounding soft tissue away from the perforator and aids with visualization of the perforator course. This technique is repeated as needed throughout the course of the intramuscular dissection (**FIG 10**).
- The perforators are dissected through the rectus muscle with the aid of a bipolar electrocautery down to the larger deep inferior epigastric arterial and venous system that runs beneath the muscle.
- The continuation of the DIEA and DIEV system to the superior epigastric vessels is encountered above the most cephalad perforator and these vessels are ligated with

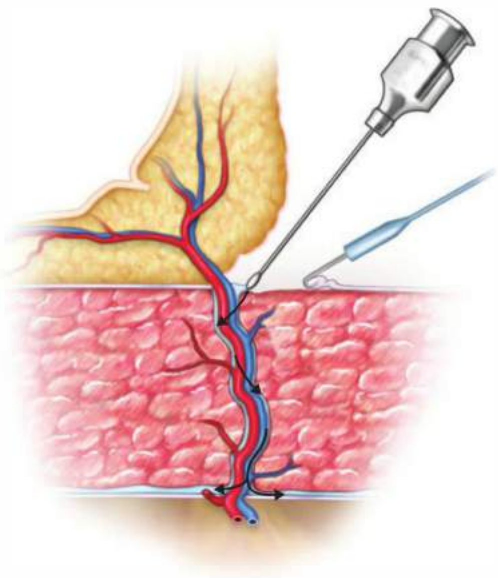
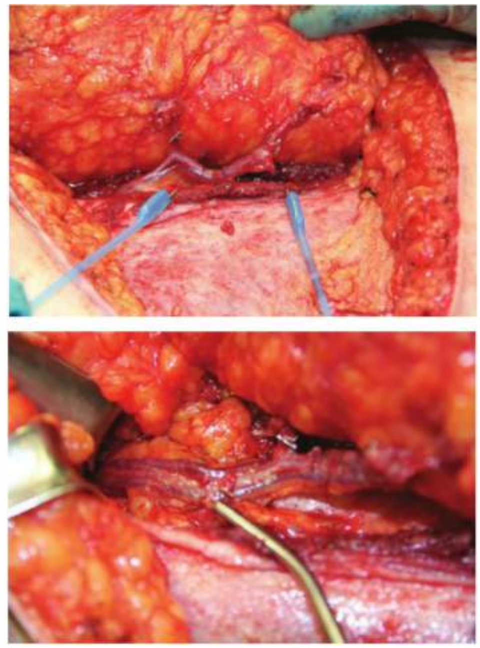


FIG 10 ● Hydrodissection technique for intramuscular perforator dissection illustrated. Heparinized saline is injected adjacent to the perforator and creates a dissection plane between the perforators and muscle. The *arrows* illustrate the course of the heparinized saline, which tracks along the perforator with each injection.



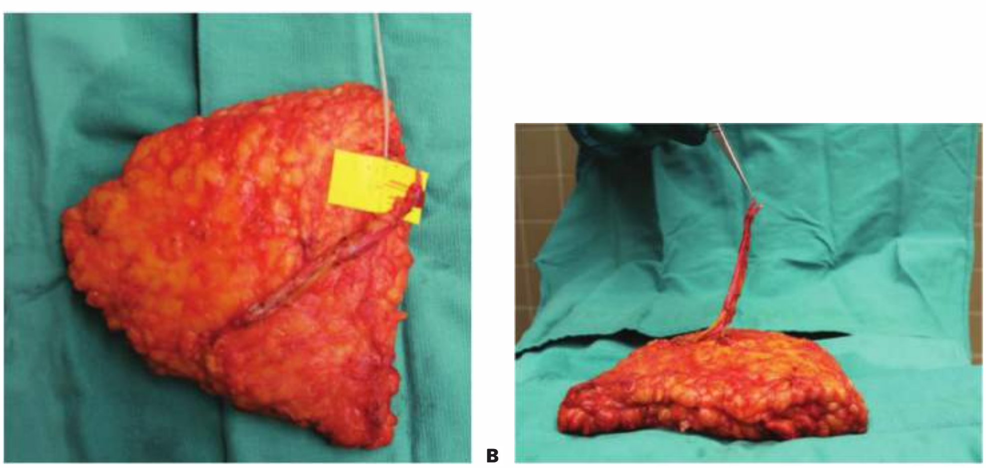
A

B

FIG 11 ● **A.** Intramuscular and submuscular dissection of perforators and vascular pedicle. **B.** DIEP flap pedicle prior to ligation.

appropriate-sized hemoclips 1 to 2 cm cephalad to the perforator.

- The submuscular dissection proceeds toward the external iliac vessels in the pelvis and is performed with the electrocautery, leaving a cuff of adipose tissue around the vessels.
- The DIEA and vein are dissected to a point where their length and size are appropriate for the recipient vessels in the chest (**FIG 11**).
- Once ready for transfer to the chest, the artery is first ligated distally with hemoclips followed by the vein(s).
- A tenotomy scissors is used to divide the vessels proximal to the clips.
- The harvested flap (**FIG 12**) is prepared on a back table by flushing the flap from its arterial end with heparinized saline until the venous outflow clears up and is less bloody.



A

B

FIG 12 ● **A,B.** Flap harvested and prepped on a back table.

RECIPIENT VESSEL EXPOSURE (INTERNAL MAMMARY)

- A common choice and the author's preference for recipient vessels are the internal mammary artery and vein. Alternatively, the thoracodorsal artery and vein can be used.
- Once the mastectomy is complete, the defect is irrigated and hemostasis with electrocautery is performed as needed.
- The medial cartilaginous aspect of the 3rd rib is palpated through the pectoralis major muscle. The muscle fibers over this medial aspect of the rib are split (ideally along the fibers) with electrocautery and a Weitlaner retractor is introduced between the muscle fibers to provide exposure. The muscle split is performed from the lateral edge of the sternum to a point approximately 6 cm lateral.
- The anterior costal perichondrium is scored along its length with the electrocautery and also perpendicular to the lengthwise incision at the medial and lateral extents of the exposed cartilage.
- A freer or narrow periosteal elevator is then used to elevate the perichondrium off the underlying cartilage circumferentially (**FIG 13**).
- The cartilage is then excised with a rongeur from lateral to medial, exposing the posterior perichondrium. The internal mammary artery and vein are sometimes visible through the posterior perichondrium at this point.
- A second Weitlaner is introduced perpendicular to the first using the lateral cut end of the rib as an anchor for one end of the retractor while the opposite end retracts the medial mastectomy flap out of the field.
- An incision is made laterally through the posterior perichondrium with a scalpel and a freer is then introduced underneath the perichondrium and used to push all soft tissue and vessel downward.
- The posterior perichondrium is then split from lateral to medial, exposing the underlying internal mammary artery (IMA) and internal mammary vein (IMV).
- The posterior perichondrium is bluntly dissected off the underlying vessels with a freer and excised completely to provide optimal exposure of the recipient vessels.
- The IMA and IMV are dissected circumferentially and a background mat with attached suction is placed beneath both vessels (**FIG 14**).

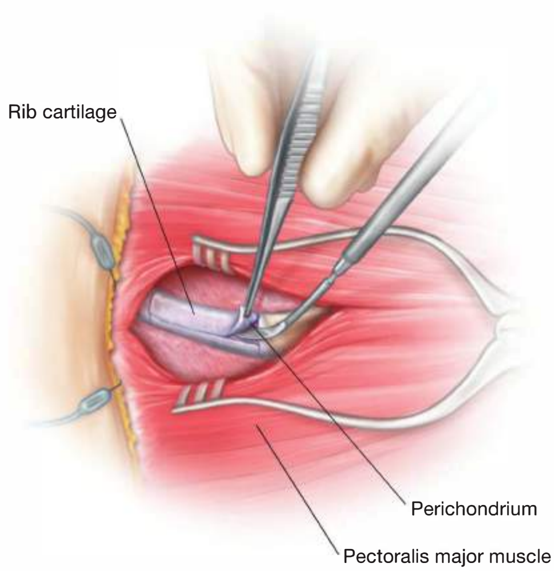


FIG 13 ● Elevation of the rib perichondrium.

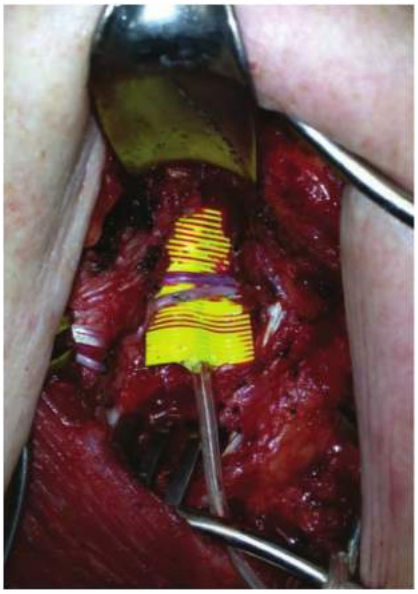


FIG 14 ● Exposed IMA and IMV with placement of a background mat with suction.

MICROVASCULAR ANASTOMOSIS

- The harvested DIEP flap is transferred to the chest and secured to the chest wall with sutures.
- With magnification from a microscope, the flap vessel ends are prepared, sharply cutting irregular vessel ends and loose adventitia.
- Similar preparation of the IMA and IMV are performed.
- Anastomosis of the arteries and veins can be performed in whichever order based on the surgeon's preference. The author preferentially couples the veins prior to the arterial anastomosis.
- An appropriate-sized single Acland clamp is placed proximally on the IMV and a hemoclip is applied distally prior to cutting the IMV with tenotomy scissors. The cut vessel end is then flushed with heparinized saline.
- A vessel sizer is used to determine the approximate vein diameter for both the flap vein and the IMV and the smaller of the two vessels determines the coupler size to be used.

- The flap vein is first placed in one end of the coupler followed by the IMV and the coupler is closed without placing tension on either vessel. The previously placed clamp is then taken off the IMV.
- One end of an appropriate-sized, double opposing Acland clamp is placed proximally on the IMA and hemoclips are applied distally prior to cutting the IMA. The flap artery is then introduced into the opposite end of the double-opposing Acland clamp.
- An end-to-end anastomosis of the arterial ends is performed with 8-0 or 9-0 nylon sutures in an interrupted or running fashion (**FIG 15**).
- Once the anastomosis is complete, the flap end of the clamp is taken off first prior to taking off the end on the IMA.
- With flow reestablished, papaverine is infiltrated into the adventitia of the arteries to prevent spasm.
- The flap and anastomosed vessels are warmed with warm saline and allowed to reperfuse for a few minutes.
- Doppler signals are identified on the flap skin and marked with sutures.
- Fat grafts obtained from either the abdominal donor site or flap edge are placed around the anastomosis to help secure the desired position of the vessels and reduce kinking.

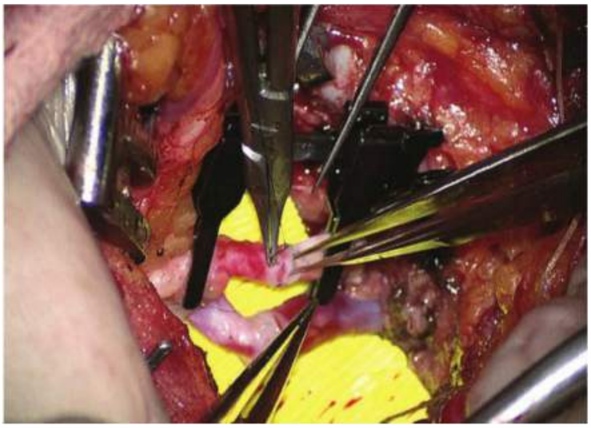


FIG 15 ● Microvascular anastomosis under an operating microscope. A double opposing Acland clamp holds the arterial ends in place and an end-to-end anastomosis is being performed with interrupted 8-0 nylon sutures. The DIEV has been coupled to the IMV in the background.

FLAP INSET/DONOR SITE CLOSURE

- Peripheral zones of the flap that may be less optimally perfused are excised.
- The flap is then placed within the mastectomy defect and interrupted absorbable sutures are used to secure the flap to the medial aspect of the chest wall.
- The pattern of the skin paddle is marked and all skin (epidermis and dermis) outside of the paddle is excised with electrocautery (**FIG 16**). De-epithelialization here is also an option.
- A drain is placed along the inferior aspect of the mastectomy defect and exits the skin along the anterior axillary line.
- Skin closure for the flap inset is performed in layers with absorbable interrupted deep dermal sutures and a running subcuticular suture.
- The OR table is reflexed; two drains are placed in the abdominal donor site; and closure of the defect is performed with approximation of Scarpa's fascia, the deep dermis, and subcuticular layer.
- The umbilicus is delivered through the skin flap above the horizontal abdominal closure along the midline by creating an appropriate-sized defect with a full-thickness excision. The umbilicus is then inset with a layered closure.
- Minimal dressings in the form of a skin glue product, Steri-Strips, or an ointment are then applied to all suture lines.

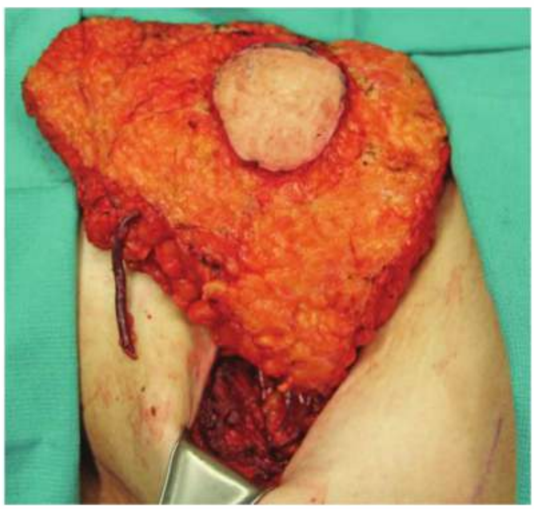


FIG 16 ● Flap with all skin outside of the skin paddle excised; preserved SIEV can be seen on the medial aspect of the flap.

PEARLS AND PITFALLS

Preoperative evaluation	■ Preoperative CT angiography is a useful tool to assist with perforator selection—It provides information on perforator location and size but does not give information on flow/perfusion. ■ Flap perfusion based on a few perforators is better assessed by laser-assisted indocyanine green fluorescents dye or by physical examination with occlusion of all perforators with the exception of the few selected perforators.
Patient positioning	■ With the patient in supine position, the table can be turned 180 degrees from the anesthesiologist, providing better access for two surgical teams.
Dissection of the vessels	■ Preserve as long a length of the SIEV (≥5 cm) as possible for use as an additional outflow vessel in flaps with venous congestion after elevation or transfer to the chest. ■ The hydrodissection technique used for the intramuscular perforator dissection simplifies this portion of the operation, creating dissection planes and allowing for better visualization of the perforators and small vascular branches.

POSTOPERATIVE CARE

- Patients can be transferred from the OR to a postanesthesia care unit (PACU) or directly to a unit with nursing capabilities for flap monitoring.
- Flaps are monitored by physical examinations (color, temperature, capillary refill, and handheld Doppler signals) performed every hour for the first 24 hours and then checks can be spaced out to every 2 hours and 4 hours over subsequent hospital days.
- Additional flap monitoring with continuous near-infrared spectroscopy (NIRS) tissue oximetry is employed for 72 hours postoperatively.
- DVT prophylaxis is the only form of anticoagulation used routinely.
- The patient's bed is kept in semi-Fowler's position at all times.
- Diet is advanced from clear liquids to regular on postoperative day (POD) 1 with restrictions to caffeine intake.
- Patients are assisted out of bed to a chair on POD 1 and they ambulate beginning on POD 2.
- Foley catheters and intravenous (IV) fluids are discontinued and IV medications/patient-controlled analgesias (PCAs) are converted to orals on POD 2.
- Patients are typically ready for discharge home from POD 3 to POD 5.
- Surgical drains are discontinued once the output is less than 30 mL for two consecutive days.
- Activities are limited and weight-lifting restrictions are in place for 6 weeks postoperatively.
- The first postoperative visit is at 1 week following discharge.
- Preoperative photographs of a patient with a left breast invasive cancer who opted for DIEP flap reconstructions are presented in **FIG 17A,B**.

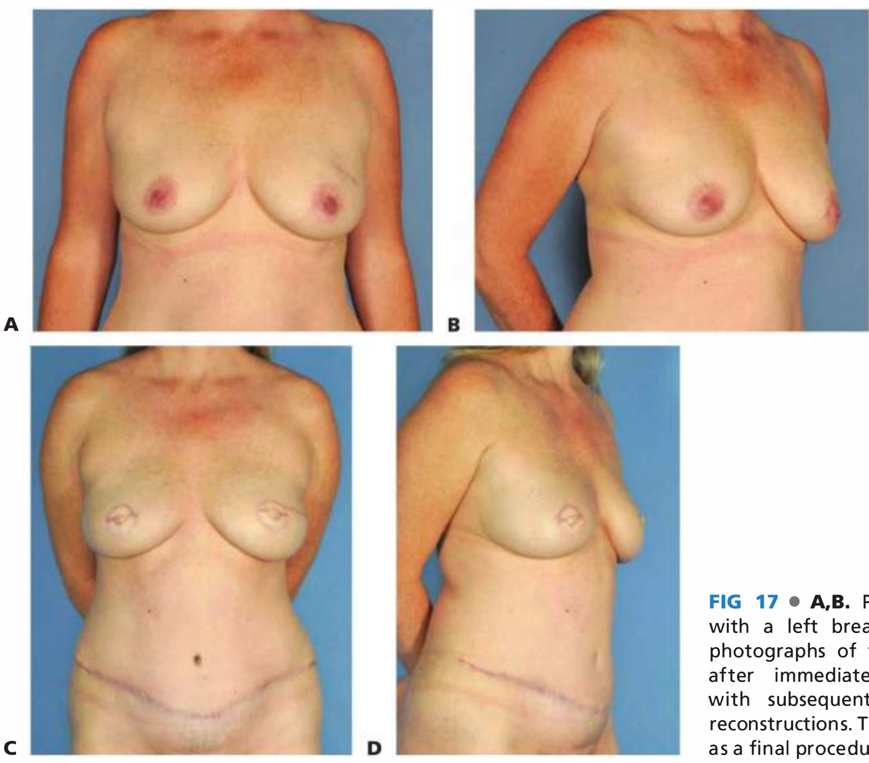


FIG 17 ● **A,B.** Preoperative photographs of a patient with a left breast invasive cancer. **C,D.** Postoperative photographs of the breasts and abdominal donor site after immediate bilateral DIEP flap reconstruction with subsequent revisions including bilateral nipple reconstructions. The patient will undergo nipple tattooing as a final procedure.

- The same patient's postoperative results after immediate bilateral DIEP flap breast reconstruction and subsequent revisions are presented in FIG 17C,D.

OUTCOMES

- The goals of breast reconstruction are to create breast mounds that are aesthetically pleasing, symmetric, and similar to the natural breast in appearance and feel.
- Patient satisfaction is of great importance in assessing outcomes of reconstruction.
- Breast reconstruction patients are typically satisfied in the short term (<5 years) with their choice of reconstruction across implant-based to autologous forms of reconstruction.[11]
- Over the long term (>8 years), satisfaction with abdominal-based flap reconstruction is maintained, whereas satisfaction with implant-based techniques tends to depreciate.[11]
- Studies have also shown greater satisfaction with autologous reconstruction in patients requiring unilateral reconstructions.[12] This is likely the result of better symmetry with the natural contralateral breast.
- Patient satisfaction in bilateral reconstructions has been found to be similar across all techniques provided that the same technique is used on both sides,[12] highlighting again the importance of symmetry.

COMPLICATIONS

Flap-Related Complications

- Infections—Surgical site infections are rare as these are clean cases and the autologous tissue transferred to the chest offer greater resistance to infection than do prostheses.
- Delayed wound healing—This complication typically occurs at the interface between the mastectomy flap and DIEP flap skin paddle. It often is a result of marginal mastectomy flap necrosis from poor skin perfusion, which is more likely in smokers and in the previously radiated breast skin.
- Fat necrosis—Varying degrees of fat necrosis are encountered in 10% to 15% of reconstructions; it occurs in small segments of flap adipose tissue with poor perfusion. This complication is apparent within a few weeks of the operation and presents as a firm palpable nodule, which occasionally causes some discomfort. These areas of necrosis can be directly excised or managed with liposuction (ultrasound assisted or suction assisted) during revision procedures.
- Partial flap loss—an uncommon complication that is also related to poor perfusion. Here, a segment of the flap is lost. It can be the result of poor perforator selection or thrombosis of one or more of the selected perforators. An excision of the necrotic segment is usually required.
- Total flap loss—This is one of the most devastating complications encountered and it occurs in less than 2% of reconstructions. The ultimate cause of flap loss is a thrombosis of the vascular pedicle, which could be brought about by a variety factors ranging from technical problems to hypercoagulable conditions. Early detection of thrombosis with a return to the OR and correction of the inciting problem leads to flap salvage in most cases.

Donor Site Complications

- Hernias/bulges—the result of abdominal wall weakness; this complication is seen with much less frequency when compared to the TRAM flap, which by definition takes muscle and fascia as part of the flap harvest. The incidence of this complication has been shown to decrease with use of mesh reinforcement in TRAM flap harvests.
- Delayed wound healing—Wound healing problems are encountered often in morbidly obese patients, diabetics, and smokers. Perfusion to the infraumbilical portion of the abdominal donor site is marginal in some patients; fat necrosis occurs in this area and ultimately results in a wound dehiscence. These wounds are managed by debridement and dressing changes with healing by secondary intention.

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Chapter 20 Nipple–Areolar Reconstruction

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DEFINITION

- Nipple–areolar reconstruction (NAR) is typically performed as the final stage of breast reconstruction after mastectomy. The nipple is reconstructed to give three-dimensional projection, and the areola is reconstructed separately to mimic a natural nipple–areolar complex (NAC).

PATIENT HISTORY AND PHYSICAL FINDINGS

- NAR is an elective stage of breast reconstruction that can be performed after any type of primary breast mound reconstruction. Published studies indicate that approximately 50% of breast reconstruction patients elect to undergo NAR.[1,2]
- NAR is performed at least 3 months after breast reconstruction is complete. This allows the final breast shape and position to be obtained prior to placement of the NAC.
- NAR can also be performed in a delayed fashion at any time a patient decides, including months or years after breast mound reconstruction.

SURGICAL MANAGEMENT

- There are many described techniques for nipple reconstruction, including nipple sharing, local flaps, cartilage grafts, dermal grafts, and prostheses.[3] Local flaps are the most popular option and are described in detail in this chapter.
- Reconstructed nipples lack the rigid ductal and smooth muscle elements of a natural nipple; therefore, the long-term maintenance of nipple projection continues to be the most challenging aspect of NAR.[4]
- Multiple autologous and prosthetic materials (auricular cartilage, rib cartilage, toe pulp, acellular dermal matrix, calcium hydroxylapatite, polytetrafluoroethylene implants, etc.) have been attempted to give permanent rigidity to the nipple; however, no single technique has demonstrated definitive superiority.[3]
- Areolar reconstruction is primarily done by skin grafting, tattoo, or both.
- The first described technique in this chapter is a skate flap for nipple reconstruction with a full-thickness skin graft for areolar reconstruction. This procedure is typically done in the operating room under sedation or general anesthesia.
- The second described technique is a C-V flap for nipple reconstruction, which can be used in combination with a tattoo for areolar reconstruction. This procedure can be done in the office under local anesthesia.

Preoperative Planning

- In unilateral NAR, the position, size, and shape of the opposite nipple are taken into consideration to design the reconstruction in addition to anatomic landmarks. In bilateral NAR, anatomic landmarks and standard measurements are used to position and design the NAC.
- Anatomically, the NAC is located at the anterior-most projecting part of the breast mound at the level of the inframammary fold, centered on the reconstructed breast mound.
- The nipple has an average projection of 5 mm and the areola has an average diameter of 35 to 45 mm.

POSITIONING

- In the operating room, patients are positioned supine with arms at 90 degrees secured to arm boards. Both breasts are prepped into the field to allow for evaluation of symmetry. Patients are secured to the operating table to allow upright evaluation intraoperatively.
- In the clinic, patients are positioned supine with arms at sides.

Skate Flap (Nipple) and Full-Thickness Skin Graft (Areola)

- The patient is placed in supine position with arms abducted at 90 degrees. Arms are secured on arm boards.
- The NAC position is selected at the anterior-most projecting part of the reconstructed breast with the patient in an upright position. In unilateral nipple reconstruction, the NAC is placed symmetrically to the opposite side (**FIG 1**).
- A donor site is chosen for the full-thickness skin graft, which will be used to reconstruct the areola. Commonly used sites include the lateral edge of the mastectomy scar, the lower abdomen, and the groin crease. Additionally, the areolar graft can be taken adjacent to any of the patient's existing scars.
- A 38- or 42-mm nipple sizer is used to mark the areolar skin graft. An ellipse is drawn tangent to the areolar graft to allow linear closure of the donor site.
- The areolar skin graft is scored with a knife prior to harvest. The ellipse is then excised as a full-thickness skin graft (**FIG 2**).
- The areolar graft is aggressively defatted with a small sharp scissor, leaving only full-thickness skin behind (**FIG 3**).
- The skate flap is designed at the previously marked site (**FIG 4**).
  - A 1- to 1.5-cm circle is drawn at the planned location of the nipple.

FIG 1 ● Nipple position is selected symmetrically to the native nipple.

FIG 2 ● Areolar skin graft is marked with a 38-mm nipple sizer. An ellipse is drawn tangentially to facilitate linear closure.

  - A 38- or 42-mm nipple sizer is used to mark the areola centered around the nipple.
  - A horizontal line is drawn across the circle at the superior edge of the marked nipple.
  - The upper portion of the circle is crosshatched to mark the area that will be de-epithelialized.
  - The lower portion of the circle will be raised as the "skate flap" to create the new nipple.
- The epidermis is scored along all incisions.
- The crosshatched semicircle is de-epithelialized (**FIG 5**).
- The flap is then raised from the edges at the level of the mid-dermis. The deepest layer of dermis is left down in order to provide a vascularized bed for the areolar skin graft (**FIG 6**).
- The flap remains attached to the deep dermis at the marked nipple. The flap is raised in a slightly deeper plane at the center in order to include some fat with the flap to provide bulk (**FIG 7**).
- The corners of the flap are centralized and sutured to the underlying dermis using 5-0 Vicryl Rapide (**FIG 8**).
- The edges of the flap are sutured together using interrupted 5-0 Rapide (**FIG 9**).
- The cap is sutured down to close off the nipple (**FIG 10**).
- The full-thickness skin areolar skin graft is sutured to the bed using 4-0 chromic half-buried horizontal mattress sutures. The buried portion of suture is placed along the native breast skin to avoid scarring on the breast (**FIG 11**).
- A 1-cm hole is cut in the center of the areolar graft to expose the nipple (**FIG 12**).

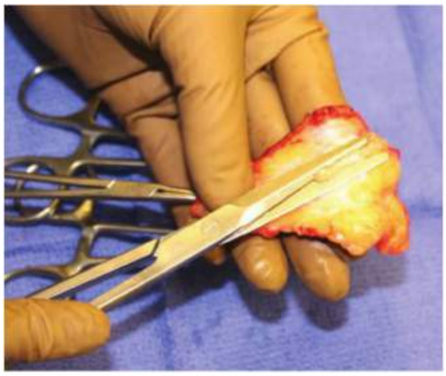

FIG 3 ● Areolar skin graft is aggressively defatted.

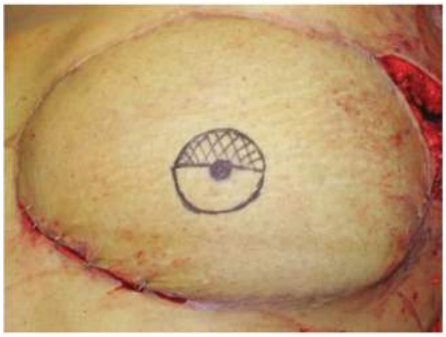

FIG 4 ● Skate flap design.

FIG 5 ● Crosshatched area is de-epithelialized.

FIG 6 ● Skate flap is raised in the middermal plane, leaving central pedicle attached.

FIG 7 ● Skate flap is shown raised.

FIG 8 ● Edges of skate flap are brought together centrally to recreate nipple.

- The graft is secured to the nipple using interrupted 5-0 chromic sutures.
- 4-0 chromic tacking sutures and piecrust incisions are placed in the areolar graft (**FIG 13**).
- A protective dressing is applied using Mastisol on the native breast, crisscrossed Steri-Strips, 2 × 2 fluffed gauze, and foam tape (**FIG 14A–D**). The goal of the dressing is to protect the NAR without putting any pressure on the skate flap.
- The dressing is kept in place for 5 to 7 days after surgery, at which time it is removed in clinic.

C-V Flap

- This procedure can be performed under local anesthesia with the patient awake.
- With the patient in a seated upright position, the NAC position is marked at the anterior-most projecting part of the breast (**FIG 15**).

FIG 9 ● Edges are sutured together in midline.

FIG 10 ● Open end of nipple is sutured down as a cap.

FIG 11 ● Areolar skin graft is sutured to skin edges.

FIG 12 ● Central hole is cut in areolar skin graft to allow nipple to protrude.

FIG 13 ● Tacking sutures and piecrust incisions are placed in areolar skin graft.

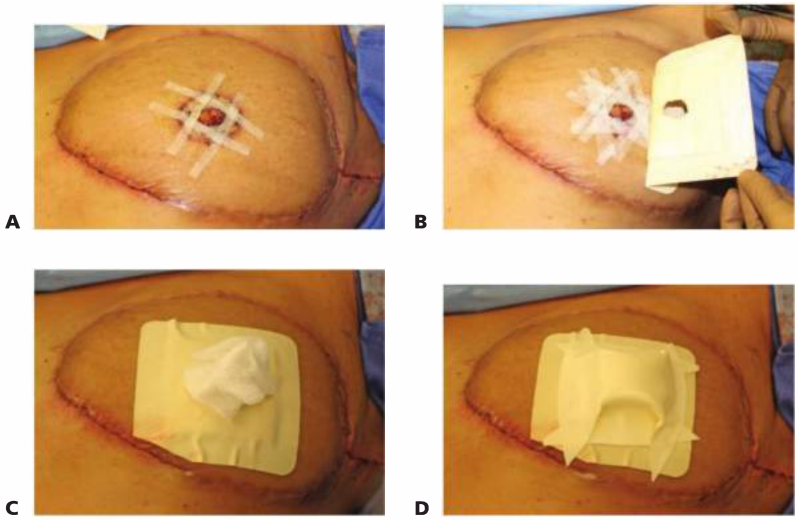

FIG 14 ● Bolster dressing. **A.** Mastisol is applied to surrounding breast skin, followed by tightly adherent Steri-Strips placed in crosswise fashion to apply pressure to graft. **B.** Foam tape dressing with a central hole for nipple is placed over crosswise Steri-Strips. **C.** 2 × 2 fluffed gauze is placed over the nipple. **D.** Additional foam tape is tented over the fluffed gauze without putting any pressure on nipple reconstruction.

- C-V flap is drawn as shown. The length of the flap is approximately 5 cm (*A* to *F*), and the width is approximately 1.5 cm. The width of the flap (*BD* to *CE*) determines the projection of the nipple (**FIG 16**).
- The subcutaneous tissue is infiltrated with 1% lidocaine with 1:100,000 epinephrine (**FIG 17**).
- Incisions are made along all edges *except* points *B* to *D* at the base of the nipple. This area is left attached and serves as the blood supply to the flap (**FIG 18**).
- The flap is raised from both sides in the midsubcutaneous fat plane (**FIG 19A,B**).
- The incision is closed from point *B* to *C* and *D* to *E* (**FIG 20**).
- One flap edge (point *A*) is brought to the center and sutured in place with 5-0 Vicryl Rapide (**FIG 21**).
- The opposite flap edge (point *F*) is brought to the center and sutured to the first flap edge (**FIG 22**).
- The cap is sutured down to close the top of the nipple and the remainder of the incision is closed with 4-0 Vicryl deep and 4-0 Monocryl running subcuticular (**FIG 23**).
- Nipple projection is shown with both reconstructions complete (**FIG 24**).

FIG 15 ● Bilateral nipple position marked at the anterior-most projecting part of breast mounds adjacent to mastectomy scars.

FIG 16 ● Markings for C-V flap. Length from *A* to *F* is approximately 5 cm, width from *BD* to *CE* is approximately 1.5 cm.

FIG 17 ● 1% lidocaine with 1:100,000 epinephrine is injected subcutaneously.

FIG 18 ● C-V flap is incised through to midfat level along all incisions except *B* to *D*.

A

B

FIG 19 • **A.** C-V flap is raised in the midfat plane. **B.** C-V flap is shown raised.

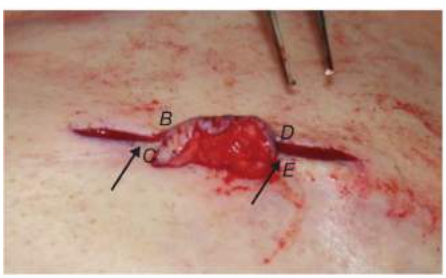

FIG 20 • Incision is closed (point *B* to *C* and *D* to *E*).

FIG 21 • One flap edge (point *A*) is centralized and sutured to the deep surface.

FIG 22 • Opposite flap edge (point *F*) is centralized and sutured to point *A*.

FIG 23 • Cap is sutured down to close off nipple, and all incisions are closed with interrupted sutures.

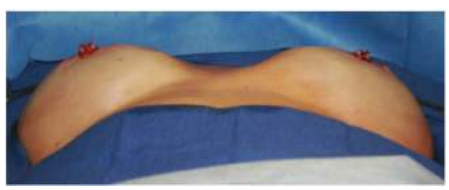

FIG 24 • Final result showing projection of bilateral C-V flaps.

PEARLS AND PITFALLS

Indications	■ Nipple–areolar reconstruction should be deferred until the final breast mound shape is obtained.
Placement of incision	■ Flaps should be based adjacent to the mastectomy scar whenever possible to avoid additional scarring.
Projection	■ Nipple projection will decrease by 50% in the first year; therefore, projection should be overestimated at the time of reconstruction. ■ Projection can be increased later with dermal fillers such as collagen or hyaluronic acid.
Areola	■ Areolar tattoo is often used as an addition to skin grafting or as a primary modality for areolar reconstruction. ■ Tattoos often need more than one application spaced over several months in order to achieve the final desired color.

POSTOPERATIVE CARE

- After nipple reconstruction, a protective dressing should be applied and maintained in place for 1 week postoperatively. Brassieres should be avoided for the first 6 weeks to prevent pressure on the nipple flap.
- If no skin graft is used, patients may shower after the dressing is removed 1 week postoperatively.
- If a skin graft is used for areolar reconstruction, the bolster is removed 1 week postoperatively in the clinic, and daily Xeroform dressing changes are performed for 1 week. After 2 weeks, patients may shower and apply moisturizer to the graft.

OUTCOMES

- All modes of nipple reconstruction result in some degree of loss of projection over time, up to 50%.[5] Most loss of projection occurs within the first 3 months, and final nipple shape and size is typically achieved by 1 year.[6] C-V flaps tend to lose more projection than skate flaps over time.
- Dermal fillers such as collagen and hyaluronic acid can be injected into the nipple to increase projection.

COMPLICATIONS

- Loss of nipple projection
- Partial or complete flap necrosis
- Partial or complete loss of areolar skin graft
- Infection

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Chapter 21

Reduction Mammoplasty

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DEFINITION

- Reduction mammoplasty is defined by the removal of expendable breast skin and parenchyma, and repositioning the nipple–areolar complex (NAC) in patients who suffer from breast hypertrophy. The goal is to achieve an overall reduction in breast volume in an aesthetic manner without sacrificing breast sensation or function. Other terms for reduction mammoplasty include breast reduction and reduction mammoplasty.

DIFFERENTIAL DIAGNOSIS

- The differential diagnoses of breast hypertrophy include breast carcinoma, phyllodes tumors, benign breast masses (including fibroadenomas, neurofibromas, lymphangiomas, and breast cysts), hematomas, ectopic tumors producing sex steroids, pregnancy, lactation, and virginal hypertrophy. It is of paramount importance to distinguish benign breast hypertrophy from breast carcinoma, which is much less common, tends to be unilateral, is usually eccentric with respect to the NAC and typically presents as a defined lesion firm to touch.

PATIENT HISTORY AND PHYSICAL FINDINGS

- A thorough history should be performed prior to treatment, identifying physical, functional, and psychological symptoms. It is also important to obtain a detailed past medical and surgical history, reproductive history, family history, social history, and current medications and allergies from the patient.[1]
- Physical and functional problems associated with macromastia include pain (neck, back, and shoulder), mastodynia, shoulder grooving, intertriginous rashes and/or infections, physical activity restriction, and difficulty fitting into clothing. Patients often suffer from psychological symptoms related to breast size, including feelings of physical unattractiveness and embarrassment in both private and social settings.[2,3]
- Past medical history should screen for any diseases that would impact the patient's ability to recover from the reduction mammoplasty, such as heart or lung disease, or impact the viability of the NAC postoperatively, such as collagen vascular diseases.[1] A history of previous benign or malignant breast masses should also be elicited. Obtaining a thorough past surgical history should identify any previous breast or chest wall incisions that may influence planning of either the skin pattern incision or the pedicle to the NAC.[1]
- Because childbearing can affect the size and shape of a woman's breasts, the reproductive history of the patient is important to understand and anticipate the effect reduction mammoplasty will have on the future breast.[1] Inquiring about plans for future pregnancies and breastfeeding is important to inform patients of the risks of the procedure. Finally, in patients who have recently given birth and who may be currently breastfeeding, it is important to discuss timing of surgery because it is ideal to delay surgery for at least 1 year after completing either.
- Obtaining a thorough family history is important to identify patients at increased risk for breast carcinoma. Younger patients with a family history of breast cancer, in addition to any patient older than the age of 40 years, should undergo a preoperative mammogram in order to identify any suspicious lesions prior to surgery.[2] Some surgeons routinely obtain a bilateral mammogram in all patients considering reduction mammoplasty.
- Smokers are at increased risk of compromise of the blood supply to the NAC and for poor wound healing.[1] Therefore, eliciting a smoking history may alter the timing of surgery. Current recommendations indicate that a period of at least 4 weeks of smoking cessation prior to surgery is ideal for best outcomes.
- Macromastia can present at different periods in a woman's life and therefore surgical timing is important. When present during adolescence, the timing of reduction mammoplasty needs to be balanced with the effects of macromastia on self-esteem and physical activity restriction with ongoing pubertal breast development and potential future childbearing.[4] In older patients who have encountered recent significant changes in overall weight, it is prudent to delay surgery for at least 1 year until their weight has stabilized, as this can translate into disproportionate changes in breast volume.
- A bilateral breast examination should be performed in every patient, including examination of the axillary and supraclavicular lymph node basins. The patient's height, weight, body mass index, and body surface area, as well as appropriate breast measurements should be taken, including breast width, sternal notch/clavicle to nipple distance, midline inframammary fold to nipple distance, and the dimensions of each areola.[2] In addition, breast characteristics should be noted including symmetry, upper pole contour and fullness, presence of breast ptosis, skin quality including presence of striae, and breast tissue density (**FIG 1**).[1]

FIG 1 • A typical patient suffering from macromastia.

- A discussion of patient's desires and expectations following surgery is essential to avoid dissatisfaction and misunderstandings. In addition, the patient should be informed about possible complications associated with reduction mammoplasty, including changes in nipple sensation, asymmetry, unappealing breast size or shape, scarring, fat necrosis, NAC loss, inability to breastfeed, hematoma, and infection.

IMAGING AND OTHER DIAGNOSTIC STUDIES

- The American Cancer Society recommends screening mammograms starting at age 40 years in patients with average risk of developing breast cancer.[5] These patients, and younger patients at increased risk of breast cancer, should therefore undergo a preoperative mammogram prior to reduction mammoplasty. Many plastic surgeons routinely perform a preoperative screening mammogram in all patients undergoing this procedure.

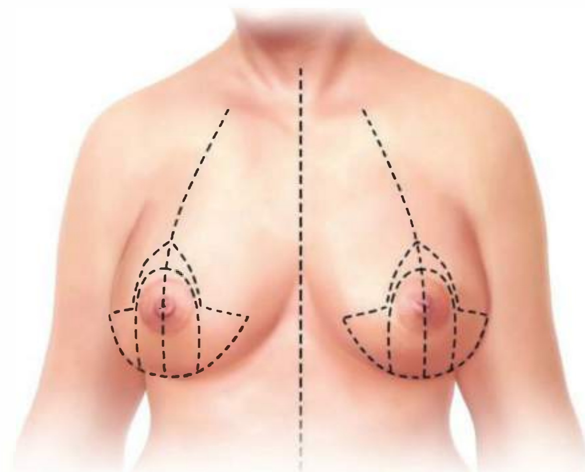
SURGICAL MANAGEMENT

- There are multiple surgical approaches to reduction mammoplasty; however, all must deal with the following four considerations: (1) reduction in the parenchymal volume of the breast, (2) creation of the NAC pedicle, (3) reduction of expendable skin followed by redraping, and (4) repositioning of the NAC.[3] This chapter will describe the most commonly practiced Wise pattern (inverted T) technique, which reduces the medial, lateral, and superior breast parenchymal volume and maintains blood supply to the NAC by an inferior pedicle. Other techniques include the superior medial breast reduction,[3] short scar periareolar inferior pedicle reduction (SPAIR),[1] and the liposuction breast reduction,[6] among others.
- Advantages to the Wise pattern technique include its reproducibility, popularity, and applicability to a wide range of breast shapes and sizes, whereas disadvantages include longer scars and a tendency toward developing breast ptosis over the long term.

Preoperative Planning

- Preoperative markings with a permanent marker should be performed in the upright position in the preoperative holding area on the day of surgery.
- The chest midline, breast meridian, and inframammary creases are initially marked. The inframammary crease should then be transposed onto the anterior breast to mark the desired new nipple position.[7] The distance from the sternal notch/clavicle to this point is measured and transposed symmetrically to the other breast. Eight-centimeter obliquely vertical limbs are then drawn medially and laterally from this point. They should be separated by a distance of 8 to 10 cm between their inferiormost points, depending on the desired breast width reduction. The bases of the vertical limbs are subsequently connected medially and laterally with a curvilinear line that joins the inframammary crease. Minor adjustments are made to account for breast asymmetry and minimize the appearance of standing cones (**FIG 2**).

A



B

FIG 2 ● **A,B.** Preoperative markings are made with the patient in the standing position prior to surgery.

- Although there is limited data to support the use of preoperative antibiotics for reduction mammoplasty, the general consensus among plastic surgeons is that prophylactic antibiotics covering skin flora should be administered at least 30 minutes prior to skin incision.[8] Data can be also be extrapolated from several general surgery mastectomy studies demonstrating that antibiotic prophylaxis reduces the incidence of postoperative wound infections.[9]

Positioning

- Reduction mammoplasty is performed under general endotracheal anesthesia.
- Because the procedure requires intraoperative assessment of breast symmetry, shape, and contour in the semi-upright position, the patient should be placed in the supine position with the bed break at the hips. The patient's arms should be securely padded on adjustable arm boards, ready for repositioning.
- Sequential compression devices are applied to the lower extremities and a Foley catheter is inserted.

PREINCISION INFILTRATION AND MARKINGS

- The breast bases and planned incisions may initially be infiltrated with 1% Xylocaine with 1:100,000 epinephrine. Then, an 8- to 10-cm–wide inferiorly based dermal pedicle is marked on the skin of each breast, extending in a circular fashion above the NAC all the way down to the chest wall. Using a cookie cutter centered on the nipple, a 40- to 44-mm circular marking is made with the breast skin under minimal to no tension to reduce the diameter of the NAC (**FIG 3**). Tourniquets may then be placed around each breast base to assist with hemostasis (**FIG 4**). After the skin incisions and de-epithelialization of the dermal pedicles are completed, the tourniquets are removed.

Initial Incisions

- The markings of the NAC and dermal pedicle are initially scored with the scalpel. The skin of the inferior pedicle is then de-epithelialized down to the inframammary line, leaving the NAC intact. The dermis between the vertical limbs is preserved to maintain the dermal and subdermal plexus blood supply to the NAC. Incisions are made around the neo-NAC and along the vertical limbs down to the subcutaneous tissue isolating the inferior pedicle from the surrounding breast parenchyma (**FIG 5**).

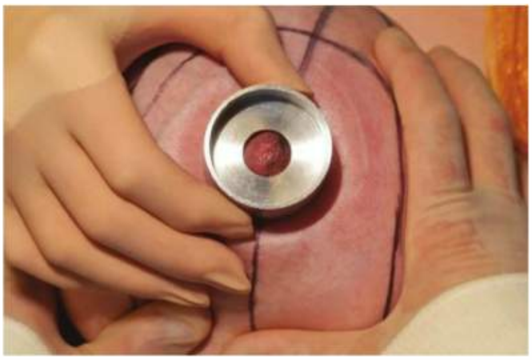


FIG 3 ● A 40- to 44-mm cookie cutter is centered on the nipple with the breast skin under minimal to no tension to mark the neo-NAC.

FIG 4 ● Tourniquets are placed around each breast base to minimize blood loss and are removed after skin incisions and de-epithelialization of the dermal pedicles.

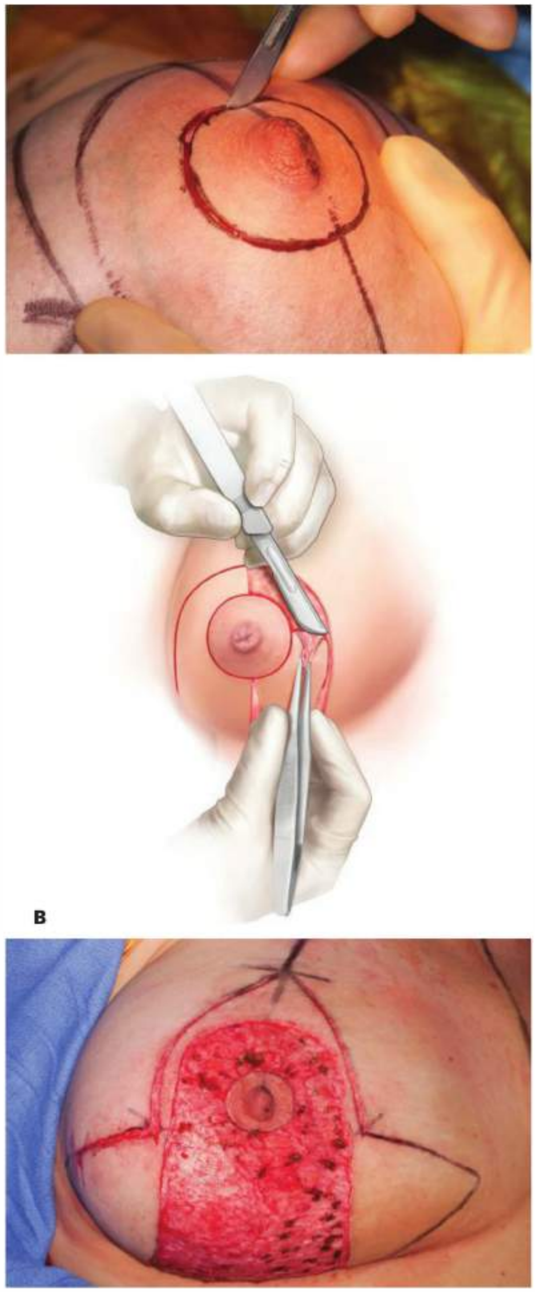
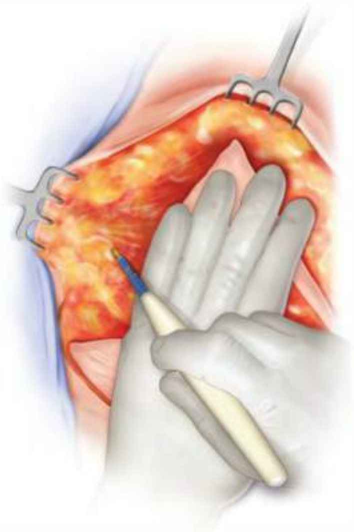


FIG 5 ● **A–C.** The skin markings are scored with the scalpel after which the inferior pedicle is de-epithelialized down to the inframammary line, leaving the neo-NAC intact.



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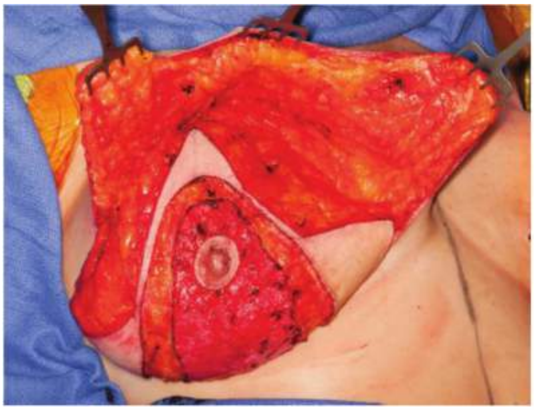


B

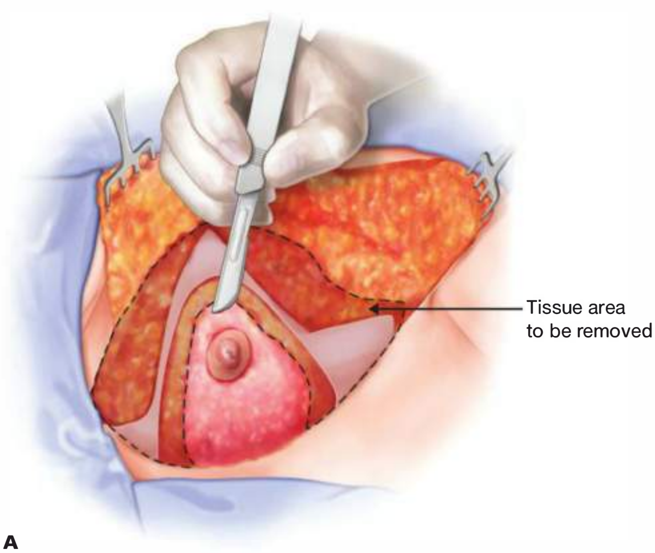
FIG 6 ● **A,B.** Skin flaps are raised medially, laterally, and superiorly around the pedicle.

Creation of Skin Flaps

- Medially, laterally, and superiorly based skin flaps are then raised to separate the skin from the breast parenchyma. The flaps are designed to gradually increase in thickness as one approaches the chest wall to ensure a smooth breast contour when the skin is eventually redraped over the breast. They should measure 1 to 2 cm in thickness (**FIG 6**).[1]

Creation of the Nipple–Areolar Complex Pedicle and Parenchymal Excision

- The inferior pedicle is then created without undermining the blood supply to the NAC. The excess breast parenchyma is systematically excised medially, laterally, and superiorly. Superiorly, breast tissue is removed down to the chest wall extending up to the level of the clavicle, whereas medially, it is removed down to the pectoral fascia but stopping short of midline. Finally, a layer of breast tissue is left on the chest wall laterally in an attempt to preserve the innervation to the NAC (**FIG 7**). Wound irrigation and meticulous hemostasis is achieved prior to proceeding.
- All breast parenchyma removed from the breast is initially weighed and subsequently sent to pathology for evaluation (**FIG 8**).



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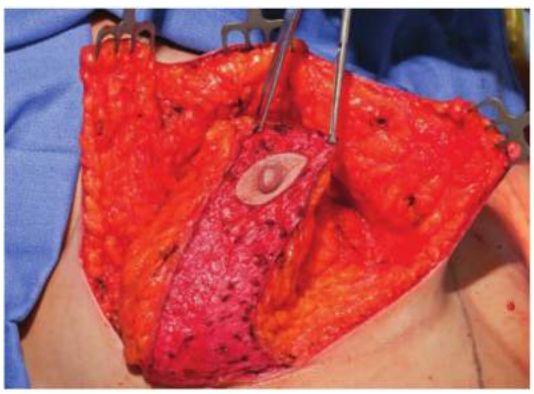


B

FIG 7 ● **A,B.** The inferior pedicle is created without compromising the blood supply to the NAC by excising breast parenchyma in the medial, lateral, and superior quadrants.

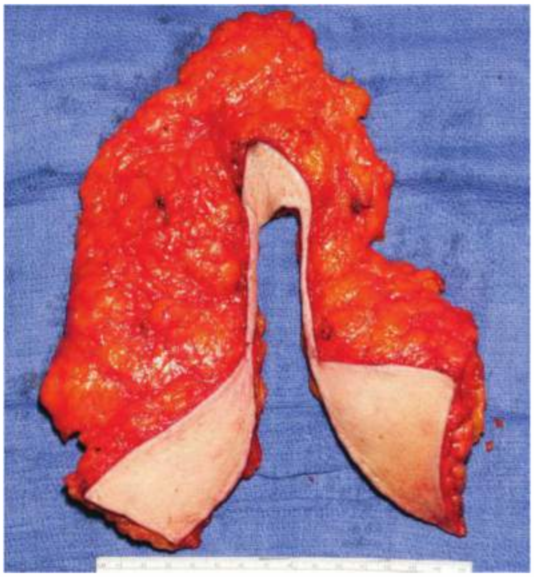


FIG 8 ● The excised specimen includes skin and parenchyma and should be weighed prior to having it sent to pathology.

- The same procedure is repeated on the opposite breast with the goal of achieving breast symmetry in shape and size.

Skin Reduction and Redraping

- The skin flaps are redraped over the breast and temporarily approximated using staples (**FIG 9**). The patient is then placed in the sitting position and minor adjustments can be made to skin approximation to achieve symmetry and improve aesthetics. The final markings for the medial and lateral inframammary margins can then be made; after which, the skin is excised as needed.
- Once symmetry is achieved, and with the patient still in a sitting position, the final NAC position is determined with a 38- to 42-mm cookie cutter and marked on the breast (**FIG 10**). The skin is then excised and the NAC is exteriorized (**FIG 11**).

Repositioning of the Nipple–Areolar Complex

- Once the NAC is exteriorized, the position and orientation of the inferior pedicle is verified to ensure that it is not distorted. A Gillies suture using absorbable monofilament may be placed at the inverted T junction, which is the point of maximal tension. The NAC is then secured in its correct orientation with buried dermal absorbable monofilament sutures in four quadrants. All incisions are then closed in layers with deep dermal interrupted absorbable monofilament sutures, followed by an absorbable running subcuticular monofilament suture (**FIG 12**). A dry dressing is applied to all wounds.
- Bulb suction drains may be left prior to closure.

FIG 9 ● The breast skin flaps are redraped over the pedicle and secured with staples.

FIG 10 ● The final NAC position is chosen and marked with a 38- to 42-mm cookie cutter.

FIG 11 ● The NAC is exteriorized by incising the circular marking and removing the circular paddle of skin and soft tissue. Care is taken not to injure the underlying NAC.

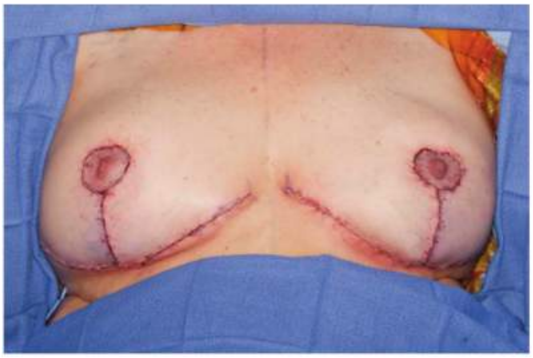


FIG 12 ● The final result after all skin incisions are closed.

PEARLS AND PITFALLS

Preincision infiltration	■ A spinal needle is helpful for thorough infiltration of the breast bases with anesthetic and epinephrine solution.
Initial incisions	■ Only the dermis of the vertical limbs should initially be incised to allow for better traction during de-epithelialization. ■ De-epithelialization can be more efficiently performed with Kaye scissors as compared to a scalpel blade.
Creation of skin flaps	■ Appropriate flap thickness is critical for good blood supply to the skin and to maintain smooth breast contour. The skin flaps should gradually increase in thickness as one approaches the chest wall.
Creation of the NAC pedicle and parenchymal excision	■ Avoid dissection below the inframammary fold medial and lateral to the NAC pedicle to prevent inferior migration of tissue and breast ptosis postoperatively.
Skin reduction and redraping	■ Staples can be an effective alternative to skin approximation clamps when redraping the skin flaps over the breast. ■ Crosshatched orientation marks can be placed after the skin is redraped to ensure skin segments are accurately approximated when staples are removed.
Repositioning of the NAC	■ Verify that the pedicle is not distorted prior to skin closure to avoid ischemia to the NAC due to unusual positioning.

POSTOPERATIVE CARE

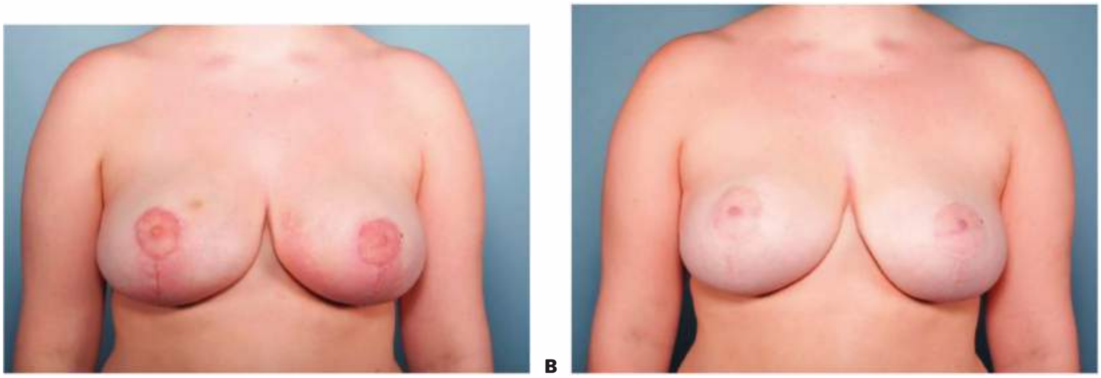
- After reduction mammoplasty, the patient should be placed in either a breast binder/wrap or supportive brassiere that should be worn regularly for 2 to 4 weeks after surgery. This maintains pressure on the breasts, minimizing hematoma and seroma formation, and also relieves tension on the skin incisions, preventing wound dehiscence and unfavorable scarring (**FIG 13**).

OUTCOMES

- Outcomes following reduction mammoplasty are excellent with high overall patient satisfaction rates.[8] The complications most frequently reported are (1) symptomatic scarring (6%), (2) wound dehiscence (5%), and (3) infection (1.2%).[10] Patients also report high reduction or resolution of common preoperative symptoms including neck pain (91%), back pain (96%), shoulder grooving (100%), as well as a subjective improvement in perception of self-image (92%).[10]

COMPLICATIONS

- Undesirable scarring
- Wound dehiscence
- Infection (cellulitis or abscess)
- Decreased NAC sensation
- Breast asymmetry
- Unappealing size and/or shape
- Fat necrosis
- NAC loss
- Difficulty or impossibility to breastfeed
- Hematoma



A B

FIG 13 ● Postoperative result at **(A)** 1 month and **(B)** 1 year after surgery, respectively.

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Chapter 22

Wide Excision of Primary Cutaneous Melanoma

Russell S. Berman   Jeffrey E. Gershenwald

DEFINITION

- Wide excision (WE) of a primary cutaneous melanoma is the term used to describe the definitive surgical management of the primary melanoma site. It is defined as the surgical removal of the primary tumor and/or the biopsy site that includes a defined radial margin of normal-appearing skin and underlying subcutaneous tissue. The appropriate margin of resection is determined by the Breslow thickness as discussed in this chapter.
- Depending on primary tumor characteristics and clinical nodal status, WE may be performed concomitantly with either intraoperative lymphatic mapping and sentinel lymph node biopsy (SNB) (for patients with clinically negative nodes and a primary tumor suggesting sufficient risk of occult regional node metastasis) or regional lymphadenectomy (for patients with clinically involved regional lymph nodes without distant metastasis)[1] (refer to Part 5, Chapters 31, 32, and 34).
- The main function of the WE is to remove the primary tumor along with any nearby microscopic melanoma cells. In addition to following oncologic principles, the surgeon should also aim to simultaneously minimize dysfunction or disfigurement. This procedure is also known as a wide local excision.

DIFFERENTIAL DIAGNOSIS

- A WE should not be performed unless a definitive pathologic diagnosis of melanoma has been obtained.

PATIENT HISTORY AND PHYSICAL FINDINGS

- A patient with newly diagnosed melanoma should undergo a comprehensive history that includes assessment of age, gender, personal or family history of melanoma or other malignancy as well as history of any nevus syndromes. The patient should also be assessed for any other significant medical and surgical history or issues, medications used, and allergies.
- History of sun exposure and use of tanning beds, if any, should also be obtained. A thorough history may also provide clinical clues as to the extent of disease present at diagnosis. Symptoms such as worsening headaches or abdominal cramps may suggest distant metastatic disease and warrant additional workup.
- A physical examination is extremely important in the newly diagnosed patient with melanoma. If a biopsy has been performed, the anatomic site and orientation of the biopsy should be documented along with the presence or absence of any residual pigmented lesion.
- Skin and soft tissue between the primary site and draining regional nodal basin(s) should be examined for any signs of satellite metastases or in-transit disease. Melanoma most commonly metastasizes via regional lymphatics to regional lymph nodes. Nonetheless, because melanoma may metastasize to both regional and distant nodes, all palpable lymph nodes should be carefully examined in the new melanoma patient, including cervical, supraclavicular, axillary, epitrochlear, inguinal, and popliteal nodes. For patients with a melanoma in a region of ambiguous drainage (typically considered to be the head and neck and trunk regions), multiple nodal basin drainage is possible. Given the importance of the lymphatics in melanoma, meticulous attention to the lymphatic exam is essential. Evidence of lymphedema in the melanoma-bearing extremity may also suggest regional nodal disease.
- It is imperative to confirm the specific site(s) of any primary melanoma to be treated. Although this may seem obvious, many patients have had concomitant and/or prior skin biopsies, and further clarification with source information, including pre-biopsy photographs and/or direct consultation with the referring clinician, may be necessary. Because biopsy sites may heal prior to treatment, photographic images are often obtained to document location(s) of all biopsy sites for which treatment is/may be planned.
- The clinician should document the presence of any lymphadenopathy along with details such as firm, fixed, or matted nodes. Clinically suspicious lymph nodes should be evaluated by fine needle aspiration biopsy (often performed with ultrasound guidance) and cytologic analysis. Biopsy-proven regional metastasis renders a sentinel node biopsy (SNB) procedure unnecessary to diagnose stage III disease in the involved basin.
- Importantly, palpable "reactive" lymphadenopathy may sometimes develop following biopsy of the primary melanoma, thus highlighting the importance of pathologic confirmation of metastatic melanoma before definitive treatment of the basin—for example, lymphadenectomy—is considered.
- Newly diagnosed melanoma patients should also undergo a head-to-toe skin examination to identify the presence of other suspicious skin lesions. Although it is beyond the scope of this section to review biopsy techniques in detail, an appropriate biopsy should include the epidermis, dermis, and at least a cuff of subdermal fat. This allows the dermatopathologist to accurately report the essential components of primary melanoma tumor histopathologic microstaging, including, at a minimum, Breslow thickness (in millimeters), presence or absence of ulceration, mitotic rate, Clark level, status of peripheral and deep margins, and presence or absence of satellite lesions.
- When signs and/or symptoms are suggestive of additional disease, a well-performed physical examination may raise suspicion for distant metastasis. Particular attention should be paid to the neurologic examination, assessing for any localizing symptoms or mental status changes. The finding of hepatomegaly, abdominal mass, or a rectal exam significant for mass or occult blood should prompt further workup. Finally, distant dermal or subcutaneous nodules or distant adenopathy also warrant investigation.

IMAGING AND OTHER DIAGNOSTIC STUDIES

- Treatment planning for patients with primary melanoma is based largely on primary tumor histologic microstaging.
- In the absence of symptoms, the use of imaging studies as part of a staging workup has not been shown to significantly impact survival or the treatment algorithm of the newly diagnosed, clinically node-negative melanoma patient. For asymptomatic preoperative stages I and II melanoma patients, preoperative cross-sectional imaging has a very low yield.[2] In one study, only 1 of 344 (0.3%) studies correlated with confirmed melanoma metastasis; no significant impact on proposed surgical management or staging was noted.[3]
- Even among asymptomatic microscopic stage III patients (i.e., sentinel-node positive), cross-sectional imaging studies infrequently identify distant metastatic melanoma.[4] Although positron emission tomography (PET)/computed tomography (CT) generally includes images of the extremities, regions not typically imaged during standard CT or magnetic resonance imaging (MRI), a benefit for routine use of PET/CT has yet to be demonstrated in this patient population.
- In the otherwise asymptomatic patient with clinically palpable adenopathy, the detection rate of asymptomatic distant metastasis is higher and baseline imaging for staging (CT, PET/CT, MRI) is recommended.[5]
- There is no specific tumor marker or biochemical parameter that has been validated and employed for melanoma screening or recurrence. Elevated serum lactate dehydrogenase (LDH) level is an adverse prognostic factor in patients with distant metastatic melanoma and is included in the American Joint Committee on Cancer (AJCC) staging system for stage IV disease. Patients with elevated serum LDH levels LDH levels are classified as M1c regardless of distant anatomic site(s) involved.[6]

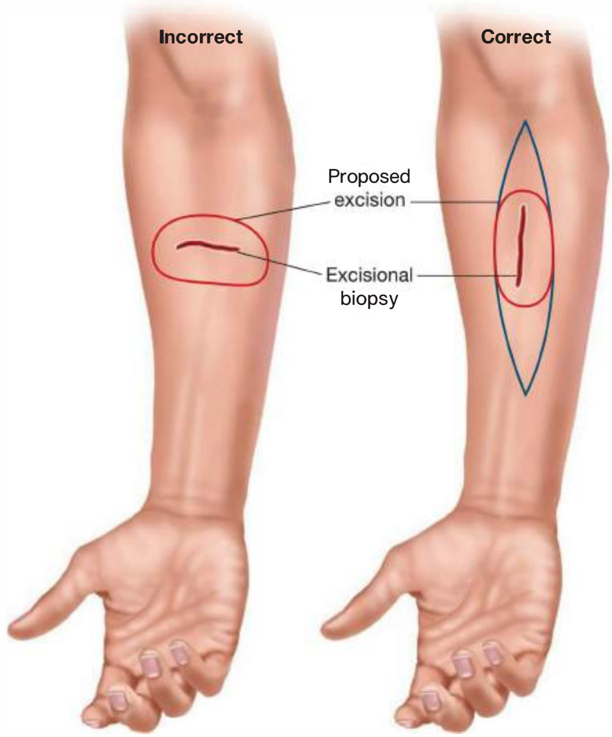


FIG 1 ● Importance of orientation of excisional biopsy. An excisional biopsy of the extremity is typically oriented parallel to the long axis of the extremity (right panel). In this example, incorrect orientation (left panel), would likely result in the need for skin graft closure, while primary closure could be likely be achieved if the biopsy had been correctly orientated (right panel). Note the in the right panel example, the overall excision has been extended to accommodate primary closure. It is always important to consider next steps when performing a biopsy.

SURGICAL MANAGEMENT

Preoperative Planning

Biopsy

- Most cutaneous lesions suspicious for melanoma have been biopsied by a dermatologist or other health care provider prior to treatment referral.
- If the biopsy of a lesion suspicious for melanoma has not yet been performed, the surgeon should plan and perform a biopsy: to establish a definitive histologic diagnosis, to obtain appropriate microstaging of the lesion (if melanoma is confirmed), and to maximize the potential for primary closure of the subsequent WE.
- An excisional biopsy should include a narrow margin of normal-appearing skin around the suspicious lesion along with a cuff of underlying subcutaneous fat to provide the dermatopathologist with sufficient material to fully diagnose and, if melanoma, to histologically microstage the primary tumor.
- An excisional biopsy of the extremities is typically oriented parallel to the long axis of the extremity (**FIG 1**). On the trunk and head and neck, the orientation of the biopsy should ideally follow the lymphatic drainage of the involved skin while also being mindful of the lines of tension for optimal closure.
- Incisional biopsies are sometimes necessary for large lesions, especially in cosmetically sensitive areas. Such a biopsy approach does not always reflect the full primary tumor microstaging of the lesion, including margin assessment, and such limitations need to be considered during definitive treatment.
- Shave biopsies are not generally recommended when a cutaneous lesion is suspicious for melanoma, because the full extent of the lesion (especially Breslow thickness) may not be included in the biopsy and the approach may limit accurate microstaging of the primary tumor.
- Confirmation of the melanoma biopsy site(s) must be performed prior to any planned definitive treatment.

Histopathologic microstaging of primary melanoma

- In order to determine the appropriate extent of surgery for a patient with a primary melanoma—including WE margin and whether to offer/perform intraoperative lymphatic mapping and SNB—assessment of several of the primary tumor's histopathologic features is essential.

- Breslow thickness (in millimeters), mitotic rate (expressed in mitoses/mm^2), presence or absence of primary tumor ulceration, and the biopsy margin status (peripheral and deep margins) are all essential to define T stage and to guide appropriate surgical therapy; they should be assessed by a dermatopathologist. Additional primary tumor information that may be useful to the operative surgeon includes the presence or absence of lymphovascular invasion, neurovascular invasion, regression, extent of tumor-infiltrating lymphocytes, histologic subtype, and Clark level.

Margins of excision

- WE includes a radial margin of skin and underlying subcutaneous tissue, with margins appropriate for tumor thickness.
- The radial margin chosen for the WE is based on the primary tumor (Breslow) thickness. At least five prospective randomized trials conducted over the past three decades informed an evidence-based approach. Although detailed discussion is beyond the scope of this section, the recommendations from the National Comprehensive Cancer Network (NCCN) for the radial margin are as follows:[5]
  - Melanoma in situ: 0.5-cm margin (Note: For large diameter melanoma in situ, for example, lentigo maligna type, margins >0.5 cm may sometimes be considered to adequately treat occult early invasive disease).
  - Less than or equal to 1.0 mm: 1.0 cm
  - 1.01 to 2.0 mm: 1.0 to 2.0 cm
  - 2.01 to 4.0 mm: 2.0 cm
  - Greater than 4.0: 2.0 cm

Positioning

General positioning strategies

- Depending on primary tumor characteristics and other considerations, lymphatic mapping and SNB are most often performed in the same operative setting as a WE. For this reason, proper patient positioning should account for both the location of the primary melanoma and the location(s) of draining regional nodal basins. This may become challenging when the primary melanoma drains to multiple nodal basins and/or to interval, ectopic, and/or in-transit sites. Skin graft donor sites or other reconstructive issues must also be considered when positioning the patient.

Proximal extremity

- For proximal upper extremity lesions, a supine position is generally appropriate for WE and SNB. For more posterior lesions near the shoulder, a modified supine position using a shoulder roll or a lateral decubitus position provides easy access for WE and closure. The arm, prepped circumferentially, should be supported to prevent injury to the brachial plexus and/or shoulder.
- For proximal lower extremity lesions, the supine position provides excellent exposure of anterior or lateral sites, allowing both WE and SNB. When the melanoma is on the posterior proximal leg or the buttock, the WE may be performed with the patient in the lateral or prone position. Pressure points need to be padded and axillary and chest rolls need to be appropriately positioned. Some surgeons are comfortable performing both WE and inguinal SNB in the lateral position; a potential advantage is that repositioning is not required. Alternately, SNB can be performed in the supine position, and the patient repositioned for the WE.

Distal extremity

- In general, a supine position is appropriate for most distal extremity lesions. If SNB is also to be performed, access to the axillary, epitrochlear, and inguinal nodal basins is readily achieved. If a patient's melanoma drains to the popliteal nodal basin, then an alternative position other than the supine approach should be used. The prone position is sometimes used so as to allow the sentinel node to be removed through an incision that could be incorporated into a full popliteal node dissection incision if evidence of metastasis were to be identified.
- Heel melanomas not only have the potential to drain to the popliteal basin but may also require specialized reconstructive approaches (e.g., wound vac device, rotational flaps, and/or vascularized free flaps). In this situation, use of a beanbag on the operating room table allows for repositioning as indicated.

Truncal sites

- When an SNB is performed with WE of a truncal melanoma, the possibility of multiple nodal basin drainage patterns must be considered when devising an operating room positioning strategy. A preoperative lymphoscintigraphy will demonstrate afferent lymphatic drainage patterns to major and unusually situated (e.g., ectopic, interval) nodal basins.
- For most anterior truncal melanomas (e.g., chest and abdomen), the supine position allows for access to the primary and draining regional nodal basins. For lateral truncal melanomas, ideal positioning for the WE may include placing the patient in a partial or formal lateral position (with appropriate padding and brachial plexus protection).
- When performing a WE only (e.g., for a thin melanoma without adverse risk features), back melanomas may be performed in the prone (e.g., for medial lesions) or lateral (e.g., for most back lesions) position at the discretion of the surgeon. Appropriate padding and brachial nerve protection must be employed and airway protection is essential. If SNB is being performed in the same operative setting, patient positioning must foster access to draining nodal basins including multiple and/or unusually situated nodal basins. It may be necessary to reposition the patient after the SNB and before the WE (**FIGS 2** and **3**).

Head and neck sites

- Head and neck melanoma patients must also be carefully positioned with consideration of the WE, reconstructive requirements, and in continuity access to draining regional nodal basins if SNB is to be performed. Whether in a supine, prone, or lateral position, the head and neck must be appropriately supported and padded. Additionally, the airway, eyes, and ears must be protected.

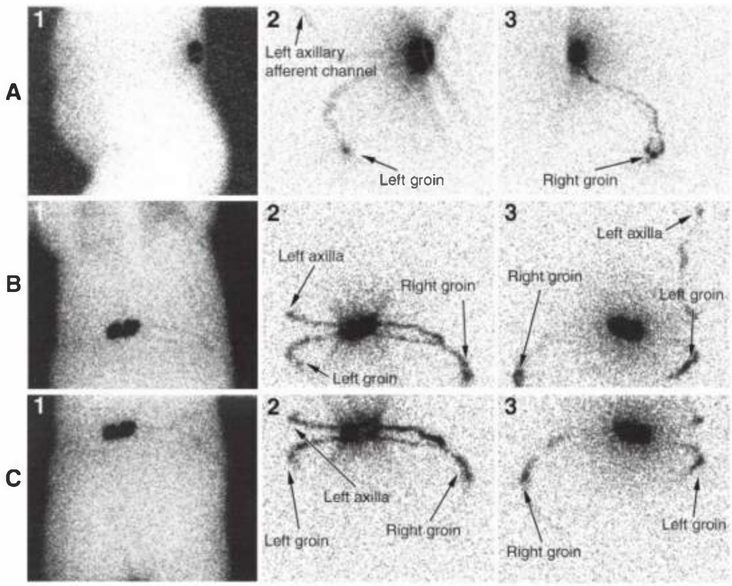


FIG 2 ● Lymphoscintigraphic images of a patient with a primary cutaneous melanoma of the midline mid back demonstrates radiotracer uptake activity in the bilateral groins and the left axilla.

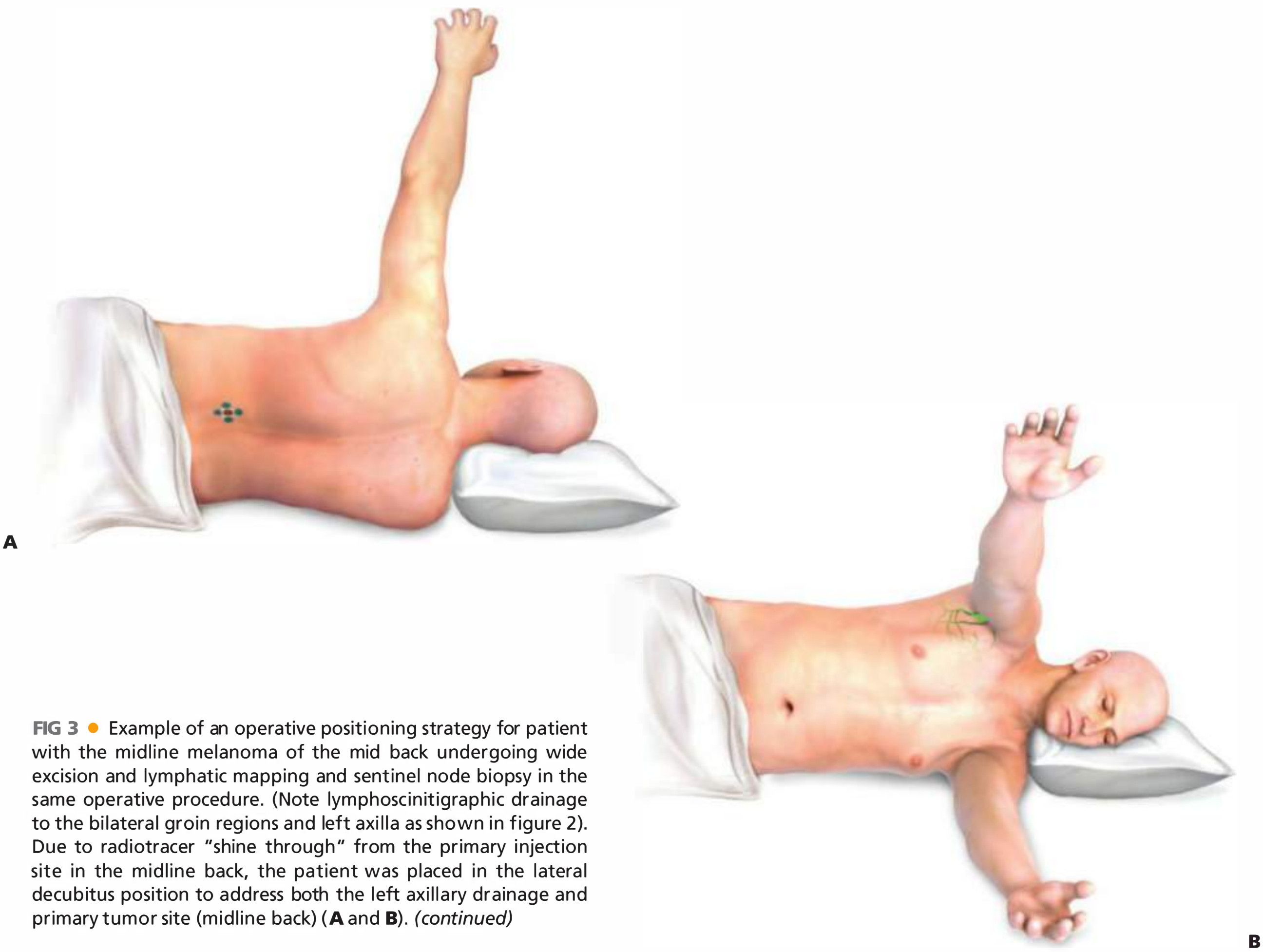


FIG 3 ● Example of an operative positioning strategy for patient with the midline melanoma of the mid back undergoing wide excision and lymphatic mapping and sentinel node biopsy in the same operative procedure. (Note lymphoscinitigraphic drainage to the bilateral groin regions and left axilla as shown in figure 2). Due to radiotracer "shine through" from the primary injection site in the midline back, the patient was placed in the lateral decubitus position to address both the left axillary drainage and primary tumor site (midline back) (**A** and **B**). *(continued)*

C

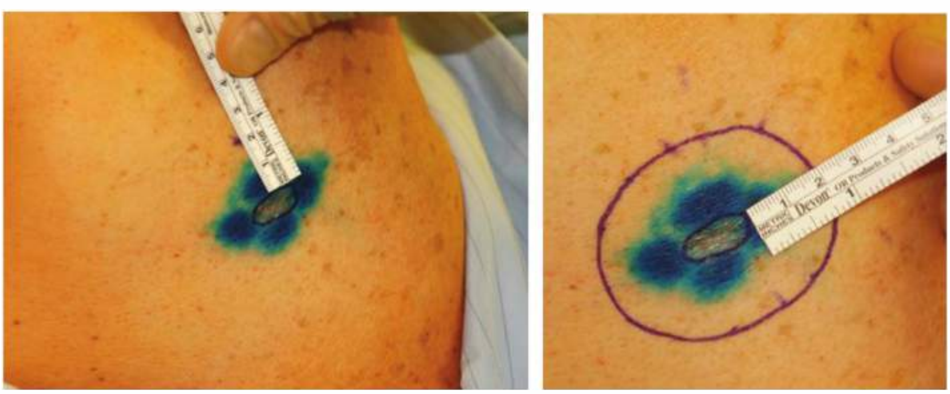
FIG 3 ● *(continued)* The patient was then repositioned to supine to perform bilateral inguinal sentinel node biopsies **(C)**. Note that if radiotracer shine through was not a problem, then the patient could have been initially positioned in the supine position (after injection of both isosulfan blue dye and radiocolloid) to address the bilateral inguinal nodal basins as well as left axillary nodal basin and then repositioned into the lateral decubitus position to perform the wide excision of the back melanoma. Regardless of approach, it is important to scan intervening regions with the gamma probe.

WIDE EXCISION MARGIN

- The planned margin of excision of the primary melanoma is based on the Breslow tumor thickness as described above and refers to the radial margin of normal-appearing skin to be resected. If the primary melanoma is entirely or partially intact, the margin should be measured from the periphery of the visible lesion. When the entire pigmented lesion has been excised by the previous biopsy, the margin should be measured from the periphery of the biopsy scar.

PLACEMENT AND ORIENTATION OF INCISION

- Proper planning of the incision is critical. The surgeon must consider the required radial margin (i.e., margin of excision), the specific anatomic primary site involved, as well as the quality and quantity of local soft tissue.
- Because the resulting final incision may be significantly longer than what the patient might have otherwise anticipated, based on the usually "small" biopsy site, we strongly recommend that this theme be integrated into the surgical consultation and preoperative visits: a "scale" drawing presented to the patient at the time of initial and/or preoperative visit is often very instructive.
- The recommended margin of excision is based on primary tumor thickness (described above) and is measured from either the edge of the intact melanoma or biopsy scar, generally resulting in the proposed circular or oval defect marked on the skin (**FIG 4A,B**). When a primary closure is planned, the circle or oval can be modified into



A B

FIG 4 ● **A,B.** In this example, the patient has already been injected with both Tc-99 sulfur colloid and isosulfan blue intradermally around the biopsy site for a lymphatic mapping and sentinel biopsy procedure at the time of wide excision in the same operative setting. The recommended margin of excision is based on primary tumor thickness and is measured from either the edge of the intact melanoma or biopsy scar, generally resulting in the proposed circular or oval defect marked on the skin.

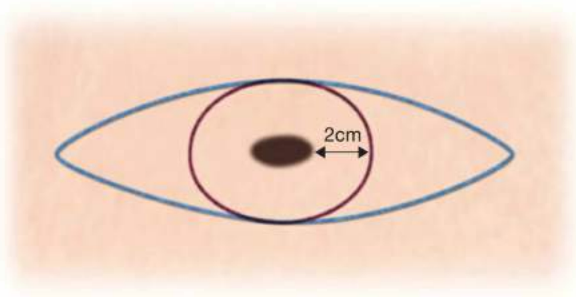


FIG 5 ● When a primary closure as planned, the circle or oval is generally fashioned into an ellipse prior to wide excision to improve cosmetic outcome and facilitate primary closure.

an ellipse prior to WE to improve cosmetic outcome and facilitate primary closure (**FIG 5**). Excision of an ellipse of tissue results in a more gradual transition in wound contour and minimizes "dog ears" at the poles of the incision.

- Creation of an ellipse three to four times as long as it is wide has often been recommended in textbooks; cosmetically acceptable closure can sometimes be achieved with a smaller ratio and should be individualized.
- Alternatively, tissue that may contribute to dog ears can be resected after the oncologic portion of the WE. Depending on the lines of tension of the skin, a modified ellipse such as lazy S or "hurricane"-type (**FIG 6**) incision may facilitate closure, generally as triangular-shaped segments of skin and underlying subcutaneous tissue.
- When feasible, the incision should be oriented to facilitate primary closure. On the extremities, for example, the WE incision is usually oriented parallel to the long axis of the limb. This facilitates primary closure, results in greater excision of lymphatics that are at risk for melanoma tumor cell emboli, and may decrease subsequent lymphedema.
- Breast—Primary cutaneous melanoma of the skin of the breast should be managed with similar principles as cutaneous melanoma elsewhere. A mastectomy is not required to achieve oncologic control.
- Hand, foot, and digits—General margin guidelines for cutaneous melanoma should be followed and consideration for preservation of function should be maximized. As a general principle, it is not usually necessary to remove bone to obtain oncologic control of the primary melanoma. However, amputation is usually necessary if standard WE for subungual or distal digit invasive cutaneous melanoma leaves insufficient soft tissue to maintain a functional digit without partial phalanx bony resection. Phalanx-preserving approaches can sometimes be employed for distal digit/subungual melanoma in situ.
- Perianal skin melanomas should be treated as cutaneous melanomas.

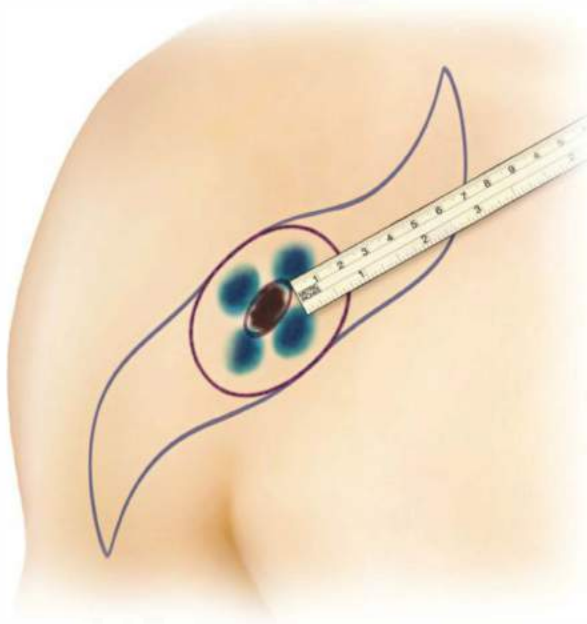


FIG 6 ● Depending on the lines of tension of the skin, a modified ellipse such as lazy S or hurricane-type incision may facilitate closure.

SKIN INCISION

- The skin incision is typically made with a no. 10 or 15 blade scalpel, initially to the level of the deep dermis. The remainder of the dermis can be divided either using the electrocautery on cutting mode or by using a scalpel. Care is required to avoid cautery to the skin edges, as this may result in wound healing issues.
- The excision continues by deepening the initial incision into the subcutaneous tissue to the level of the muscular fascia; care must be taken to maintain an angle of attack through the subcutaneous tissue that is perpendicular to the skin surface. The actual depth of excision will vary according to the anatomic location of the primary melanoma. It is rarely necessary to include fascia with WE[5]; an exception is when prior surgery at the site included or abutted the fascia such that clear margin cannot be achieved or in the case of obvious tumor involvement at the fascia.

EXCISION OF SPECIMEN

- Once the depth of the resection has reached the underlying muscular fascia, the WE is completed by dissecting skin and soft tissue from the underlying fascia using the electrocautery (**FIG 7**).
- WE specimens are almost always submitted for permanent section analysis; intraoperative frozen section analysis is the exception. When reconstruction may be significantly impacted by an involved margin, "rush" permanent pathology (turnaround about 24 to 48 hours) may be coordinated with the pathology team (see also "Delayed Wound Closure" later in this chapter).
- It is important to properly orient the specimen in the event that final margins are involved and an additional resection (usually as a separate operative procedure) is required (**FIG 8**).

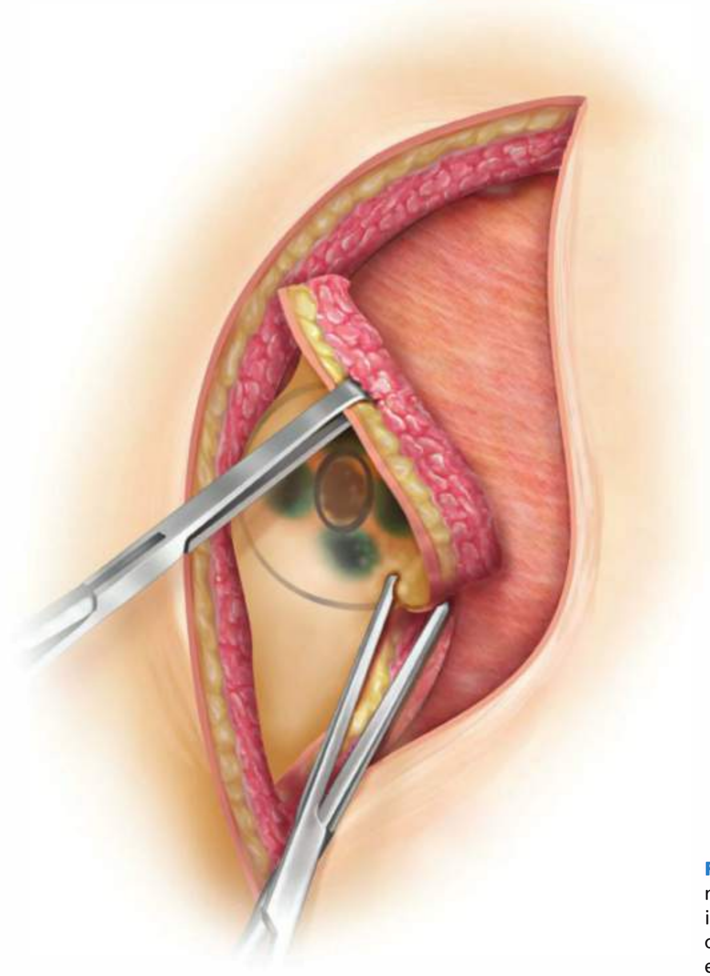


FIG 7 ● The depth of wide excision down to the muscular fascia is demonstrated. Once this depth is reached, the skin and soft tissue is dissected off the underlying fascia, completing the wide excision.

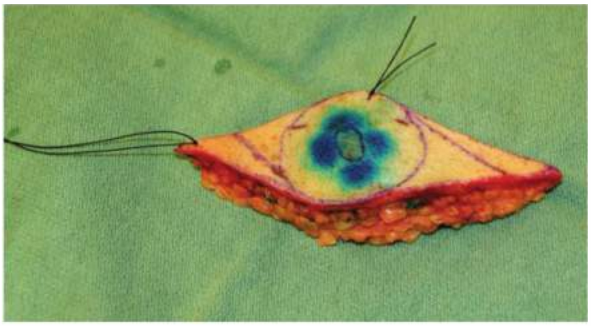
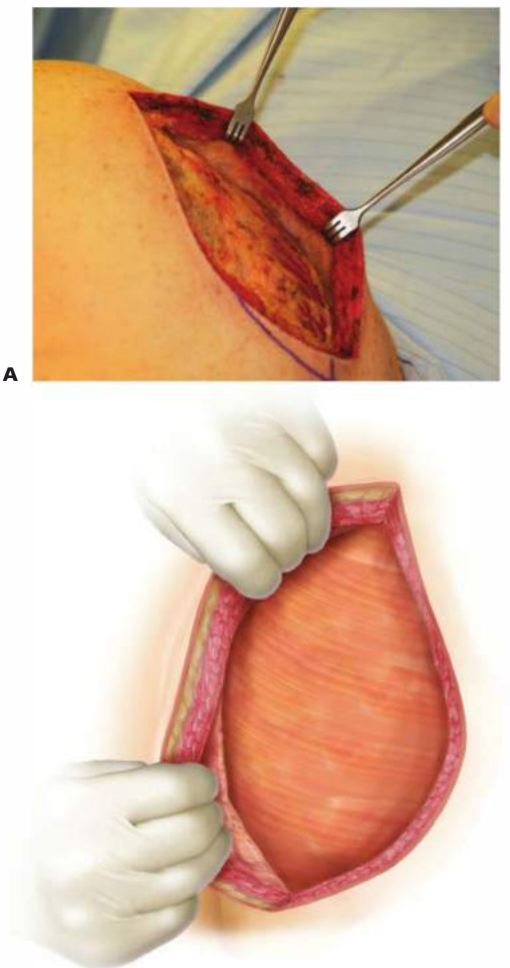


FIG 8 ● The resected specimen is carefully oriented to ensure accurate margin assessment by the pathologist. It is also important to orient in such a fashion that re-excision of involved margins can be accurately mapped back to the patient.

CLOSURE

- The majority of 1-cm margin defects and many 2-cm margin defects can be closed primarily. Recruitment of adjacent tissue by fashioning local flaps often facilitates primary closure and is dependent on the primary tumor location, margin, and the laxity of adjacent skin. Surgical defects may often be closed by mobilizing tissue flaps that have been created by undermining in a suprafascial plane and include full-thickness skin and underlying subcutaneous fat (**FIG 9A,B**).
- Complex closure of a WE defect involves placement of one or two layers of deep absorbable sutures (**FIG 10**), followed by placement of an intradermal layer of a buried absorbable suture. Skin closure can be carried out using a number of techniques, depending on the tissue tension, anatomic location, mobility, and surgeon preference. A subcuticular skin closure may be performed using an absorbable monofilament suture or a nonabsorbable pull-through suture that requires removal. Interrupted or running nonabsorbable sutures and skin staples may also be used as per surgeon preference (**FIG 11**). Dermal adhesives or adhesive bands may be used to directly cover the skin.

FIG 10 ● Photo demonstrating placement of deep absorbable sutures to facilitate complex primary closure of a WE. Typically one or two layers of deep absorbable sutures are used.



A

B

FIG 9 ● Photo **(A)** and illustration **(B)** demonstrating the mobilization of tissue flaps by undermining the full thickness of skin and subcutaneous fat at a level just superficial to the muscular fascia.

FIG 11 ● After reapproximation of deep layer(s), the skin may be closed using a number of different techniques and sutures depending on location, tension, and surgeon preference. In this photograph, interrupted vertical mattress sutures were used.

- At the discretion of the surgeon, closed suction drainage may be used when extensive undermining or large flaps are necessary or when considerable dead space persists after layered closure. If a drain is used, the exit site should be placed in line with the incision so that any potential recurrence can be reexcised without jeopardizing subsequent wound closure. Alternatively, suture plication of the more superficial tissue to the underlying fascia may sometimes be used and obviate the need for drainage, even when larger flaps are used.

RECONSTRUCTION

- When primary closure is not feasible, consideration should be given to skin grafts or local tissue flaps. The advantage of a skin graft is that it is a relatively straightforward procedure that minimizes adjacent tissue manipulation, allows for easy long-term monitoring of the primary melanoma site, and does not disrupt lymphatic drainage pathways. Skin grafts, however, are insensate, provide little protection to underlying tissue, and may result in a more pronounced contour defect. Furthermore, compared to local tissue flaps, skin grafts may result in more disfigurement and prolonged healing. Skin grafts are discussed in detail in Part 5, Chapter 24.
- Typically, split-thickness skin grafts are harvested from the posterior or proximal lateral thigh. Of note, when a lower extremity melanoma requires a skin graft closure, the graft should be harvested from the contralateral extremity.
- Full-thickness skin grafts can be harvested from multiple locations, allowing for better skin color and texture matching to skin adjacent to the melanoma excision. Full-thickness skin grafts may be harvested from the inguinal groin crease, the lower neck region overlying the clavicle, or behind the ear. After an appropriately sized ellipse of skin is excised down into the subcutaneous fat, the donor site is primarily closed, resulting in less morbidity than the typical split-thickness skin graft donor site. The full-thickness harvested skin is de-fatted and prepared as a skin graft.
- The decision to proceed with a local tissue or rotational flap should be made after careful consideration of the features of the local tumor, including risk of satellite or in-transit metastases, the potential benefit to the patient from the functional and cosmetic perspective, the comorbidities of the patient, and the local tissue options available. The advantages of local flaps include durable, sensate, similar thickness, and textured skin. Disadvantages include rearrangement of regional soft tissue at risk for in-transit/satellite metastatic disease. Advancement and rotational flaps are discussed in detail in Part 5, Chapter 23.

DELAYED WOUND CLOSURE

- The majority of WE defects are closed or reconstructed during the same operation as the WE. There are circumstances, however, when delayed reconstruction is the most appropriate course of action. These situations may include delaying reconstruction in the setting of large diameter or poorly defined melanomas where margins are clinically equivocal at time of WE. Unlike its common use for assessment of margins for nonmelanoma skin cancer, intraoperative frozen section margin assessment is infrequently employed for intraoperative margin assessment of melanoma WE.
- Delayed reconstruction may also be beneficial when time is needed for a granulation bed to form in order to facilitate grafting, such as after excision of a heel melanoma where skin grafting onto a granulating bed is often performed in such a fashion (**FIG 12**).
- When wound closure is delayed, options for wound coverage include temporary wound dressings with routine dressing changes or a vacuum-assisted sponge dressing device (e.g., vacuum-assisted closure [VAC] device). VAC devices are sometimes not available until negative margins are confirmed.
- In some situations, a request for rush permanent pathology of the WE specimen may be coordinated in advance with the pathology team, thus facilitating advance surgical planning (often at 48 hours postoperative) both in terms of operating room space and collaboration with the reconstructive team. In such cases, a temporary occlusive dressing is often used to protect the WE site until final margins are available.

FIG 12 ● Photographs demonstrating use of delayed reconstruction for a large heel melanoma **(A)**. Upon completion of the WE **(B)**, a vacuum- assisted sponge dressing device is placed intraoperatively **(C)**. The recipient granulation bed, shown here after use of a vacuum-assisted device for approximately 3 weeks, is now optimized for skin grafting **(D)**.

PEARLS AND PITFALLS

Preoperative strategies	■ Orientation of biopsy is important whenever performed. ■ Healing of biopsy—Photo document biopsy site for later site confirmation whenever it may be possible that site will be healed prior to definitive WE. ■ Complete history and physical essential to identify additional suspicious primary lesions as well as potential sites of in-transit metastasis, satellites, and clinical nodal disease.
Operative positioning	■ Pad all pressure points. ■ Include potential interval and/or in-transit drainage sites within operative field if SNB is to be performed. ■ Do not harvest skin grafts from in-transit region (i.e., between primary tumor and draining nodal basin); as a practical approach, it is generally not prudent to harvest skin grafts from ipsilateral extremity.
Placement of incision	■ Extremities—Incision is generally oriented parallel to the long axis of extremity. ■ Always consider reconstructive options when placing and planning incision for WE. ■ Use radial margins appropriate for tumor thickness. ■ Be aware of superficial (subcutaneous) motor nerves (e.g., superficial peroneal and portion of spinal accessory)
Intraoperative considerations	■ Excision should be performed to, but not include, level of the underlying muscular fascia, unless the fascia itself is involved with tumor or the prior biopsy procedure. ■ Maintain perpendicular orientation through subcutaneous tissue. ■ Frozen section margin analysis is rarely employed. ■ Proper orientation of WE specimen is essential to facilitate reexcision of involved margins when necessary.
Closure	■ Consider overall risks of locoregional and other metastases with any extensive reconstruction option employed. ■ Consider closing dead space where appropriate to reduce likelihood of seroma formation.

POSTOPERATIVE CARE

- Specific postoperative care is dependent on the type of closure, the use of absorbable or permanent suture material, the extent of tension on the wound, and the presence or absence of a drain.
- In general, the patient can shower in 24 to 48 hours unless skin grafts are used.
- Drains (if used) usually stay in place until collected volumes remain 30 mL or less for 2 consecutive days.
- Specific restrictions may apply depending on anatomic location (e.g., restrictions on weight bearing for melanomas on the plantar surface of foot) and type of closure (e.g., skin graft).
- Progressive increase in activity, weight bearing, or lifting over a 4- to 6-week period

OUTCOMES

- After an appropriate WE based on tumor thickness, true local melanoma recurrences are uncommon and likely represent lymphatic tumor emboli. Some “local recurrences” are a result of an incompletely or inadequately excised primary melanoma.
- Functional outcome is critical and early use of physical therapy is encouraged when appropriate.

COMPLICATIONS

- Infection (cellulitis or abscess)
- Seroma
- Hematoma/ bleeding
- Wound dehiscence or separation
- Failure of take of skin graft or flap
- Poor functional or cosmetic outcome
- Numbness and/or hyperesthesia and/or pain
- Edema/lymphedema

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Chapter 23 Advancement and Rotational Flaps

Jeffrey H. Kozlow

DEFINITION

- Advancement and rotational flaps are tissue transfer techniques used in reconstructive surgery for the closure of acquired defects.
- A flap is an area of tissue designed for movement to another area while remaining vascularized. This is in contrast to a graft, which is transferred in a nonvascularized fashion and becomes revascularized only with local incorporation and vascular neogenesis.
- Advancement and rotation flaps are both considered local flaps because they borrow from the tissue adjacent to the defect. Distant flaps use tissue from areas away from the defect, and free flaps involve the transfer of tissue from a distant site by means of a microsurgical anastomosis.
- Local flaps can be defined by their vascularity. Random flaps are based on blood flow through the subdermal plexus to provide vascularity to the distal end of the flap (**FIG 1**). Axial flaps are based on a longitudinal blood vessel incorporated into the flap design that can extend the effective length of a flap (**FIG 2**). Perforator flaps are based on underlying septocutaneous or musculocutaneous perforators into the central area of the flap (**FIG 3**).
- Local flaps can also be defined by the geometry of the incisions used with example of common designs shown in the following text.
- Flap design includes evaluation of tissue laxity, optimization of scar position, and management of standing cutaneous deformities.

PATIENT HISTORY AND PHYSICAL FINDINGS

- The choice and design of local flaps is dependent on multiple factors including the region on the body for reconstruction, local and regional soft tissue laxity, relationships with underlying critical anatomy, relaxed lines of skin tension for scarring, and underlying flap vascularity.
- Poor quality of tissue adjacent to the defect may preclude the use of local flaps.
- Local radiation damage will often limit the pliability of tissues for transfer and inhibit the healing potential of tissue.
- Each patient is different and flap choice must be tailored to the individual, the size of the defect, and the location of the defect.
- There are often multiple different flaps that will adequately reconstruct a defect; there is no "one right answer" for any given case.
- Flap design should also consider potential oncologic implications including the need for recurrence monitoring, secondary reconstruction techniques, and margin management when reconstruction is done immediately after resection and margin status cannot be confirmed.
- For patients with lower extremity defects, an evaluation of arterial status and venous insufficiency should be considered.

IMAGING AND OTHER DIAGNOSTIC STUDIES

- In general, local flaps do not require preoperative imaging or diagnostic studies.
- Doppler can be used to identify either axial or perforating blood vessels if clinically indicated.

SURGICAL MANAGEMENT

Preoperative Planning

- A reconstructive plan can only be made after the resection is designed. In cases that may require a plastic and reconstructive surgeon for advanced reconstructive techniques, it is always best to plan accordingly ahead of time and not consult intraoperatively.

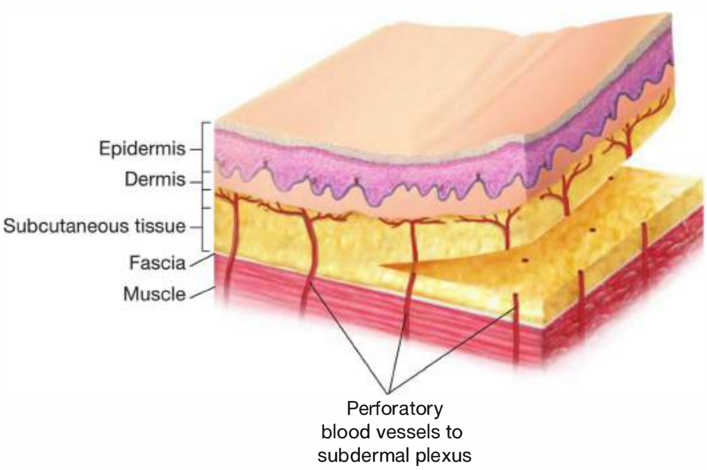


FIG 1 • Demonstration of a "random" pattern flap based on the subdermal plexus—The distal aspect of the flap remains vascularized through the small vessels running underneath the dermis only. As the length of the flap increases, the blood flow through the subdermal plexus decreases.

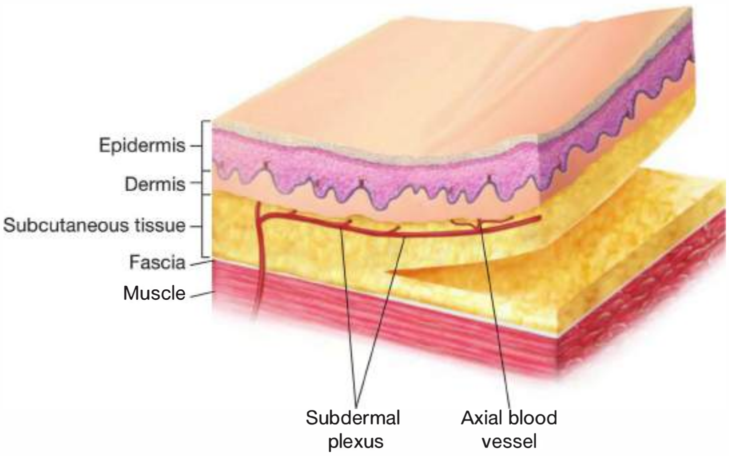


FIG 2 ● Demonstration of an axial pattern flap—The flap design incorporates a named arterial supply along the length of the flap, which increases perfusion to the distal aspect of the flap compared to a random pattern flap.

- Preoperative markings may include important regional anatomic landmarks (such as facial rhytids) that may be obscured with the injection of local anesthetic intraoperatively.

Positioning

- Patients should be positioned to optimize not only surgical access for tumor resection but also for access to any local areas potentially usable for the subsequent reconstruction.
- All areas should be prepped widely to allow for access to all local and regional flap option. All extremities should be prepped and draped circumferentially. For areas where symmetry is important (such as the face or breasts), it is important to have the contralateral side in the operative field as well.

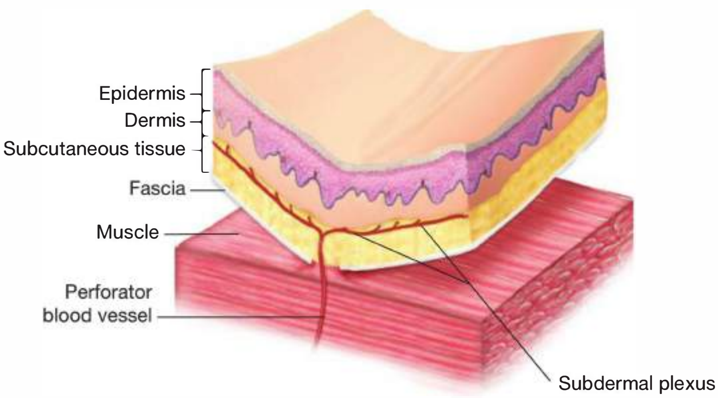


FIG 3 ● Demonstration of a perforator-based flap—The flap is centered around a single blood vessel, which perforates through the fascial layer from the underlying muscle or muscular septa to then supply the subdermal plexus.

- There are multiple local flaps that are available for use in reconstruction. Not all of them can be highlighted in this text; however, the most common flaps for general reconstruction are described in the following text. In some cases, multiple local flaps are required and techniques can be combined to achieve closure of the defect.
- In most flaps, the area is often infiltrated with local anesthesia including 1:100,000 to 1:200,000 parts epinephrine to help with hemostasis and minimize electrocautery injury to dermal edges. However, overinjection of local anesthesia can result in tissue edema that decreases flap mobility.
- Skin hooks are used on the margins of a flap for handling; the use of forceps is discouraged due to injury to the flap edges from overzealous pressure.
- Drains are typically not used unless flaps are large.
- Flaps designed around joints should be inset under the greatest tension of the joint to avoid postoperative dehiscence.

SIMPLE ADVANCEMENT FLAPS

Flap Design

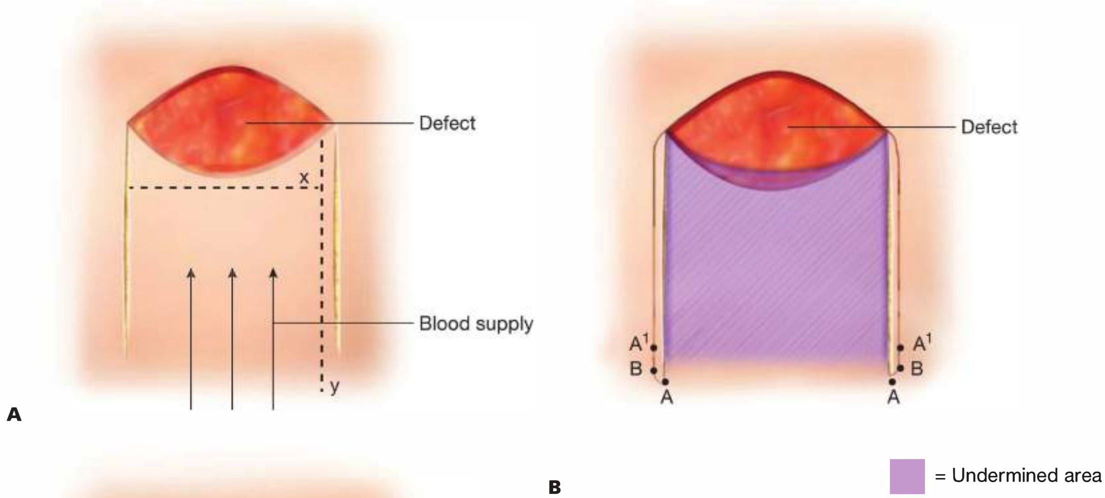
- Based on either the subdermal plexus as a vascular supply from the base of the flap to the distal end or can include an axial vessel for additional length and degrees of freedom
- Incisions are designed in a parallel fashion equal to the dimensions of the defect (**FIGS 4A** and **5A**); choice of direction is based on local tissue laxity.
- Classic teaching is that a maximum 3:1 ratio of length to width can be used when the flap is based on the subdermal plexus.

Flap Elevation

- Incisions are made extending from the defect in a parallel fashion toward base of flap.
- Dissection is carried down to the depth of defect or deeper in order to match volumetric dimensions of reconstruction.
- The central portion of the flap is undermined either in the deep subcutaneous level or below the fascia, depending on flap design and reliance on subdermal only versus axial-based blood supply (**FIGS 4B** and **5B**).

Defect Closure

- Careful hemostasis is assured after flap elevation; hematomas under the flap can compromise vascularity and overall outcome.
- Once flap has adequate advancement to fill defect, closure often occurs from the base of the flap to help "push" the flap into the defect, which can help alleviate tension over the distal closure (**FIG 4C**).
- Standing cutaneous deformities can occur as the base is advanced. These areas can be resected with a scar perpendicular to the direction of the flap.
- Dermal closure is performed using an absorbable suture followed by either a subcuticular or simple external suture (**FIG 5C**).



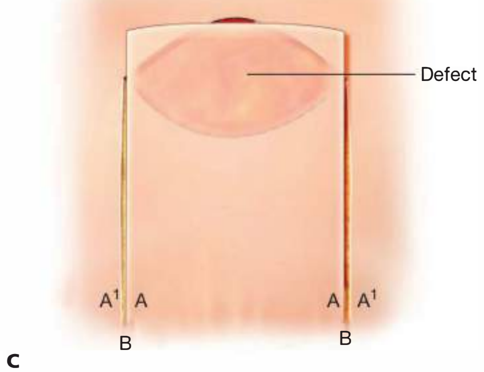
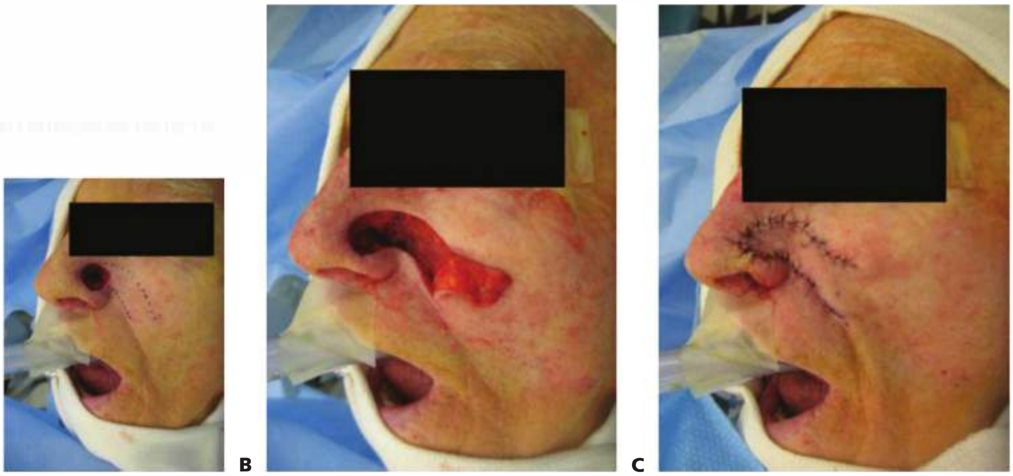


FIG 4 ● The design of an advancement flap is based on subdermal blood supply from the base of the flap. The initial parallel incisions are drawn from the wound edges **(A)**. The advancement flap is undermined toward the base, leaving only the subdermal blood supply to vascularize the distal tip **(B)**. The flap is then advanced forward and pushed into the defect. The previous base corner of the flap (point *A*) has been pushed forward and is approximated to point A^1 **(C)**.



A B C

FIG 5 ● **A.** In this case, an axial-based advancement flap for nasal reconstruction is designed to incorporate the angular artery for additional length. This undermining is seen in **B** as the flap is fold back toward its base prior to advancement. The final advancement and closure of the advancement flap is demonstrated in **C**.

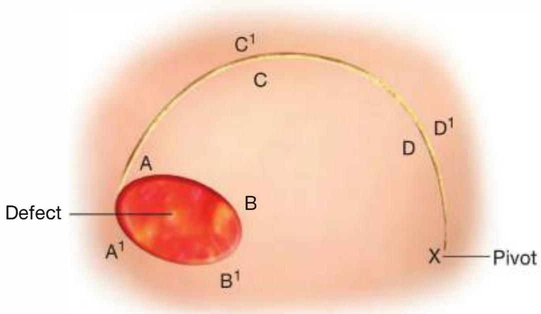
ROTATIONAL/TRANSPOSITION FLAPS

Flap Design

- Designed as a semicircle extending from one corner of the defect (FIGS 6A and 7A)
- Direction and orientation of flap is based on local areas of laxity.
- Based on a pivot point at "base" of flap that determines amount of rotation available

Flap Elevation

- Incision is made through skin and subcutaneous tissues to depth of defect or greater.
- Flap is undermined in same or deeper plan up to the base (FIG 6B).
- Careful hemostasis is assured in undermined area to avoid a hematoma that may compromise flap.



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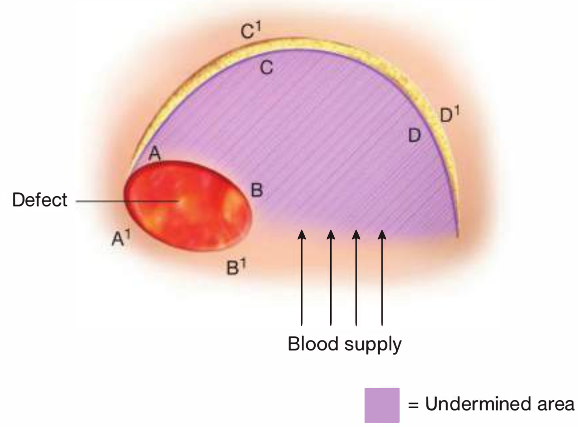
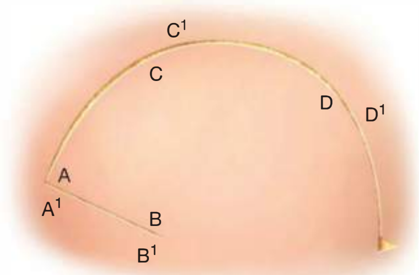
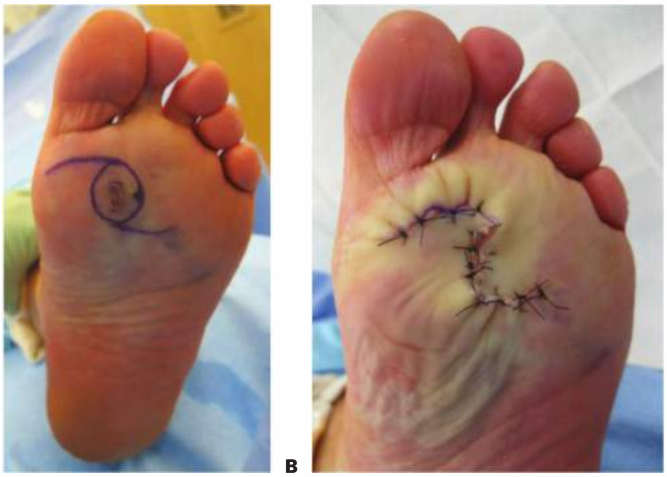


B



C

FIG 6 ● The semicircular markings for a rotation flap are demonstrated. The subsequent advancement of the flap is demonstrated by the movement of points *A*, *B*, *C*, and *D* to A^1, B^1, C^1, and D^1, respectively **(A)**. The rotation flap is undermined back toward the base leaving the distal portion of the tissue perfused through the subdermal plexus. Additional back-cuts across the base should be done judicious to not compromise vascularity of the flap **(B)**. The rotation flap is rotated into the defect for closure. The movement of the flap relative to the adjacent skin is noted by the changed alignment of the *C* and *D* marks to the C^1 and D^1 marks, respectively. **C.** A small standing cutaneous deformity at the base of the flap may require excision.



A B

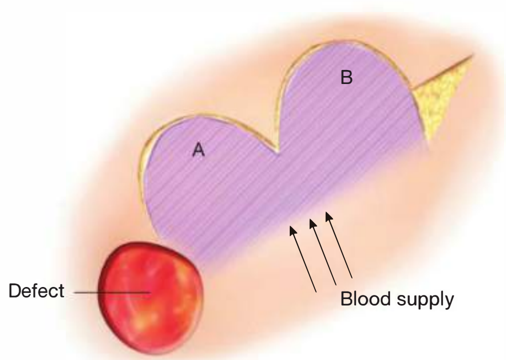
FIG 7 ● A. In this clinical case, opposing advancement flaps have been designed for reconstruction of a plantar foot wound. B. In this case, the opposing flaps have both been advanced to reconstruct the defect.

Defect Closure

- Flap is advanced and rotated into defect with closure often starting at base of defect to help push and rotate flap into defect (FIG 6C).
- Dermal closure is performed using an absorbable suture followed by either a subcuticular or simple external suture (FIG 7B).
- Excision of standing cutaneous deformities should be away from the base of the flap to avoid decreasing flap vascularity.

Additional Designs

- Multiple variations in flap design are commonly used but based on the same principle as earlier. For example
  - A bilobed flap uses two adjacent rotation/transposition flaps. The flap directly adjacent to the defect is used to close the primary defect and the other flap is then used to close the donor site for the first flap (FIG 8A–C).
  - A rhomboid flap is designed along the longer edge of a defect and transposes skin from an area of laxity to the defect, allowing for primary closure of the donor site (FIG 9A–C).



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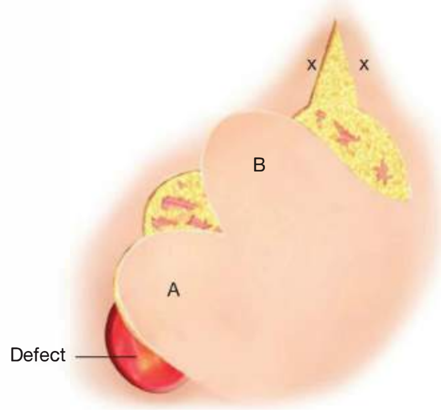

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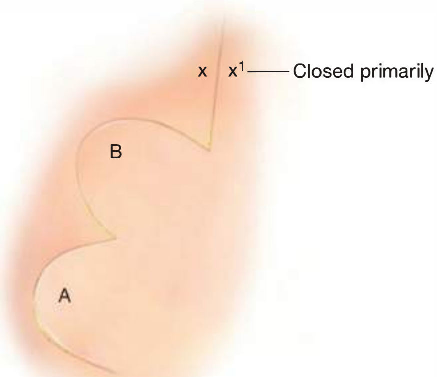
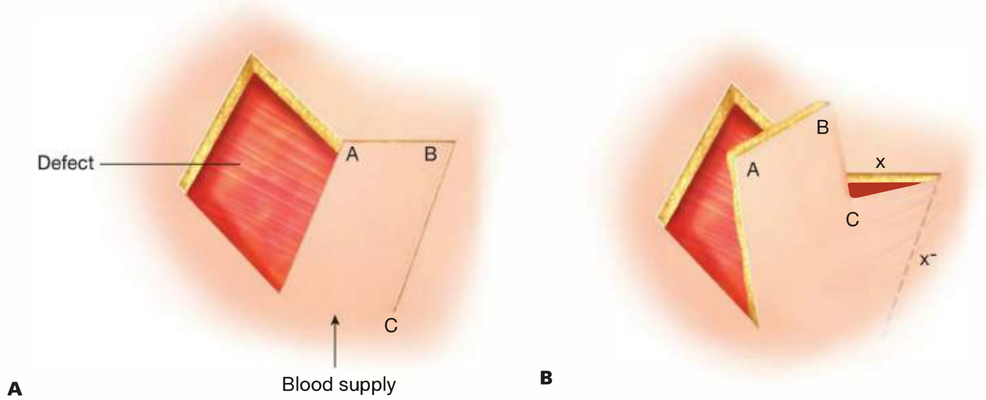


C

FIG 8 ● The bilobed flap uses two rotation-transposition flaps for closure of a defect. **A.** *Flap A* is used to close the primary defect and *flap B* is used to close the donor site from *flap A*. **B.** The flap is elevated in the subcutaneous tissues leaving blood supply from the subdermal plexus at the base of the both "lobes" of the flap. **C.** The flaps are then transposed with primary closure of the donor site for *flap B* by reapproximation of x to x^1.



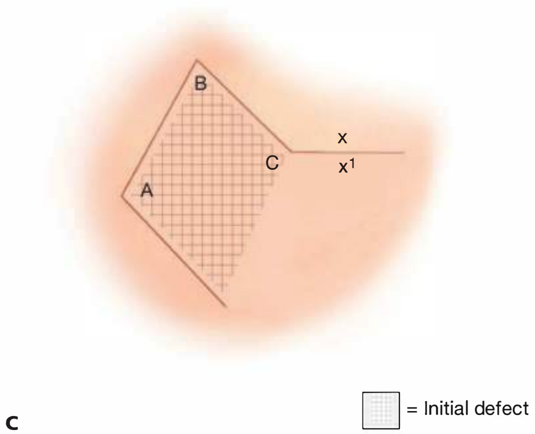


FIG 9 ● The rhomboid flap is another variation on the rotation-transposition flap and works well with elliptical- or rhomboid-shaped defects. The flap is designed off the "oblique" angle of the defect directly perpendicular to the defect. An additional incision designed parallel to the side of the defect is used to create a mirror image of the defect through the shared border of the flap and the defect **(A)**. The flap is then elevated in the subcutaneous tissues leaving blood supply from the subdermal plexus **(B)**. The flap is then rotated and transposed to fill the defect with the flap donor site closed primarily with approximation of *x* to x^1 **(C)**.

V-Y ADVANCEMENT FLAP

Flap Design

- The vascularity of the V-Y advancement flap is based on the central perforating vessels.
- Orientation is designed on areas of local laxity and mobility.
- Incisions are designed from wide part of defect and then gently tapered into a triangle perpendicular to wound edge (**FIG 10A** and **FIG 11A**).
- Care is taken to design large enough flap to allow for some undermining at base of flap for additional advancement while still leaving enough central contact with deeper tissues for vascularity.

Flap Elevation

- Incisions are made through skin and subcutaneous tissues. Dissection through the subcutaneous tissues should be beveled away from the flap in order to increase the area for capture of underlying perforators into the central flap.
- The fascia can also be divided to allow for additional flap mobility.
- Can undermine the distal and proximal one-fourth of flap to allow for additional advancement but must *not* undermine centrally because this area is key to vascularity (**FIG 10B**). This is often done by spreading with a scissors vertically to preserve any potential blood vessels entering the flap.

Defect Closure

- Careful hemostasis is assured after flap elevation; hematomas under the flap can compromise vascularity and overall outcome.
- Closure starts at the "point" of the triangle where the donor site is closed primarily to form the vertical limb of the "Y." This also helps push the flap forward into the defect (**FIG 10C**).
- The flap is then pushed forward into the defect by closure of the sides of the triangle (**FIG 11B**).

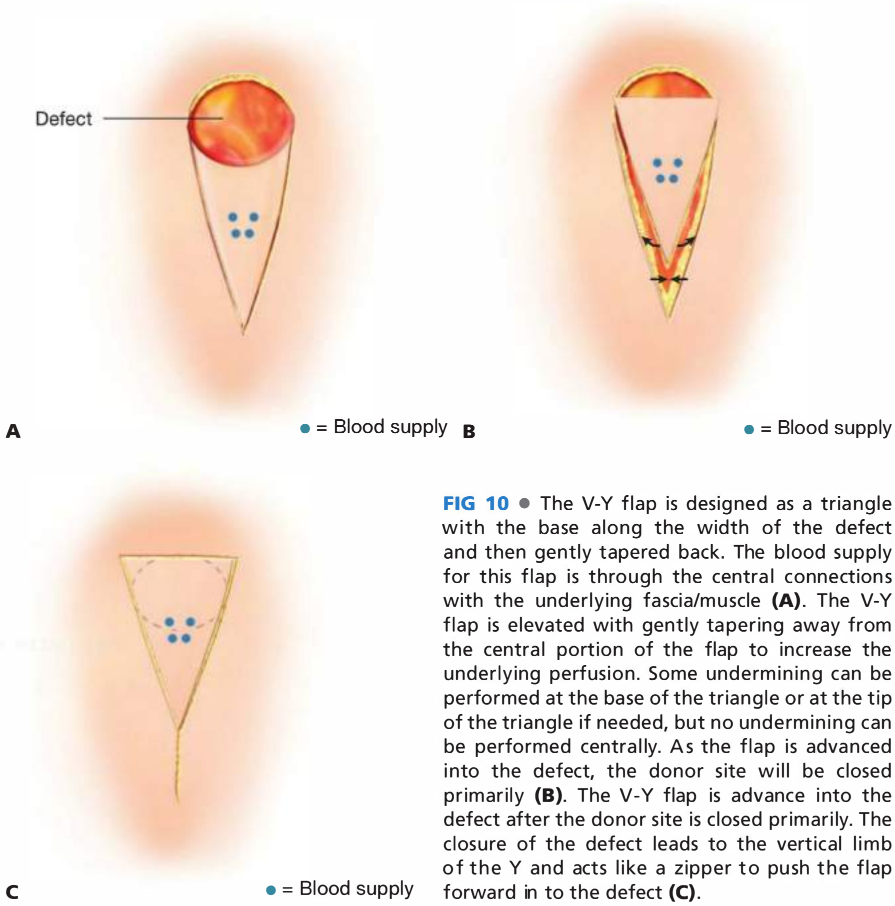


FIG 10 ● The V-Y flap is designed as a triangle with the base along the width of the defect and then gently tapered back. The blood supply for this flap is through the central connections with the underlying fascia/muscle **(A)**. The V-Y flap is elevated with gently tapering away from the central portion of the flap to increase the underlying perfusion. Some undermining can be performed at the base of the triangle or at the tip of the triangle if needed, but no undermining can be performed centrally. As the flap is advanced into the defect, the donor site will be closed primarily **(B)**. The V-Y flap is advance into the defect after the donor site is closed primarily. The closure of the defect leads to the vertical limb of the Y and acts like a zipper to push the flap forward in to the defect **(C)**.

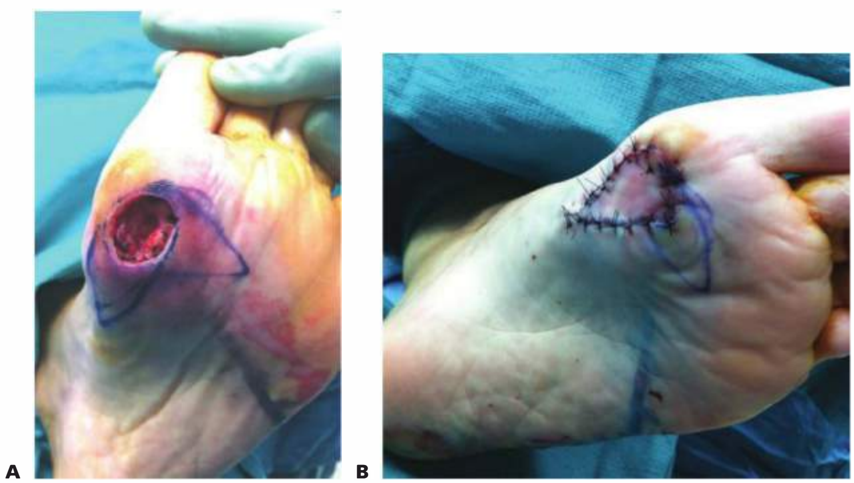


FIG 11 ● **A.** In this clinical case, two potential options for a V-Y flap have been designed with the decision to use the flap designed back toward the heel selected due to the relative laxity of that donor site compared to the flap running transversely across the plantar foot. **B.** In this case, the flap has been nicely advanced into the defect with the resultant Y closure demonstrated.

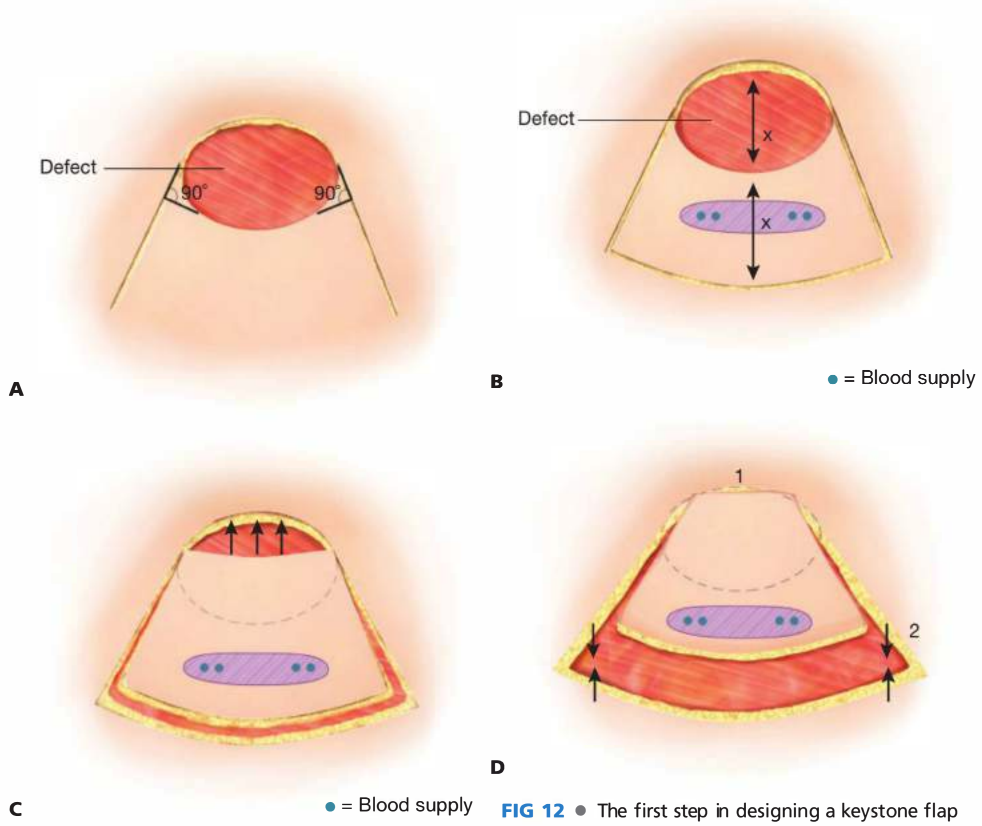
KEYSTONE FLAP

Flap Design

- Flap design is based on central perforators and use of "V-Y" closures to gain local tissue for advancement into the defect.
- A handheld Doppler can be used to identify specific large central perforators for preservation if additional mobilization is expected.
- The flap is most often designed from the longer border of a defect by first marking out the lateral borders of the flap at a 90-degree angle to the defect (**FIG 12A**).
- The flap width is then determined to be at least the width of the defect if not large. The flap is designed to remain this width along the entire length to each of the lateral borders (**FIGS 12B** and **13A**).

Flap Elevation

- Incisions are made through skin and subcutaneous tissues. This dissection is carried perpendicular to the skin with minimal beveling.
- The underlying fascia may also be divided for additional mobility and can be especially helpful in larger flaps.
- A small amount of subcutaneous or subfascial undermining can be performed, but this must be done judiciously unless large perforators have been knowingly included in the flap design.



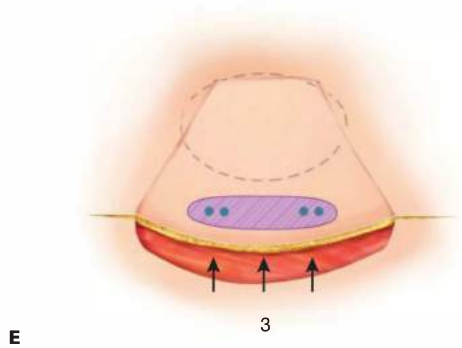
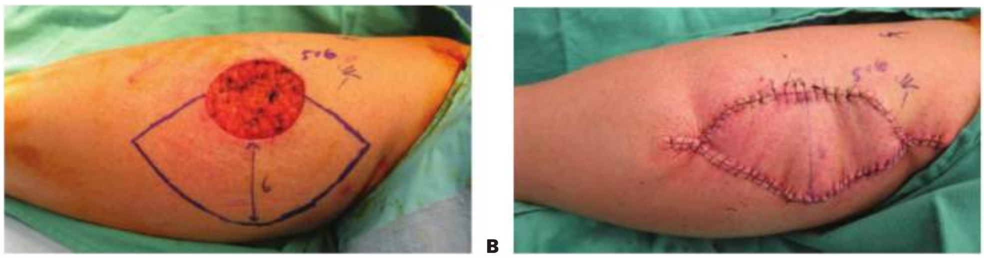


FIG 12 ● The first step in designing a keystone flap is to plan incisions from the corners of the defect perpendicular to the defect **(A)**. Next, the flap is designed to be at least the width of the defect with the central blood supply from the underlying tissue providing the vascularity to the flap **(B)**. The flap is elevated by incising through the skin, subcutaneous tissues, and fascia. The flap is then advanced into the defect and closure occurs first in this area of maximal tension **(C)**. After the flap has been advanced into the defect, the corners of the donor site are closed in a V-Y fashion, which also help push the flap into the defect and transitions the flap into a rounder shape **(D)**. The incision along the flap border opposite the initial defect is then closed by advancing the adjacent skin flap, which is often undermined **(E)**.

Defect Closure

- The leading edge of flap is advanced into the defect with deep dermal sutures. In situations where this may be initially under significant tension, one can start away from this area and work from peripheral to central, helping push the flap toward the defect (**FIG 12C**).
- The defect tissue margin opposite the flap can also be undermined to provide some advancement. Alternatively, an opposing keystone flap may also be designed along this border to provide additional tissue laxity.
- The lateral ends of flap donor site are then closed in a V-Y fashion to help recruit additional tissue centrally as the flap transitions from a hemi-arc shape to an ellipse (**FIG 12D**).
- Finally, the trailing edge of the flap opposite the defect is sutured back the edge of the donor site. This may require undermining of adjacent skin flaps to ease the overall tension on the closure (**FIGS 12E** and **13B**)



A B

FIG 13 ● In this case, a 6-cm wide flap has been designed to match the 6-cm width of the defect **(A)**. In this case, the flap has been advanced and reconstructed the defect. The corners of the flap donor site have been closed in a V-Y fashion and the flap shape has changed from a "keystone" or semi-arc shape to a more round shape **(B)**.

PEARLS AND PITFALLS

Flap selection	■ Flaps that are not undermined (e.g., keystone flaps) should be considered when margin status is unknown.
Flap design	■ Flaps should be large enough for readvancement if necessary.
Flap elevation	■ Care must be taken with perforator-based flaps to avoid central undermining because the subdermal plexus is transected circumferentially around the flap.
Defect closure	■ Care must be taken to avoid hematomas or infections, which can compromise a flap. ■ Postoperative immobilization should be considered for flaps around movable areas. ■ Excision of residual standing cutaneous deformities should be done judiciously to avoid compromise of flap vascularity and can be done at a later operative date if necessary.

POSTOPERATIVE CARE

- Flaps near joints should be immobilized with splinting to prevent mechanical dehiscence.
- Elevation for flaps on the extremities is critical for postoperative edema control.

COMPLICATIONS

- Marginal flap ischemia
- Delayed wound healing
- Infection (cellulitis or abscess)
- Hematoma
- Poor cosmetic outcome
- Flap failure/loss

OUTCOMES

- Outcome data for cutaneous reconstruction are quite heterogeneous due to the multiple body areas, flap techniques, and individual surgeon preferences.
- In general, the average incidence of a major complication is low but increases with the size of the defect and reconstruction. Minor complications include delayed wound healing, nonoperative infections, and need for secondary revision surgery.[1–3]
- The incidence of total flap failure is low when appropriate reconstructive principles are followed.

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2. Coombs CJ, Ng S, Stewart DA. The use of V-Y advancement flaps for closure of pretibial skin defects after excision of cutaneous lesions. *Ann Plast Surg*. 2013;71(4):402–405.
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Chapter 24 Skin Grafts

David L. Brown

DEFINITION

- A graft, unlike a flap, does not bring an independent blood supply with its tissue to the recipient site. Skin grafts can be defined based on their origin: autograft (same individual), allograft/homograft (another individual of the same species), or xenograft (from another species).
- Skin grafts represent a rung on the proverbial reconstructive ladder above those of primary closure and healing by secondary intention and below local flaps (**FIG 1**).

PATIENT HISTORY AND PHYSICAL FINDINGS

- Skin grafting should only be considered once a viable recipient bed is obtained. This includes debridement of nonviable tissues, elimination of active infection, assurance of good vascularization to the wound bed, lack of significant fluid efflux from the wound (i.e., edema or bleeding), and coverage of vital structures (exposed bone, vessels, tendons, nerves, etc.).
- Indications include inability to perform primary closure or insufficient tissues for local skin flap coverage, uncertainty of tumor clearance, and comorbid conditions.
- Contraindications include active infection (i.e., bacterial counts $>10^5$ CFU/g via quantitative culture), poor vascularity of recipient bed (i.e., history of radiation to the area), and anticipation of further underlying reconstruction (i.e., nerve or tendon grafting).

The Reconstructive Ladder

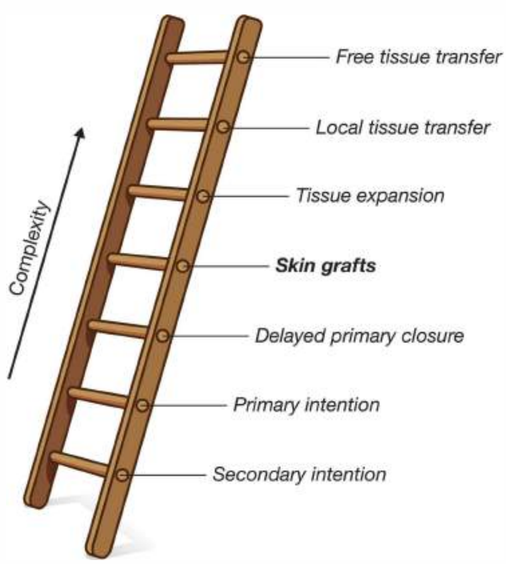


FIG 1 ● The reconstructive ladder. Skin grafts occupy an intermediate position in the heirarchy of complexity of closure technique.

- Relative contraindications: comorbidities that can affect the healing of skin grafts such as diabetes, smoking, and venous insufficiency.

SURGICAL MANAGEMENT

Preoperative Planning

- Patients should be counseled regarding postoperative expectations, wound management, and restrictions so that they can make preparations prior to the operation.
  - Care of the donor site
    - Split-thickness grafts—Xeroform versus OpSite versus other coverings. May shower; more pain with Xeroform; watch for leaks and infection with OpSite
    - Full-thickness grafts—Steri-Strips. May shower; some bruising; minimal pain
  - Care of the graft site—bolster dressing. May shower if bolster is exposed, but do not let water run through the bolster continuous as this will wash out mineral oil (if used on cotton inside) and allow bolster to dry out over graft. Bolsters are usually taken down in 4 to 6 days, unless infection is suspected, then earlier.
- Choice of graft thickness
  - Split-thickness skin grafts (STSGs)
    - 12/1,000 inch is standard, with 6–16/1,000 inch being used for special situations.
    - Thinner grafts: more assured healing at the recipient site; the more dermis is left behind for subsequent harvest as necessary and the less primary contraction and greater secondary contraction.
    - Thicker grafts: more durable, as they carry more dermis with them.
    - "Sheet" (unmeshed) grafts have the advantage of better cosmesis but are encumbered by seroma or hematoma formation underneath, which can lead to local failure of the graft. These grafts should be inspected early at approximately 24 to 48 hours and any underlying fluid removed via aspiration. "Pie crusting" is unaesthetic and is not associated with higher graft survival.
    - Meshing of grafts can be performed with two advantages. One is coverage of greater recipient surface area with less donor graft. The ratios 1:2 or 1:1.5 are more commonly used, whereas 1:4 is typically reserved for extreme cases only. The larger the graft expansion, the more tenuous the coverage, and the more secondary contraction will occur. The second advantage is wound bed drainage and prevention of seroma or hematoma formation resulting in graft failure. A common method is meshing 1:1.5 but applying the graft to the recipient site in an unmeshed fashion.
  - Full-thickness skin grafts (FTSGs)
    - Primary contraction is greater (about 40%), but secondary contraction is less (about 15%), making them a good choice for joints, neck, eyelids, and so forth.

- Donor sites from FTSGs (usually straight-line layered closures) have the benefits of little postoperative pain and minimal scarring compared to STSGs.
- Choice of meshing versus sheet grafts
  - Meshing: allows for egress of wound fluids and lessens the risk of seroma and hematoma. As interstices must heal via secondary contraction and re-epithelialization, meshed grafts will contract more over time and be less durable. More wound area is able to be covered with less donor site.
  - Sheet grafts: prone to hematoma and seroma but are aesthetically more pleasing and exhibit less secondary contraction. Useful on hands and feet, across joints, and on the face and neck.

SPLIT-THICKNESS SKIN GRAFTS

Patient Positioning and Setup

- The patient is positioned either prone or supine, so that the lateral or anterolateral thigh is accessible for graft harvesting.
- The approximate donor site is marked out from several inches below the trochanter to several inches above the knee (smaller if less is needed).
- The donor site is injected with local anesthetic in the subdermal space, using a 22-gauge spinal needle. A mixture of 0.5% lidocaine with 1:200,000 concentration of epinephrine and 0.25% bupivacaine works nicely for providing both hemostasis and postoperative pain relief.
- Mineral oil is spread over the area to allow for smooth gliding of the dermatome over the skin (**FIG 2**).

Preparing the Dermatome

- The dermatome is assembled, and the appropriate width guard is attached (**FIG 3A**). A 3-in guard is appropriate for most applications and fits the contour of the thigh well in most adult patients.
- Proper seating of the blade in the machine and underneath the guard is assured; uneven seating can cause an excessively thin graft at one edge and overly thick at the other.
- The desired thickness of skin harvest is selected via the dial on the side (12/1,000 inch is shown here) (**FIG 3B**).

Harvesting the graft

- Either the surgeon (using his nondominant hand) or an assistant hold manual countertension on the skin (**FIG 4A**).
- The dermatome is pressed against the skin at a 45-degree angle and, with moderate down force, is slowly advanced the length of graft harvest (**FIG 4B,C**).

FIG 2 ● Prone patient, with the lateral thigh showing from buttock crease (left) to knee (right). Note blanching of skin from epinephrine injection and glossiness of mineral oil application.

A B

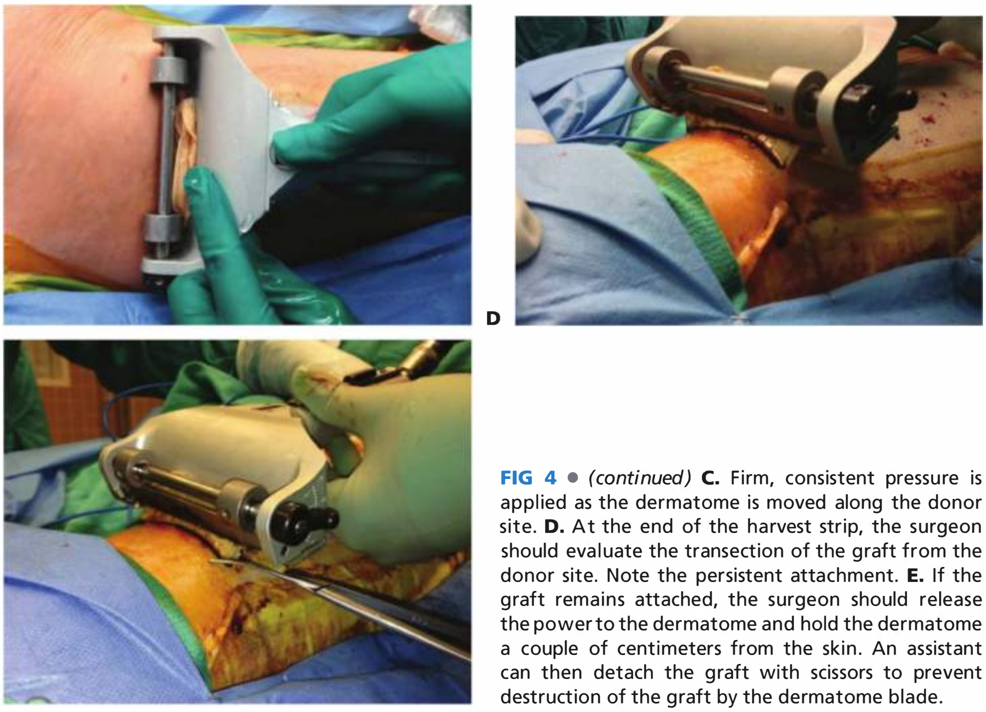
FIG 3 ● **A.** Underside of dermatome, with blade and 3-in guard attached. Blade and guard are flush against machine, as assembled. **B.** Dermatome set to 12/1,000 inch thickness.

- To complete the harvest and separate the end of the graft from the patient, the surgeon lowers the handle of the dermatome toward the patient (decreasing the angle of attack) and slowly lifts off the skin surface (**FIG 4D**).

A

B

FIG 4 ● Assistant holding countertraction on skin with the use of laparotomy sponge. **B.** Dermatome is placed on skin, running at a 45-degree angle. *(continued)*



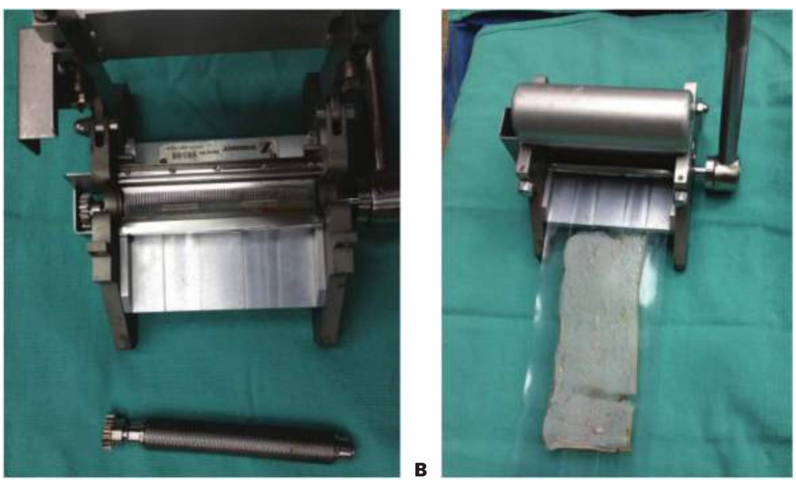
C D E

FIG 4 ● *(continued)* **C.** Firm, consistent pressure is applied as the dermatome is moved along the donor site. **D.** At the end of the harvest strip, the surgeon should evaluate the transection of the graft from the donor site. Note the persistent attachment. **E.** If the graft remains attached, the surgeon should release the power to the dermatome and hold the dermatome a couple of centimeters from the skin. An assistant can then detach the graft with scissors to prevent destruction of the graft by the dermatome blade.

- Power is released on the dermatome when it rises 1 cm above the skin, in case the graft remains attached.
- If the graft is not immediately separated from the donor site at the end of the run with the dermatome, the surgeon should release power to the dermatome and hold it a couple of centimeters over the skin until an assistant can cut it free with a Metzenbaum scissor. Otherwise, the graft is pulled back out through the blade entrance and can result in mangling of the graft (**FIG 4E**).

Meshing the Skin Graft

- For meshed grafts, the mesher is assembled, and an appropriate cutting wheel is chosen. 1:1.5 (shown here, **FIG 5A**) is a standard ratio but can be varied up to 1:4 depending on the amount of donor sites available compared to the area needing coverage as well as the specific application.
- The graft is placed superficial side down on the carrier and run through the mesher (**FIG 5B,C**).



A B

FIG 5 ● **A.** View of an opened mesher with space to place the chosen cutting wheel (in this case 1:1.5 ratio). **B.** Graft placed dermal side up on the carrier, which is positioned within the mesher entrance. *(continued)*

C

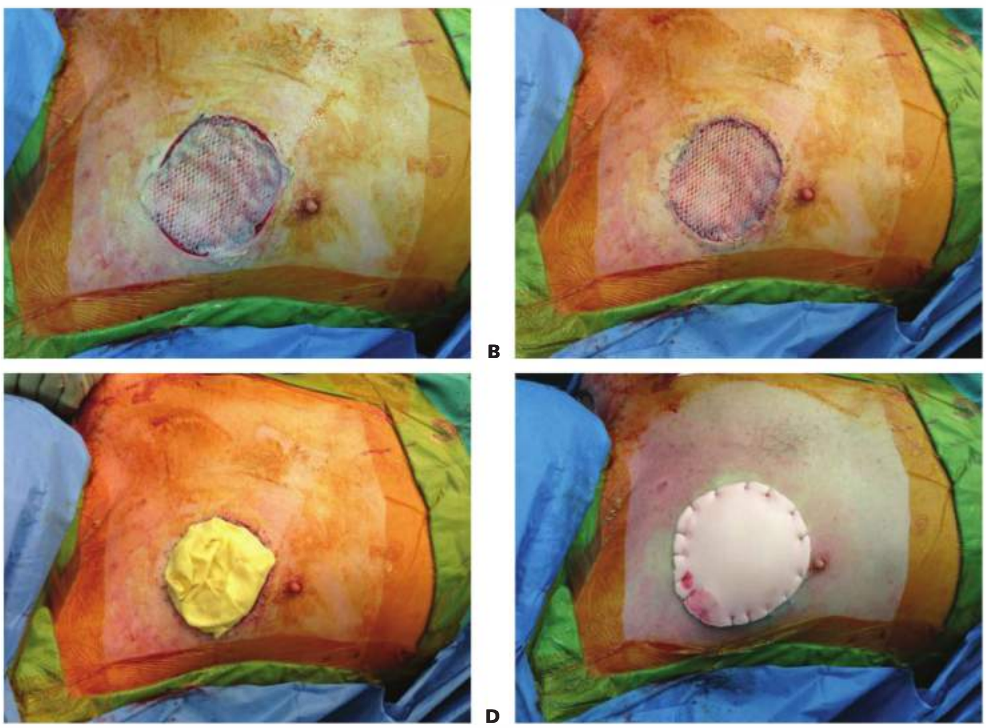
FIG 5 ● *(continued)* **C.** Graft, postmeshing.

Insertion of the Graft into the Wound Site

- The graft is placed in the wound bed, trimmed appropriately, and secured to the wound edges with surgical clips or sutures (4-0 chromic work well) (**FIG 6A,B**).
- A nonstick dressing is applied. A bolster consisting of mineral oil– and saline-soaked cotton balls or batting will provide pressure on and moisture to the graft (**FIG 6C**). Trunk wounds can be covered with Allevyn (Smith and Nephew) foam, whereas tie-over's with interrupted silk are suitable for the face and hand, or wrapping with gauze and an elastic bandage for the extremities (**FIG 6D**).

Other Considerations

- Excess ("left over") skin graft can be preserved in tissue culture media at 4°C for application to the wound should original graft loss occur. Graft survival diminishes with storage time and is generally considered to be poor after 10 to 14 days.
- Some clinical situations call for delayed graft placement (24 to 48 hours postoperatively) due to wound fluid seepage. In cases such as coverage of muscle and omental flaps, or recently debrided wounds over edematous tissues, graft application can be performed at the bedside. This saves a return trip to the operating room (OR) for the patient.



A B C D

FIG 6 ● **A.** Patient with right superior chest wound. Meshed graft placed within wound, dermal side down, and minimally expanded. **B.** The graft is trimmed appropriately and secured with stainless steel clips. **C.** Mineral oil– and saline-soaked cotton batting, wrapped in Xeroform, is shaped to the size of the wound. **D.** A foam bolster is used to secure the dressing over the graft.

PEARLS AND PITFALLS

Harvesting the graft	▪ Proper seating of the blade in the machine underneath the guard should be assured; uneven seating can cause an excessively thin graft at one edge and an overly thick one at the other. ▪ If the graft is not immediately separated from the donor site at the end of the run with the dermatome, the surgeon should release power to the dermatome and hold it over the skin for an assistant to cut it free with a Metzenbaum scissor. Otherwise, the graft can be pulled back out through the blade entrance, mangling the graft. ▪ Rinsing the graft washes away vital procoagulant factors and should be avoided, if possible.
Placing the graft in the wound bed	▪ To assure consistent application of the graft to the wound bed dermis-side down and to transfer it without bunching, it should be placed on the carrier dermis side up. ▪ If the graft is not immediately needed for wound coverage, it can be stored on the back table (appropriately marked to avoid disposal), wrapped in moistened gauze, or left on the carrier and covered with the same. ▪ Care should be taken to avoid "tenting" a graft over an uneven wound bed. Extra graft should be placed to allow for complete contour touchdown. ▪ Placement of a meshed graft does not need to involve full expansion of the graft; leaving it relatively unexpanded will allow for egress of wound fluids while speeding healing. ▪ "Pie-crusting" of sheet (unmeshed) grafts is thought to be superfluous, as it will likely not prevent a hematoma or seroma from forming between slits and is aesthetically unappealing.
Donor site	▪ Some surgeons apply epinephrine-soaked sponges to the fresh donor site to limit bleeding. This is obviated with the use of local anesthetic.

POSTOPERATIVE CARE

Patient Expectations

- Patients should be told that the donor site is likely to cause more pain than the wound site postoperatively.
- Healing stages of the graft and donor site are discussed to educate the patient.
- Over large areas of grafting and/or uneven surfaces, some graft loss is to be expected.

Wound Management

- Dressings
  - Bolsters should be left in place, barring complications such as fever and so forth, for 5 to 8 days.
  - Patients may shower and get the bolsters wet with incidental water contact. Soaking or significant water rinsing of the bolster is discouraged, as this washes out the mineral oil and allows the bolster to dry out.
  - Following bolster removal, the graft is protected with once-daily dressing changes with petrolatum gauze until it is more fully healed (usually another 7 to 10 days). After this point, the patient should moisturize the graft (and donor site) twice daily for a few months to prevent desiccation, as oil and sweat glands are not transferred with the graft.
- Donor site care
  - Typically, split-thickness donor sites are covered with petrolatum gauze, which is loosely attached to the skin with surgical clips around the perimeter. An ABD pad and a gauze wrap are applied in the OR.
    - On postoperative day 1, the wrap and ABD are removed, and the attached gauze is left open to the air. It can get wet in the shower, but afterward, and several times per day, is dried with the use of a hair dryer set on cool air only.
    - Rewrapping with gauze is performed for the patient to get dressed. The attached petrolatum gauze will form an artificial "scab" on the wound, and re-epithelialization will cause the gauze to become nonadherent at its edges over the next 10 days or so. Trimming of the gauze so that it does not catch and get pulled off is recommended.
  - Other dressings are used for donor site care, each for a specific quality. Silver-impregnated dressings help to prevent infection. Occlusive dressings are significantly less painful but are plagued by infection.

Restrictions

- Judgment is exercised to determine the degree of immobilization prescribed, depending on graft location. It is not necessary to splint the foot for grafts on the lower leg, but patients should keep the extremity elevated to prevent swelling and edema and thus graft loss.

COMPLICATIONS

- Seroma and hematoma are the most common complications. If left untreated, they will lead to graft loss due to lack of contact with the wound surface.
- Infection can destroy a graft, particularly in the early postoperative period, prior to revascularization. In the case of unexplained postoperative fevers, the dressings should be removed early and the wound inspected for infection, which can be potentially treated, with graft salvage.
- Secondary contraction of skin grafts is increased with thinner grafts and with greater expansion of meshed grafts. This can affect underlying joint mobility and aesthetics.
- Incompletely debrided or poorly vascularized wound beds can lead to nonadherence and ultimate loss of the graft.

Chapter 25 Digit Amputations

Steven C. Haase

DEFINITION

- Digital amputation refers to the removal of a finger or thumb, most commonly at the level of the phalanges or interphalangeal joints (**FIG 1**). More proximal amputations that include a significant portion of the metacarpal are referred to as ray amputations. The techniques found in this chapter have been described chiefly for the hand, although similar procedures can be used on the foot in many cases.
- Digital or ray amputation may be indicated for subungual melanoma, or for other large, invasive melanomas of the finger or thumb.

PATIENT HISTORY AND PHYSICAL FINDINGS

- It is important to assess how long the lesion has been present; how fast it has grown; and whether there has been any history of ulceration, bleeding, or pain. Lesions exhibiting rapid growth in addition to these other findings may require more aggressive treatment.
- A patient's age, handedness, occupation, and hobbies should be considered carefully in planning an operation that might significantly affect their function. In some cases, preoperative consultation with a physiatrist and/or occupational therapist may help a patient mentally prepare for what is a sometimes emotionally difficult operation.
- Physical examination should include both the epitrochlear and axillary lymph nodes. For lesions on the toes, examination should include the popliteal and inguinal basins.

Clinically node-negative patients with melanoma greater than or equal to 1 mm in thickness, or thin lesions with other worrisome histologic features, may be candidates for sentinel lymph node biopsy at the time of amputation. (see Part 5, Chapter 27). Patients with clinically involved nodes should undergo fine needle aspiration (FNA) biopsy and staging for distant metastases. These patients may require lymph node dissection at the time of amputation.

IMAGING AND OTHER DIAGNOSTIC STUDIES

- Suspicious lesions require biopsy to establish diagnosis. This should include a full-thickness sampling of the skin and/or nail matrix for accurate assessment of depth of the lesion. Increased depth of invasion is consistently associated with worse prognosis.[1]
- For large or fixed lesions, radiographs of the digit should be obtained to assess for the presence of bone involvement. If radiographs demonstrate significant bone destruction, additional imaging with magnetic resonance imaging (MRI) may be required to assess the full extent of tumor spread in the hand.

SURGICAL MANAGEMENT

Positioning

- For hand operations, patients are positioned supine, with the affected extremity extended on a hand table attached to the operating room table.

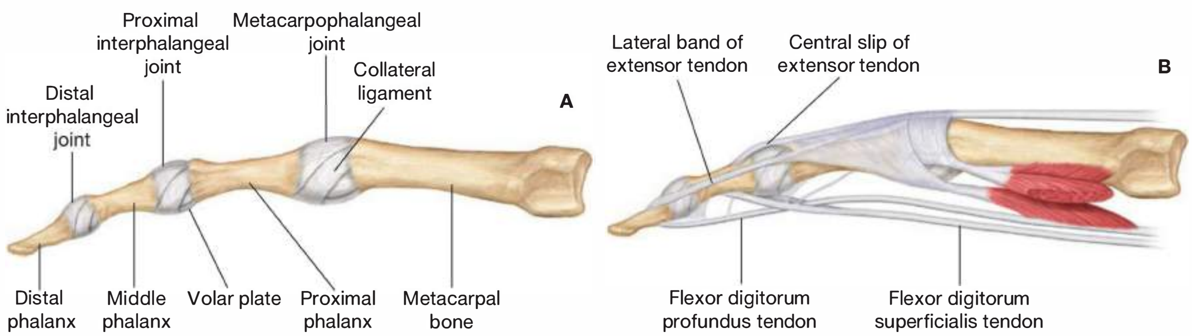


FIG 1 ● **A,B.** Anatomy of the digit.

TECHNIQUES

DIGITAL AMPUTATION

Skin Incision

- The skin incision should be designed as a "fish mouth," such that dorsal and volar flaps are created that close in a more or less transverse line of closure that gives a smooth, rounded contour to the amputation stump.
- The skin flaps should be designed with enough laxity to close over the underlying skeleton to be preserved. Typically, the level of disarticulation or osteotomy should be a few millimeters proximal to the level of the skin incision.
- Ideally, the volar flap can be designed a bit longer than the dorsal flap (**FIG 2A**) to allow resurfacing of the entire

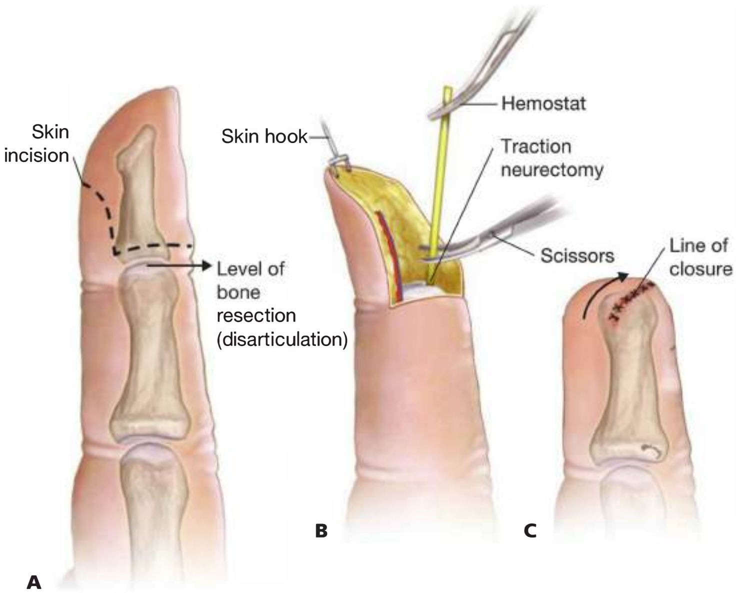


FIG 2 ● Digital amputation technique. **A.** The skin incision is designed just distal to the level of planned bone resection or disarticulation. The volar flap is designed longer than the dorsal flap to allow for coverage of the fingertip with more durable, well-innervated volar skin. **B.** After removal of the skeletal elements and nail complex, the neurovascular bundle is identified on the volar flap, and the nerve is gently dissected proximally, ultimately dividing the nerve while on traction, and allowing the stump to retract proximally. **C.** The volar skin is advanced to cover the wound, and a smooth, rounded closure is performed.

opposition surface (contact surface) of the fingertip with the thicker, more densely innervated palmar skin.

Soft Tissue Dissection

- The soft tissue should be divided in a way that minimizes devascularization of the tissues or skin flaps. Sharp scalpel dissection directly to the bone can be performed both dorsally and volarly, dividing the neurovascular bundles, tendons, and periosteum.

Bone Dissection and Osteotomy

- The periosteum should then be sharply elevated proximally using an elevator or scalpel, circumferentially around the digit. This will allow the bone cut to be positioned slightly proximal to the soft tissue dissection.
- Bone division is most efficiently accomplished with a small oscillating power saw. Instruments such as bone cutters or rongeurs tend to crush and fracture the proximal bone stock and are not recommended.
- If disarticulation is planned, the collateral ligaments should be detached from the proximal aspect of the joint, so this bulky, poorly vascularized tissue is discarded with the amputated part.

Traction Neurectomy

- The neurovascular bundle should be identified with delicate dissection. The artery may be cauterized; the nerve should be dissected away from the artery and followed proximally several millimeters. The nerve should be placed on traction, divided proximally, and allowed to retract (**FIG 2B**). This will ensure that the neuromas that inevitably form at the end of each digital nerve will be located proximally to the contact surface of the fingertip.

Closure

- Closure is usually performed with a single layer of nonabsorbable sutures (**FIG 2C**), which are removed about 2 weeks later. Do *not* suture the extensor tendon to the flexor tendon over the end of the exposed bone; this will functionally shorten the flexor tendon to that digit, resulting in weakened grip strength due to the quadrigia effect.

RAY AMPUTATION

Skin Incision

- Incisions are designed to avoid a scar in the webspace. Conceptually, the goal is to preserve one webspace and resect the other, rather than having a webspace at the operative site with a contracted scar in its midline (**FIG 3A–E**).
- Usually the dissection is performed mostly through a dorsal incision, which extends longitudinally from the base of the finger. Palmar incisions are limited to avoid the possibility of sensitive scarring in that location.

Dorsal Dissection

- Major sensory nerves in the subcutaneous tissue are preserved when possible. The extensor tendon is divided proximally and the metacarpal exposed.
- The periosteum of the metacarpal is incised longitudinally and subperiosteal dissection carried out circumferentially along the shaft of the bone. The attachments of

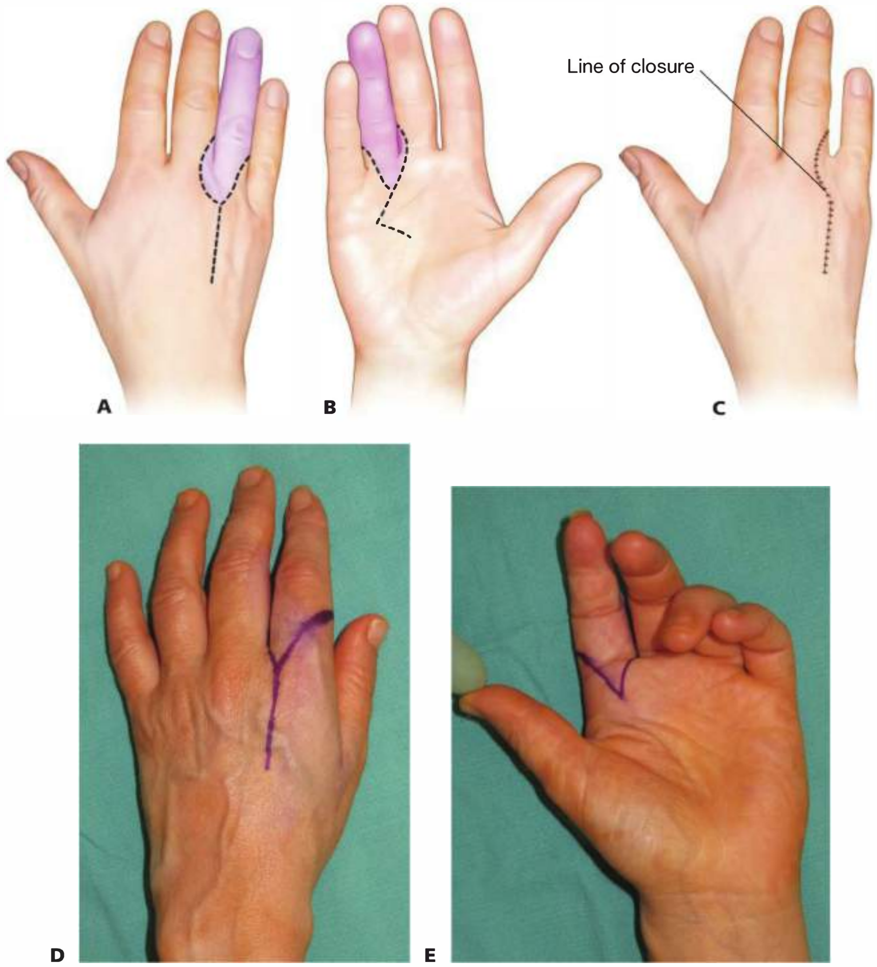


FIG 3 ● Skin incision for ray amputation. **A.** Dorsal incision can be designed proximally as a straight line, or as a zigzag, extending distally to encircle the base of the finger to be removed. Note the preservation of an intact webspace for closure, rather than dividing the web with the incision. **B.** Volar incision must be a zigzag or chevron-style incision to avoid longitudinal scars crossing the flexion creases of the palm. **C.** Closure is shown, with preservation of the delicate webspace skin. **D.** Dorsal and **(E)** volar skin markings for index finger ray amputation.

the intrinsic muscles are disrupted with this dissection; most of these do not require transfer or repair, with the exception of the origin of adductor pollicis (FIG 4). When removed from the middle metacarpal during ray amputation, this muscle origin should be reattached to the index metacarpal with bone anchors or transosseous sutures.

Bone Dissection

- For index, middle, and small finger ray amputations, the osteotomy should be performed distal to the insertion of the wrist extensors: extensor carpi radialis longus, extensor carpi radialis brevis, and extensor carpi ulnaris, respectively (refer to FIG 5).
- For the ring finger metacarpal, which has no extrinsic tendon attachments, the entire metacarpal can be disarticulated at the base and removed (if no transposition is planned).
- For middle or ring finger ray amputations, some effort should be made in eliminating the troublesome gap between digits that can result.[2,3] This can be accomplished by two principle methods:
  - Meticulous soft tissue repair, including permanent sutures in the intermetacarpal ligaments and careful postoperative splinting (FIG 6)

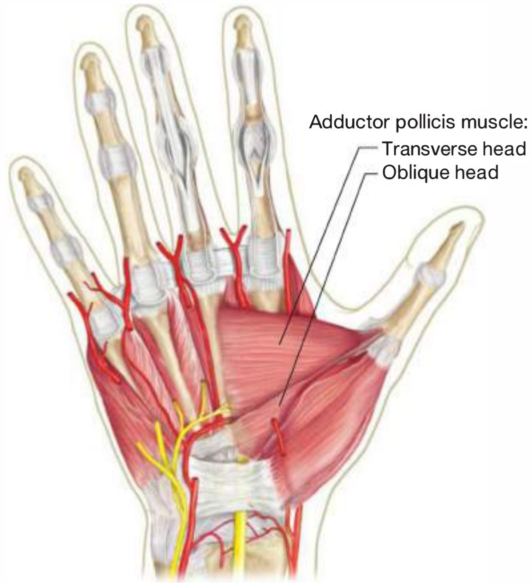


FIG 4 ● Anatomy of the adductor pollicis.

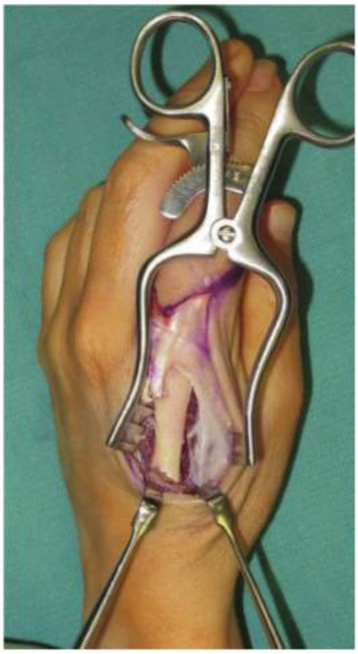


FIG 5 ● Dorsal dissection completed, with division of the metacarpal at the proximal shaft, preserving the base with its tendon attachments.

- Transposition of the adjacent border digit, requiring bony fixation of the metacarpal, and often longer postoperative immobilization (**FIG 7**)
- Once the bone has been transected, dissection proceeds around the side(s) of the metacarpal head to divide the intermetacarpal ligaments.

Volar Dissection

- The volar dissection is usually done last. The digital neurovascular bundles are identified and transected distally, keeping them rather long, in contrast to the shortening that is done for phalangeal-level amputations (**FIG 8A,B**).
- Once the ray amputation is complete, the digital nerves are folded dorsally into the periosteal sleeve left behind after metacarpal removal (**FIG 9**). The nerves are secured in this deep, padded area, surrounded by healthy interosseous muscle, where they are protected from trauma during routine hand function.

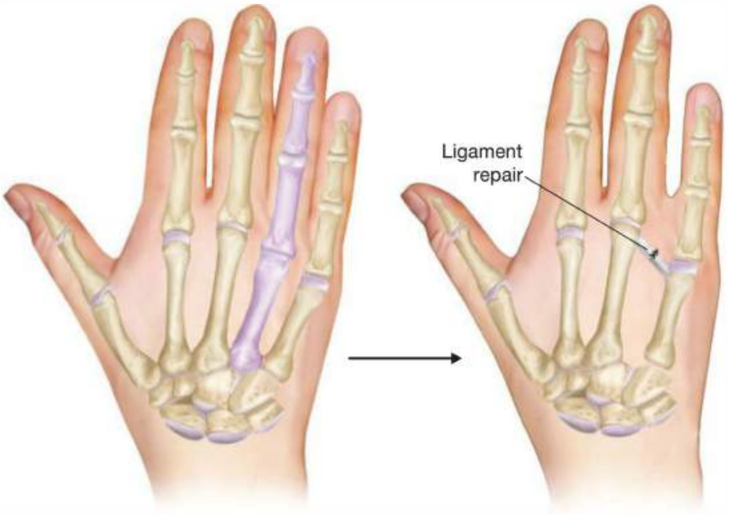


FIG 6 ● Ray resection without transposition. Using permanent sutures to reapproximate the intermetacarpal ligament, as well as meticulous skin closure, the finger "gap" can be closed with soft tissue repair alone.

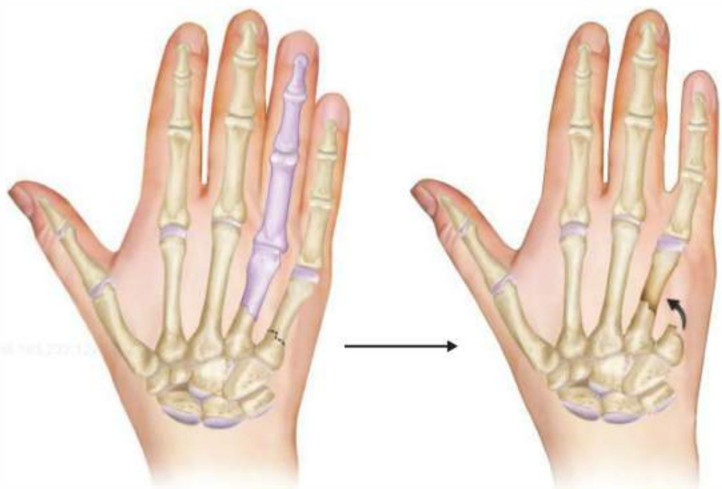
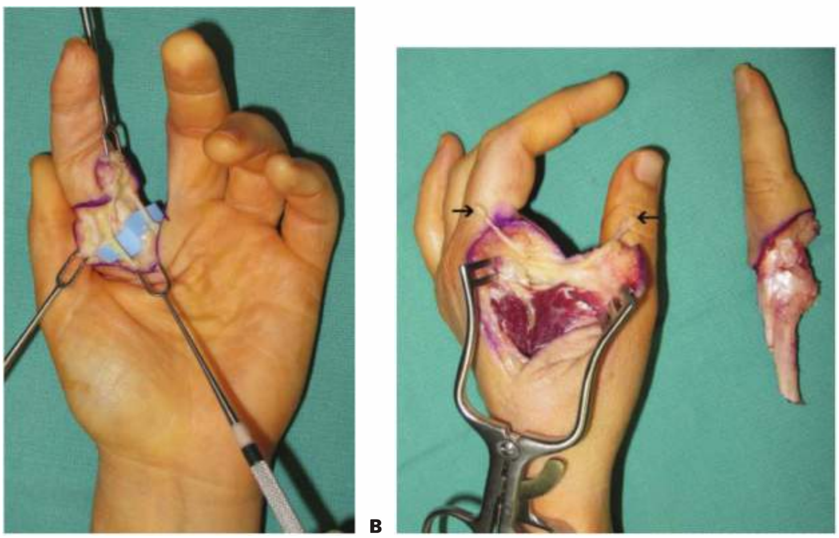


FIG 7 ● Ray resection with transposition. Transposition requires osteosynthesis of the involved metacarpals with wires, pins, or plate and screws. One advantage is the potential to minimize length discrepancy of the small finger by preserving added length at the base of the ring metacarpal, as illustrated here.



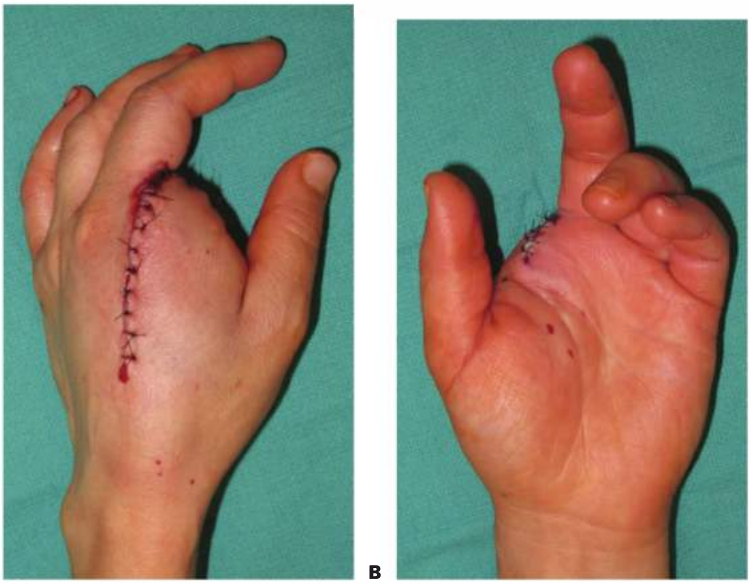
A B

FIG 8 ● **A.** Volar dissection with identification of the digital nerves, which are preserved with some length, so they can be relocated in the deeper dorsal tissues at the time of closure. **B.** Ray resection completed, with digital nerves transected *(black arrows)*.

FIG 9 ● Digital nerves *(white arrow)* transposed deep into the periosteal sleeve between the interosseous muscles.

Closure

- Skin closure should be meticulous, addressing excess laxity and/or standing cutaneous deformities ("dog ears") if encountered (**FIG 10A,B**). The relative tightness or looseness of the dorsal skin closure, in particular, can help maintain proper orientation of the adjacent digits and help avoid malalignment or "scissoring."



A B

FIG 10 ● **A,B.** Final wound closure, which avoids extensive incisions on the sensitive palmar skin.

PEARLS AND PITFALLS

Digital amputations	■ When required, retract the skin edges with skin hooks only. This avoids tissue damage that can occur from repeated grasping of the tissues with forceps.
Quadrigia effect	■ Because the flexor digitorum profundus tendons share a common muscular origin, effectively shortening any one of the tendons can lead to an overall decrease in grip strength. During force generation, the foreshortened tendon becomes tight early, preventing transmission of force to the adjacent digits.
Neuroma detection	■ It can be difficult to differentiate symptomatic neuroma from ordinary hypersensitivity after finger amputation. A diagnostic injection of local anesthetic into the specific area of the neuroma, to anesthetize the nerve in isolation, can confirm the diagnosis of neuroma.

POSTOPERATIVE CARE

- For digital amputations, the postoperative dressing should be amply padded to allow for postoperative swelling. A hand-based splint for a short time (1 or 2 weeks) can be used if desired. Prolonged immobilization should be avoided so that the remaining finger joints (including the adjacent digits) do not become stiff.
- For ray amputations, the hand should be splinted for the first 2 weeks, taking care to maintain proper alignment of the digits in the splint, to avoid divergence or convergence of the fingers on either side of the amputation site. Sometimes, temporary pinning of the fingers is warranted to maintain good alignment in this early postoperative period, as the soft tissues are healing. Splinting beyond 2 weeks may still be required for comfort and protection, but the orthosis use should not interfere with early mobilization of the interphalangeal and metacarpophalangeal joints, which may become permanently stiff if immobilized for too long.
- In all cases, consultation with a certified hand therapist may be of benefit to the patient, for help with orthosis fabrication, edema control, joint mobilization, scar massage, desensitization, and molding of the finger stump for prosthesis wear, if desired.

OUTCOMES

- Compared to the contralateral hand, patients with single-ray amputations have on average 13% less key pinch strength, 26% less oppositional strength, and 28% less grip strength at long-term follow-up.[4,5]

COMPLICATIONS

- Acute complications such as bleeding, infection, and delayed healing should be uncommon.
- Chronic complications include phantom pain and painful neuromas.
  - Persistent sensation in an amputated part is common (over 80% in one prospective study) but is not always painful.[6]
  - Neuromas will form at the stump of divided nerves but are not usually symptomatic if the nerve endings are properly padded and located away from contact surfaces.

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Chapter 26

Resection of Head and Neck Melanoma

Scott A. McLean

DEFINITION

- Resection of head and neck cutaneous melanoma is performed with wide surgical margins intended to achieve histologically negative margins. Current guidelines for wide excision of the primary lesion, with an adequate margin of surrounding normal skin and deep soft tissue necessary to achieve clear surgical margins, are based on depth of invasion of the primary lesion (Table 1).[1] However, given the complex anatomic and functional nature of the head and neck, resection margins are sometimes modified to preserve normal function. Reconstruction of complex head and neck defects is often delayed until final histopathologic evaluation of margins is deemed negative. Reconstruction can be accomplished with primary closure, split- or full-thickness skin grafts, local or regional adjacent tissue transfer, or free tissue transfer.
- Patients with invasive melanoma and no clinical evidence or regional metastatic disease may warrant assessment of regional lymph nodes via sentinel lymph node (SLN) biopsy. SLN biopsy has been shown to be both accurate and prognostic in head and neck melanoma.[2,3] Current recommendations on use of SLN biopsy are based on depth of invasion of the primary lesion as well as the presence of adverse histologic features such as ulceration and mitotic rate. Patients with melanoma measuring 1 mm or greater should be offered SLN biopsy. SLN biopsy should also be considered in patients with a thickness of between 0.76 and 0.99 mm if they have any of the following adverse features: greater than or equal to 1 mitotic figure per square millimeter, lymphovascular invasion, satellitosis, or young patient age. SLN biopsy may also be considered with thin melanoma when the deep margin was broadly transected.[1–5]
- Patients who present with clinical evidence of regional metastatic disease and patients who are found to have micrometastatic disease on sentinel lymph node biopsy (SLNB) are offered completion lymph node dissection (CLND). Based on the site of the primary lesion, the nodal basins included in the CLND may include the postauricular and suboccipital lymph nodes, the parotid gland and its associated lymph nodes, and the cervical lymph nodes levels I to V (Table 2) (see Part 5, Chapter 31).[6]

Table 1: Surgical Margin Recommendations for Cutaneous Melanoma

Primary Tumor Thickness	Clinically Measured Surgical Margin
In situ	0.5–1.0 cm
≤1 mm	1 cm
1.01–2.0 mm	1–2 cm
2.01–4 mm	2 cm
>4 mm	2 cm

From National Comprehensive Cancer Network. Guidelines version 4.2014. http://www.nccn.org. Accessed August 2014.

Table 2: Nodal Basins Included in Therapeutic Lymph Node Dissection

Primary Cutaneous Lesion Location	Nodal Basins Included in Therapeutic Lymph Node Dissection
Anterolateral scalp, temple, lateral forehead, lateral cheek, and ear: all arising anterior to coronal plane through the external auditory canal	Parotid and cervical lymphatic levels I–V
Chin and neck	Cervical lymphatic levels I–V
Scalp and occiput posterior to coronal plane through the external auditory canal	Postauricular, suboccipital, and cervical lymphatic levels II–V

DIFFERENTIAL DIAGNOSIS

- Cutaneous melanoma of the head and neck usually presents as a pigmented lesion of varying size, shape, and color. Other benign and malignant cutaneous lesions can present in a similar fashion and include the following:
  - Seborrheic keratosis
  - Junctional nevi
  - Compound nevi
  - Dermal nevi
  - Hemangioma
  - Blue nevus
  - Pyogenic granuloma
  - Spitz nevus
  - Pigmented actinic keratosis
  - Pigmented or nonpigmented basal cell carcinoma
  - Squamous cell carcinoma

PATIENT HISTORY AND PHYSICAL FINDINGS

- A thorough history of the lesion of concern should include the duration of clinical symptoms; the presence of pruritus; bleeding; and any changes in the size, shape, or color of the lesion.
- Most cutaneous melanomas will present as either a new pigmented lesion or changes in an existing lesion that exhibit the ABCDs of melanoma: A–Asymmetry, B–Border, C–Color, D–Difference (a change in the lesion).
- A thorough past medical history should be performed and include information regarding any previous malignancies, past surgical procedures, current medications and allergies, family history of cancer, problems with anesthesia, and social history—including smoking history, occupation, sun exposure, and history of blistering sunburns.

- A focused review of systems should also be completed and include review of any constitutional, musculoskeletal, neurologic, respiratory, gastrointestinal, hepatic, skin, and lymphatic signs or symptoms.
- All newly diagnosed melanoma patients should undergo full body skin evaluation.
- A complete head and neck exam should be performed on every patient and include a thorough skin exam and palpation of the suboccipital, postauricular, parotid, and cervical nodal basins to rule out the presence of clinically palpable regional metastatic disease.
- A detailed cranial nerve exam should be performed to document preoperative cranial nerve function.

IMAGING AND OTHER DIAGNOSTIC STUDIES

- Newly diagnosed patients with localized cutaneous melanoma are not recommended to undergo distant metastatic workup. In the absence of clinical signs or symptoms of distant metastatic disease, no imaging modality has been shown to be useful in detecting occult metastatic disease and in fact more often lead to false-positive findings, requiring further unnecessary invasive procedures.[1]
- Chest x-ray and serum lactate dehydrogenase are also both insensitive for the detection of occult metastatic disease.
- Many patients will require preoperative chest x-ray, complete blood count (CBC), and electrocardiogram (EKG), depending on age, health status, and need for general anesthesia.

SURGICAL MANAGEMENT

Preoperative Planning

- Prior to proceeding to the operating room, the primary cutaneous lesion should be reexamined and confirmed with the patient. The surrounding skin should also be reexamined to make sure no new lesions have developed. In addition, the plan regarding surgical margins and primary closure versus delayed reconstruction should be confirmed with the patient. All cranial nerve functions in the operative field should also be retested prior to surgery.
- Patients who are scheduled for SLN biopsy in conjunction with excision of their primary cutaneous lesion will undergo lymphoscintigraphy prior to their definitive excision. This procedure is done in the nuclear medicine department and is enhanced by the use of single-photon emission computed tomography–computed tomography (SPECT-CT) imaging.[7] Prior to proceeding to the operating room, the SPECT-CT/lymphoscintigraphy should be reviewed to determine the likely location of the SLN(s) (**FIGS 1** and **2**). These locations should then be discussed with the patient and marked appropriately. If the location of a likely SLN is in close proximity to a cranial nerve, this should be discussed with the patient and the cranial nerve function should be well documented.
- Appropriate use of antibiotics and deep vein thrombosis (DVT) prophylaxis should also be discussed prior to proceeding to the operating room.
- In addition, it is crucial to have a thorough discussion with the anesthesia team regarding the use of long-acting paralytics. If cranial nerves are likely to be in the operative field, as is almost always the case in the resection of head and neck melanoma, the anesthesia team must be aware to avoid the use of long-acting paralytics.

Positioning

- Patients who are scheduled for wide local excision alone (melanoma in situ or T1a lesions) often can tolerate surgery under sedation with monitored anesthesia. In these cases, the head of the bed is often rotated 90 degrees away from the anesthesia cart to allow for easy access to the surgical field. Oxygen delivery methods can be designed to avoid

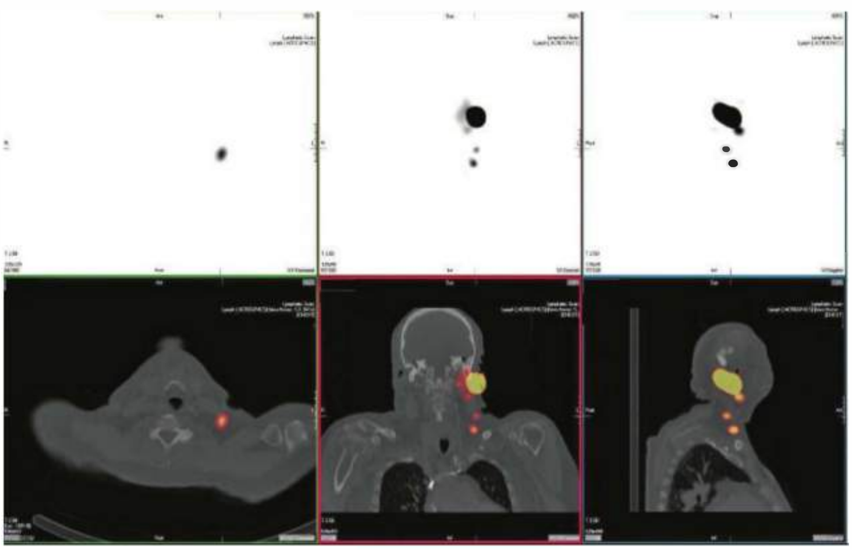

FIG 1 • Lymphoscintigraphy with SPECT-CT imaging after injection of left postauricular primary melanoma site. Imaging reveals a left level II lymph node as well as secondary drainage to left levels Va and Vb.

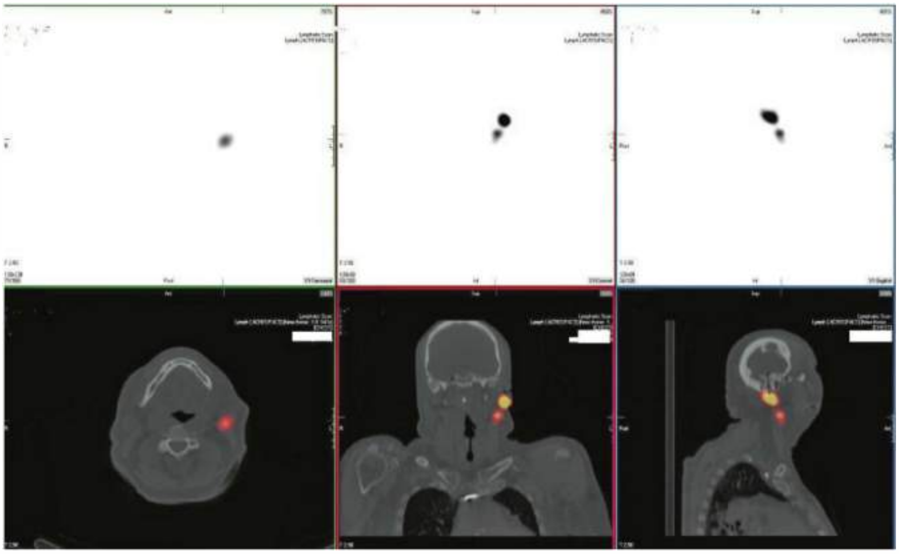

FIG 2 ● Lymphoscintigraphy with SPECT-CT imaging after injection of left postauricular primary melanoma site. Careful observation reveals the level II lymph node to be located just inferior to the tail of the parotid and just anterior to the sternocleidomastoid muscle. Likely, this represents an external jugular lymph node.

crossing the surgical field and may include either nasal cannula or mask. In these cases with free-flowing oxygen, it is very important to discuss the risk of fire with the entire operating room team. The entire face and neck can be prepped into the operative field. Wide draping can then be used with attention to avoid any tenting of drapes, which could lead to pooling of oxygen in the operative field (**FIG 3**).

- Patients who are scheduled to undergo SLN biopsy in conjunction with the primary excision are almost always placed under general anesthesia. Again, the use of long-acting paralytics must be avoided. The head of the bed can be rotated 180 degrees away from the anesthesia cart to allow for easy surgical access to the operative field. Most primary lesions can be excised with the patient in the supine position. Rarely, the patient may need to be turned prone to allow access to the posterior scalp or suboccipital nodal basin. With the patient intubated, either half of the face and neck or the entire face and neck can be prepped and draped, depending on the need for surgical access.

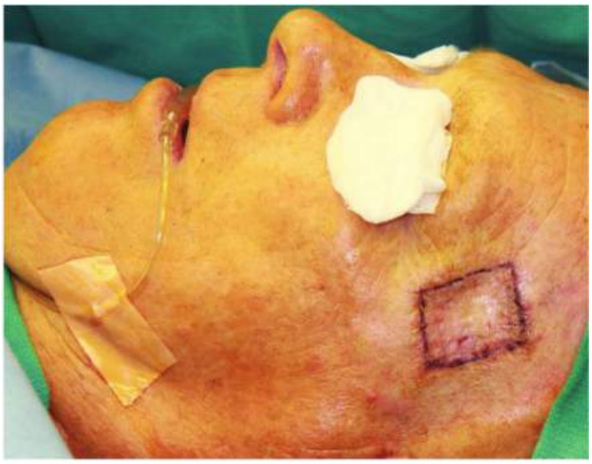

FIG 3 ● Patient is under sedation with the entire face prepped to allow for wide draping and to avoid pooling of oxygen within the surgical field.

PLACEMENT OF PLANNED INCISIONS

Primary Lesion Excision Site

- The primary lesion is carefully inspected and cleaned with a moist sponge. The lesion should be marked out with careful attention to include any evidence of dermal extension. This may include any pale, erythematous, or lightly pigmented extension from the primary lesion (**FIG 4**).
- With the primary lesion now marked, the appropriate margin is then marked circumferentially around the visible lesion. The excision margin is most often 1 to 2 cm, depending on the depth of invasion of the primary lesion.
- In certain functional situations, the excision margin may be left a little short of standard margins. For example, if a lower eyelid lesion requires 2-cm margins, but at 1 cm the excision would cross the lid margin, it may be acceptable to use 1 cm (**FIG 5**). In this case, the surgeon must be willing to reexcise this margin should it return positive on final histopathologic review.

Injection of Methylene Blue Dye

- To assist with SLN identification, the dermis surrounding the primary lesion is injected with methylene blue dye. Usually only 1 or 2 mL of dye is injected (**FIG 6**).

FIG 4 ● The main lesion is pink and raised. Notice the pigmented extension into the surrounding skin. The entire pigmented area must be marked out prior to marking out circumferential margins.

- The injection is made with a 30-gauge needle with the bevel of the needle facing up. There should be slight pressure as the dye is injected and visually the dermis should begin to turn blue. If the dermis is not turning blue or the injection is passing with no resistance, the needle is likely too deep. This will cause the subcutaneous tissue to turn blue and can make recognition of tissue planes more difficult.
- Several injections should be made into the dermis surrounding the primary lesion until the lesion is surrounded by blue dye (**FIG 7**).

FIG 5 ● In this planned resection, the lower eyelid margin is left a little narrow in the hopes of avoiding postoperative ectropion. The margins must be carefully examined by pathology and reexcised should they return positive.

FIG 6 ● Methylene blue dye injected circumferentially into the dermis surrounding the lesion. A 30-gauge needle is used and effort is made to inject directly into the dermis only.

Placement of Incisions for Sentinel Lymph Node Biopsy

- The preoperative lymphoscintigraphy/SPECT-CT is again reviewed to help determine the approximate location of the SLNs in relation to visible or palpable anatomic structures. The intraoperative gamma probe can then be used to confirm the site of the sentinel nodes. Once the location is confirmed, incisions are marked to allow access to remove the sentinel nodes (**FIG 8**).
- Marking the planned incisions should take into account placement along relaxed skin tension lines. In addition, consideration should be given to any future potential procedures such as rotation flap reconstruction sites or the need for parotidectomy and cervical lymphadenectomy (**FIG 9**).
- At this point, all planned incisions are usually injected with local anesthesia. Typically 1% lidocaine with 1:100,000 epinephrine solution is used. A small volume should be used to help avoid inadvertent paralysis of cranial nerves close to the operative sites.

FIG 7 ● Methylene blue dye injected into the dermis circumferentially around the lesion.

FIG 8 ● The intraoperative gamma probe is used to confirm the sites of the potential SLNs.

FIG 9 ● Small incisions are planned along relaxed skin tension lines.

EXCISION OF THE PRIMARY LESION

Skin Incision

- The skin surrounding the primary lesion is now sharply incised, being careful to follow the exact marking. The incision is carried thru the subcutaneous tissue, now being careful to avoid beveling the cut toward the primary lesion.

Determining the Depth of the Excision

- Once the peripheral incisions are made around the primary lesion, the depth of the excision must be determined. In general, the depth of the excision is carried to the fascial plane deep to the subcutaneous tissue. The depth of the excision is highly dependent on the location of the primary lesion, the size and depth of the lesion, and the amount of subcutaneous tissue deep to the lesion.
- For facial lesions, the excision is most often carried to a plane just above the facial musculature (**FIG 10**).
- Preauricular lesions are excised to a depth of the parotid fascia (**FIG 11**).
- Nasal lesions are excised above the level of the nasal cartilages.
- Auricular lesions are removed either with or without the underlying cartilage, depending on the size of the primary lesion. In many cases, the underlying cartilage should be removed to ensure adequate negative margins.
- Scalp lesions are usually excised in a subgaleal plane with the underlying pericranium left intact. In large bulky lesions, the underlying pericranium can also be removed to allow for wider clear margins (**FIG 12**).

FIG 10 ● The facial lesion has been excised to a depth just above the facial musculature.

FIG 11 ● Preauricular lesions are excised to a depth just above the parotid fascia.

- Neck skin can be excised either with or without the underlying platysma muscle, depending on the size of the lesion. If there is any concern about deep invasion, it is easy to remove platysma.
- With all excisions, attention must be paid to avoiding injury to any underlying cranial nerves.

Orientation

- Once the primary lesion is completely excised, it must be carefully oriented and marked for permanent pathology. Marking stitches should be easily understood and allow for easy communication between surgeon and pathologist. Any areas of special concern should also be noted on the pathology request, such as when margins are less than ideal due to functional considerations.

FIG 12 ● Scalp lesions are usually excised in a subgaleal plane with the underlying pericranium left intact.

SENTINEL LYMPH NODE BIOPSY

Intraoperative Gamma Probe

- The intraoperative gamma probe is now used to confirm the site of the SLN. In some cases, the primary excision site should be surveyed to look for potential SLNs, which may be deep to the primary excision site. These nodes may not appear on the SPECT-CT due to the shadowing caused by the high intensity of the primary lesion injection site. Sometimes, a blue lymphatic channel can be seen at the edge of the excision site and can be followed to an SLN (**FIG 13**).

Incision and Node Dissection

- Before proceeding with lymph node dissection, it is important to confirm that the patient has not been given any paralytic agents.
- After confirming the previously marked SLN sites with the gamma probe, the incision is made and carried to the deep soft tissue. Usually a 2- to 3-cm incision is long enough to allow for easy dissection and visualization.
- With the incision made, skin hooks are used to retract the skin edges. Blunt dissection is then used to enter the deeper soft tissue. In the neck, dissection will go deep to the platysma muscle. In the preauricular region, the dissection will often proceed deep to the parotid fascia into the parotid parenchyma.
- The intraoperative gamma probe is used frequently to help determine the direction of further dissection. As the tip of the probe gets closer to the sentinel node, the gamma counts will increase.
- Oftentimes, a blue lymphatic channel can be identified and can then be followed to the SLN (**FIGS 14** and **15**).
- Once the node is identified, it is carefully removed with blunt dissection and judicious use of bipolar electrocautery.
- The node is then examined away from the patient to document the gamma count and the presence of blue dye. The node is labeled with the anatomic

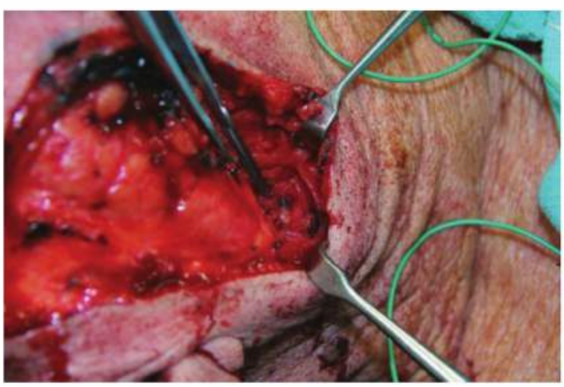

FIG 13 ● The SLN is identified deep to the primary excision site.

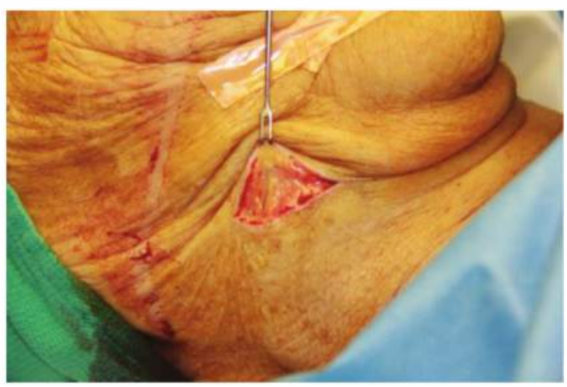

FIG 14 ● Oftentimes, a blue lymphatic channel can be identified.

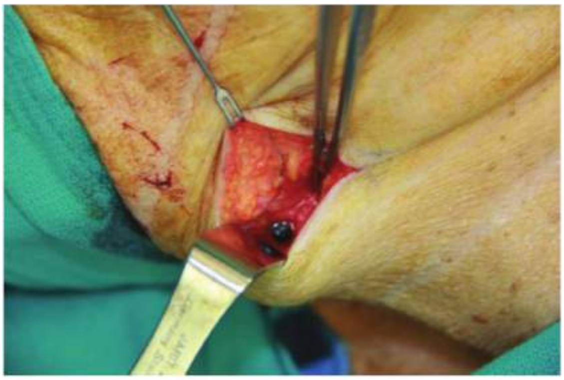

FIG 15 ● Lymphatic channels can then be followed to the SLN.

location, gamma count, and presence of blue dye and sent for histopathology.

Confirmation and Closure

- After removing the SLN, the gamma probe is then used to reexamine the surgical bed. The area where the node was removed should now have a very low count compared to the count prior to node removal. As a general rule, the count should drop to less than 10% of the count prior to node removal. If the count remains elevated, further dissection is warranted to remove any other SLNs identified.
- Once all potential SLNs are removed, the surgical bed is irrigated with saline. A Valsalva maneuver should be performed to confirm there is no ongoing bleeding. The incision can be closed in standard fashion and a small pressure dressing applied.

PRIMARY CLOSURE VERSUS DELAYED RECONSTRUCTION OF THE PRIMARY SITE

Primary Closure

- After the primary lesion has been resected and the SLN biopsy completed, it is time to determine the best method of closing the primary site. If the primary site can be closed without distorting the surgical margins and without the use of rotation flaps or grafts, this can be done immediately. Should a margin return positive on permanent pathology, it would still be easy to return for wider excision.
- This is usually the case for small lesions or for lesions on the neck where excess skin can easily be advanced.
- In these cases, bilateral Burrow's triangle excisions can be performed along the direction of relaxed skin tension lines. The skin is then undermined, advanced, and closed with deep absorbable suture and superficial suture at the skin edge.
- The wound is then dressed with a small pressure dressing, which can be removed after 24 hours.

FIG 16 ● Circumferential purse-string suture is used to decrease the size of the wound.

Delayed Reconstruction

- In many cases, reconstruction of the primary resection site will require significant tissue rearrangement, skin grafting, or even free tissue transfer. In these situations, it is preferable to wait for final histopathologic confirmation of negative surgical margins prior to proceeding with definitive reconstruction.
- In these cases, the size of the wound can often be decreased with use of a circumferential purse-string suture (**FIG 16**).
- The wound can then be dressed with a moist bolster dressing using Vaseline or Xeroform gauze, bacitracin, cotton balls (**FIG 17**), or a foam-type dressing (**FIG 18**). The bolster dressing can be secured with either silk suture or surgical staples.
- Wound infections are very rare in the head and neck and therefore postoperative antibiotics are not routinely used even in the setting of an open wound with a bolster

FIG 17 ● A Xeroform gauze dressing is placed over the resection site.

FIG 18 ● A Reston foam bolster is secured to the scalp to apply pressure after either resection or skin graft reconstruction.

applied. In some cases, such as immune suppression or previous infection, antibiotics may be indicated.

Skin Graft and Rotation Flap Reconstruction

- Once the final surgical margins have returned clear, definitive reconstruction can be completed. The method of reconstruction is dependent on the site of the defect and the goals of the patient. Complex facial defects should be addressed by colleagues with experience in facial plastic and reconstructive surgery.
- Facial skin and preauricular skin defects are most often closed with the use of cervicofacial rotation flaps and transposition flaps. Incisions are planned along relaxed skin tension lines when possible and are carried to postauricular and posterior cervical skin. These flaps create standing cutaneous deformities along the arc of rotation, which will need to be excised. Very large defects can be closed and achieve excellent cosmetic outcomes (**FIGS 19–21**).
- Eyelid defects can be very difficult to repair without causing significant ectropion. Lid-tightening procedures can be done in conjunction with skin grafts, transposition flaps, and rotation flaps. Oculoplastic surgeons should be involved if there is concern about postoperative eyelid function (**FIGS 22–24**).
- Nasal defects can be closed with skin grafts, composite grafts, transposition flaps, advancement flaps, and the interpolated paramedian forehead flap. Each technique can yield excellent results when used in the proper clinical setting (**FIGS 25–27**).
- Auricular defects are most easily closed with wedge excision and advancement flap closure. Transposition flaps can be used to reconstruct large defects and achieve acceptable cosmetic results (**FIGS 28** and **29**).

FIG 19 ● Large facial defect with posterior cervical incision made to allow for cervicofacial rotation flap reconstruction.

FIG 20 ● Cervicofacial rotation flap brought into position.

FIG 21 ● Excellent cosmetic result several weeks after cervicofacial reconstruction of large facial defect.

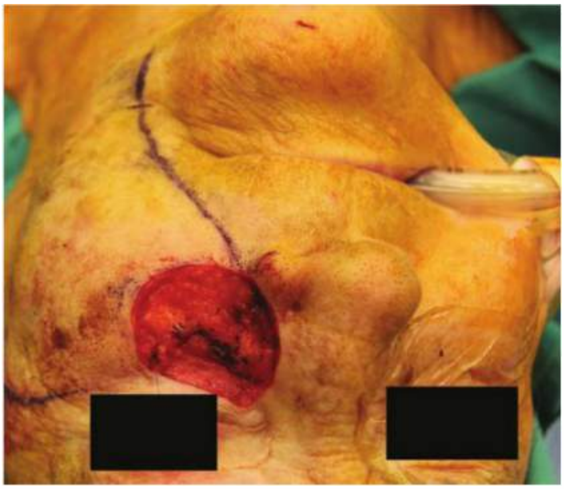

FIG 22 ● Large rotation flap designed for reconstruction of lower eyelid defect.

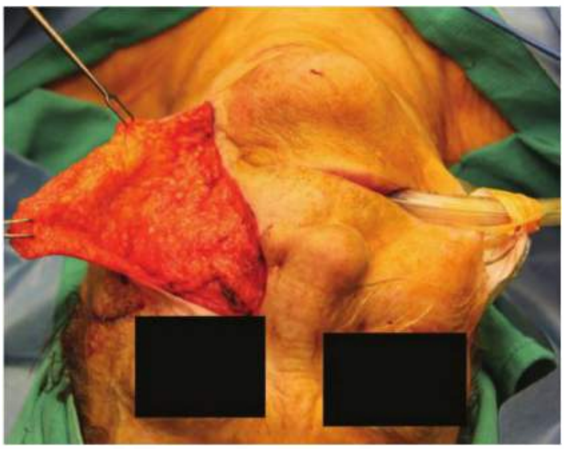

FIG 23 ● The flap is raised far enough to allow for tension-free closure.

FIG 24 ● The rotation flap is sewn into place with no tension inferiorly, thus avoiding postoperative ectropion.

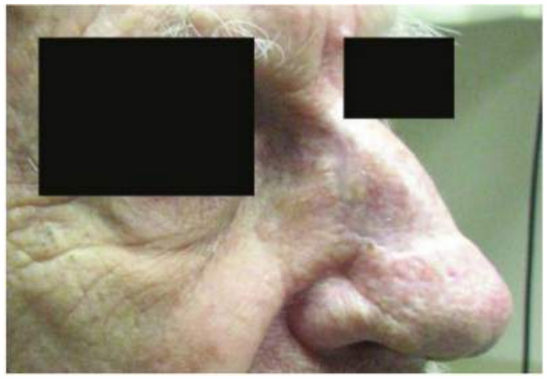

FIG 25 ● Postoperative result after full-thickness skin graft reconstruction of the nasal dorsum.

- Scalp defects are most easily closed with the use of full-thickness or split-thickness skin grafts. In older patients, large amounts of supraclavicular skin can be harvested and used to graft large scalp defects. The skin is thinned to the dermal layer, making sure to remove all subcutaneous tissue. The skin graft can be placed over intact periosteum or can be grafted directly to exposed bone. In this case, a burr can be used to burr down the bone until punctate vessels are seen. The graft is then secured with a bolster dressing and left intact for 7 to 10 days.
- Neck skin defects can almost always be closed with adjacent tissue transfer reconstruction as described earlier.

FIG 26 ● Postoperative result after paramedian forehead flap reconstruction of right lateral nasal wall and alar rim with use of ear cartilage grafting to alar rim (lateral view).

FIG 27 ● Postoperative result after paramedian forehead flap reconstruction of right lateral nasal wall and alar rim with use of ear cartilage grafting to alar rim (frontal view).

FIG 28 ● Resection of left lower ear and helical rim.

FIG 29 ● Reconstruction of left ear with postauricular transposition flaps.

PEARLS AND PITFALLS

Indications and preoperative workup	■ A complete history and physical exam should be performed including full body skin check. ■ If SLN biopsy is indicated, lymphoscintigraphy with SPECT-CT imaging should be reviewed prior to surgery. ■ A detailed cranial nerve exam should be completed prior to proceeding with surgery.
Excision of primary lesion	■ The primary lesion should be marked to include any pale, erythematous, or pigmented adjacent skin. One to 2-cm circumferential margins are marked depending of depth of invasion of the primary lesion. ■ The depth of excision needs to include enough normal tissue to ensure complete surgical excision. ■ Mark the specimen with clear orientation sutures to allow for definitive margin analysis.

SLNB	■ Review preoperative lymphoscintigraphy/SPECT-CT to identify likely sites of SLNs. ■ Carefully, inject methylene blue dye circumferentially into the dermis surrounding the primary lesion. ■ Ensure anesthesia has not paralyzed the patient prior to lymph node surgery. ■ Make incisions along relaxed skin tension lines and keep in mind the possible need for rotation advancement flap reconstruction or future parotid/neck dissection incisions. ■ Use the intraoperative gamma probe to localize SLNs and make sure that all potential SLNs are removed.
Closure vs. delayed reconstruction	■ If wound can be closed by simple advancement flap without reorienting margins, then wound can be closed primarily. ■ If rotation/transposition flap or skin graft is needed, it may be wise to delay reconstruction until final surgical margins are clear. ■ Facial plastic and oculoplastic colleagues should be consulted for closure of complex wounds.

POSTOPERATIVE CARE

- Small pressure dressings are usually applied to small advancement flap reconstruction sites as well as SLN biopsy sites and are left intact for 24 hours. Larger cervicofacial advancement flap reconstruction sites are dressed with Jobst pressure dressings and are left intact for 2 to 3 days. When the dressings are removed, the incisions should be kept clean with half-strength peroxide and moist with Vaseline. Topical antibiotic ointment may be used for 2 to 3 days but can cause skin irritation with longer use. When skin grafts are used, the bolster dressing is left intact for 7 to 10 days. After the bolster is removed, the graft is kept moist with Vaseline for 1 to 2 weeks or until the wound has completely healed.

OUTCOMES

- In the hands of experienced head and neck surgeons, an SLN can be identified in nearly all patients. In patients with cutaneous melanoma of the head and neck with Breslow depth of 1 mm or greater or with Breslow depth between 0.75 mm and 0.99 mm with other adverse features, approximately 20% are found to have a positive SLN. Upon completion lymphadenectomy, 25% of patients with a positive SLN will have at least one more positive non-SLN. Approximately 4% of patients with negative SLNs will fail regionally within the sentinel node basin.[2]
- Positive SLN status is the factor most strongly associated with decreased recurrence-free survival (hazard ratio [HR] 4.23) and decreased overall survival (HR 3.33).[2] The estimated 4-year overall survival approaches 84% in patients with negative SLN biopsy and decreases to an estimated 58% in patients with a positive SLN.[2]

COMPLICATIONS

- Seroma or hematoma at the SLN biopsy site
- Infection at either the SLNB or primary resection site
- Wound dehiscence or epidermolysis of rotation flap reconstruction site
- Decrease in sensation at either surgical site
- Theoretical risk of cranial nerve injury
- Poor cosmetic outcome

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Chapter 27 Sentinel Lymph Node Biopsy for Melanoma

Merrick I. Ross Michael Kim

DEFINITIONS

- The sentinel lymph node(s) are defined as the first nodes to receive direct lymphatic drainage from the cutaneous site of a primary melanoma and therefore the most likely lymph node(s) to harbor microscopic metastases. The technique of lymphatic mapping and sentinel lymph node (SLN) biopsy is used to determine the histologic status of the regional lymph node basin(s) in patients with early-stage (American Joint Committee on Cancer [AJCC] clinical stages I and II) melanoma without performing a formal lymph node dissection. The SLN concept as well as the minimally invasive technique, which initially used intradermal injections of vital blue dye[1] (**FIG 1**) and was later modified with the addition of radiolabeled colloid injections[2,3] at the site of the primary melanoma, was first studied and reported in detail by Morton and colleagues, demonstrating proof of concept in a large group of patients with primary melanoma and clinically negative regional lymph nodes.[1] This and several subsequent studies have confirmed that the lymphatic drainage patterns from specific regions of the skin can be accurately determined, the SLN is the most likely first site of regional lymph node metastasis, and if the SLN is histologically negative, the remaining lymph nodes in the mapped basin are unlikely to contain disease.

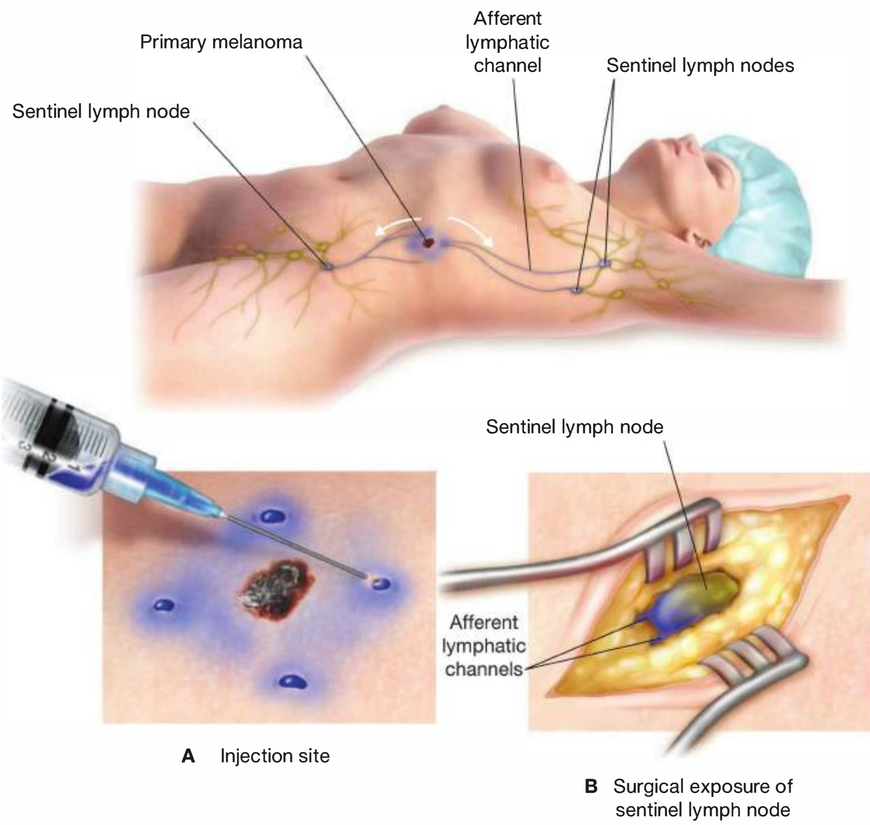


FIG 1 ● Sentinel node localization using blue dye injections. An artistic rendition of the sentinel node concept and afferent lymphatic drainage patterns is depicted. After the intradermal injection of blue dye around a primary cutaneous melanoma (left abdominal wall, **Panel A**), afferent lymphatic drainage to a left inguinal sentinel lymph node and two left axillary sentinel lymph nodes is shown. **Panel B** shows surgical exposure, using a self-retaining retractor, of the first of two sentinel nodes in the left axilla. Note the two afferent lymphatic vessels entering the sentinel node. Both nodes in the axilla would be defined as "sentinel" because they each receive first (primary) echelon drainage from a specific afferent lymphatic vessel. Both nodes need to be removed from the axilla as well as the SLN in the groin to complete the surgical procedure of SLN biopsy.

The reported accuracy (sensitivity) of SLN biopsy is 95%.[1,3–5] The term "biopsy" is perhaps a misnomer (particularly to patients) because the biopsy procedure is excisional in nature in that the entire SLN is removed and subjected to rigorous histologic analysis. Alternatively, the term "sentinel lymphadenectomy" can be used to define the surgical procedure.

CLINICAL IMPORTANCE

- Improving outcomes: The sobering reality is that once patients with melanoma develop clinically apparent (palpable) nodal disease (advanced AJCC stage III), the risk of subsequent distant stage IV disease and recurrent lymph node basin disease, despite a complete therapeutic lymphadenectomy, is at least 50%[6] and 15% to 50%,[7] respectively. Therefore, the original motivation to study SLN biopsy was to establish an effective method of identifying and then treating lymph node disease early when microscopic, an approach termed "selective lymphadenectomy," not to be confused with the aforementioned "sentinel lymphadenectomy," which refers specifically to the SLN biopsy procedure. Such an approach would prevent the development of clinically palpable nodal disease and in turn improve the outcomes for the node-positive patients in terms of both regional disease control and survival. The collective experience with SLN biopsy demonstrates that these two goals have been accomplished.[8,9]
- Staging and reducing morbidity: The stages I and II melanoma patient population represent at least 85% of the newly diagnosed patients. The prognosis of this group is very heterogeneous and dependent on a variety of primary tumor factors, specifically tumor thickness, ulceration, and mitotic rate, and probably most importantly, the presence of occult lymph node involvement.[10] The role of SLN biopsy as a staging tool has been well established, as several published multivariable analyses demonstrate that the histologic status of the SLN is the strongest independent predictor of survival for stages I and II melanoma and therefore offers another motivation for SLN biopsy.[10,11] The procedure is also intended to identify patients with pathologically node-negative disease for whom additional surgery is not indicated and adjuvant systemic therapy may not be of benefit, sparing these patients the morbidity of unnecessary surgery and treatment-related toxicities.
- SLN biopsy is now accepted as a standard of care[12,13] in the surgical management of appropriately selected melanoma patients. Central to the success of this minimally invasive approach, and in turn achieving the earlier described staging and treatment goals, is the consistent and accurate identification and complete removal of the SLN(s).
- Although in simplest terms SLN biopsy is a straightforward surgical procedure, in reality, the overall approach integrates several necessary components: identification of the appropriate candidates, careful physical examination of the potential nodal basins at risk, preoperative assessment of the lymphatic drainage patterns, intraoperative localization and removal of all the SLN(s), and careful histologic assessment of the SLN(s).

IDENTIFYING THE APPROPRIATE CANDIDATES

- Primary invasive cutaneous melanoma: The selection criteria for identifying the appropriate candidates for SLN biopsy is based on the predicted risk for the presence of microscopic lymph node involvement for those patients with newly diagnosed primary melanoma and clinically negative nodes. This is best determined by the various primary tumor factors inclusive of tumor thickness, ulceration,[14] and mitotic rate, which define the five AJCC stages I and II substages of primary melanoma.[10] The consensus recommendations are to offer SLN biopsy to any patient with a thickness of 1 mm or greater as long as they are safe operative candidates. SLN biopsy should also be strongly considered in any patient with a thickness of 0.7 to 0.99 mm, particularly if they have at least one of the following adverse prognostic features: Clark level IV or V, one mitotic figure or more per square millimeter, and lymphovascular invasion or microsatellites.[12,15–17] For patients with a thickness of less than 0.76 mm, SLN can be considered if, based on other adverse risk factors, a risk of 8% to 10% of SLN involvement is anticipated. This, however, would be a minority of patients in this subset.[14] Although these patients represent the vast majority who will be offered an SLN biopsy, a variety of other clinical scenarios are encountered with some frequency where SLN may also be considered. These scenarios are described in the 6 bulleted points that follow directly.
- Primary melanoma in an ambiguous (unpredictable) lymphatic drainage site (i.e., head and neck or trunk location) and proven synchronous nodal involvement in at least one, but not all, of the potential regional lymph node basins at risk: These patients may be candidates for SLN biopsy to stage the other regional nodal basins proven to receive direct lymphatic drainage from the primary site but without clinical nodal involvement. Generally speaking, these patients will undergo treatment of the primary melanoma and the involved nodal basin with a wide excision and formal therapeutic lymphadenectomy in the same operative setting. In the event that preoperative lymphoscintigraphy (**FIG 2**) demonstrates lymphatic drainage to an additional but clinically negative regional nodal basin, SLN biopsy

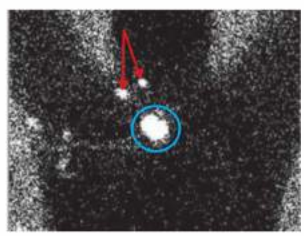


FIG 2 ● Lymphoscintigraphy showing lymphatic drainage to more than one nodal basin. An anterior–posterior view of a lymphoscintigraphy is shown, demonstrating lymphatic drainage from a primary melanoma site *(blue circle)* in an ambiguous (unpredictable) drainage location. Afferent drainage is seen to the right axilla and right neck *(red arrows)*. This patient presented with a newly diagnosed melanoma in the right mid back. Palpable nodes were appreciated on physical exam in the right axilla; an ultrasound-guided fine needle aspiration confirmed metastatic disease. The neck was clinically uninvolved by palpation and ultrasound. The patient underwent surgery with curative intent, which included a right axillary dissection, wide excision of the primary site, and an SLN biopsy in the right neck. Final pathology showed micrometastatic disease in both SLNs removed.

can also be performed at the same time in an attempt to be inclusive in the treatment of all nodal disease, both macro- and microscopic.

- Mucosal melanoma: Patients with primary mucosal melanomas that are in locations with easy access for direct injection with the SLN localizing agents, conjunctival and anorectal in particular, can be candidates for SLN biopsy as part of their initial surgical management strategy. Although specific primary tumor criteria for these lesions are not well established for predicting the presence of occult regional node involvement, these tumors are most often diagnosed late and likely to have a high enough inherent risk to consider SLN biopsy.
- True locally recurrent melanoma: Some patients develop recurrent melanoma at the edge of a previous wide excision site and may have one of the following three histologic features: in situ disease alone, in situ disease plus an invasive component, or invasive (dermal) component only. All three of these events are likely the result of an inadequate wide excision and an undetected positive margin and therefore represent a "true" local recurrence and have a good chance for long-term survival with surgical treatment. Most of these patients have clinically negative nodes, and in the context of a recurrent invasive component with the appropriate tumor characteristics (see earlier discussion), it is rational to offer these patients an SLN biopsy as a part of the definitive surgical therapy.
- Limited satellite/in-transit metastases: In contrast to the patients with "true" locally recurrent disease, these patients represent manifestations of the biologic disease continuum of regional cutaneous metastases (stage III). Not infrequently, these patients will present with clinically negative regional lymph nodes, stage IIIb. If the extent of the regionally metastatic disease is limited (one or two lesions), a surgical approach to the recurrence is rational. The presence of synchronous microscopic nodal disease not only impacts disease stage, advancing to IIIc and therefore the prognosis, but also the treatment strategies. Therefore, SLN biopsy could also be used in this clinical scenario in conjunction with the resection of the recurrence(s).
- After a wide excision: It is typical and preferable that the SLN biopsy be performed together in a single operative setting in conjunction with the definitive wide excision of the primary melanoma following a diagnostic incisional or excisional biopsy. Occasionally, a patient will have undergone a formal wide excision of the primary melanoma site and then be referred for consideration of an SLN biopsy. A theoretical concern is that the lymphatic drainage pattern of the skin brought together to close the surgical defect or surrounding a skin graft reconstruction has either been altered by the surgery or is far enough away from the original primary lesion that it may not accurately reflect that of the removed skin that was directly adjacent to the primary melanoma, resulting in the identification and removal of the wrong SLN(s). A few publications have put most of these concerns to rest. The data shows that although more afferent lymphatic vessels are likely to be accessed because of the broadened area injected, leading to more SLNs being removed and even the possibility of additional nodal basins explored in sites of ambiguous drainage (trunk and head and neck), the correct SLNs will likely be among the specimens removed, providing accurate nodal staging information.[18] As long as complex rotational flaps were not used for the reconstruction, SLN can be recommended to patients when this clinical setting is encountered.
- Prior surgery in a nodal basin: Occasionally, a primary melanoma will be diagnosed in a location with predicted or possible lymphatic drainage to a regional nodal basin in which surgical intervention has previously been performed, such as an SLN biopsy or lymph node dissection, as treatment for a previous melanoma or other malignancies. An SLN biopsy may still be possible, but a preoperative lymphoscintigraphy is mandated to determine how the lymphatic drainage has been affected or altered by the previous nodal surgery. Lymphatic drainage patterns may be demonstrated in one or more of the remaining nodes (if any exist) in the previously treated basin or diverted to another basin. This information is critical for appropriate surgical planning and operative positioning.

PATIENT HISTORY AND PHYSICAL FINDINGS

- Pertinent information such as a prior personal history of melanoma or other malignancies and current or recent symptoms referable to the presence of metastatic disease should be elicited from the patient during the history.
- Questions about allergic reactions to antibiotics, sulfa in particular, and intravenous (IV) contrast agents should be documented as this information may suggest an increased risk of an allergic reaction to the isosulfan blue dye and therefore may influence the decision to use a different blue dye such as methylene blue or not use any blue dye at all for the SLN procedure (see more details in the following text).
- A thorough head-to-toe skin examination should be performed with the intent of identifying additional suspicious lesions that could represent another primary melanoma or other skin cancers. Diagnostic full-thickness punch or excisional biopsies should be performed on selected lesions.
- Special attention should be paid to the region of the index melanoma. Visual inspection as well as palpation of the biopsy site and surrounding skin and soft tissues should be performed to determine the presence of any residual primary disease and/or satellite and in-transit metastases.
- Skin and soft tissues between the primary lesion and draining lymph node basins should be palpated and closely examined for in-transit disease. All suspicious cutaneous and subcutaneous lesions may undergo fine needle aspiration for pathologic diagnosis.
- All potential regional lymph node basins should be palpated for the presence of clinically apparent disease. This examination should include the epitrochlear and popliteal minor nodal basins when the primary melanoma is located distal to the elbow and knee, respectively.
- Palpable lymph nodes suspicious for metastatic disease should be assessed by either direct fine needle aspiration or further examined with ultrasound and biopsied with ultrasound guidance if confirmed to be radiographically suspicious. Such data may obviate the need for SLN biopsy in that basin and instead invoke a formal radiographic staging evaluation prior to carrying out a therapeutic lymph node dissection of the affected lymph node basin(s).

HISTOLOGIC EVALUATION OF THE PRIMARY MELANOMA

- An experienced dermatopathologist should review all pathology slides related to the melanocytic lesion in question to both confirm the diagnosis of melanoma as well as to provide the microstaging (tumor thickness, ulceration status, and mitotic rate) information and other relevant adverse histologic features (see earlier discussion).
- The decision to proceed with an SLN biopsy should be based on the earlier described established criteria. In some situations, however, the primary lesion is essentially intact and the diagnostic biopsy represents only a small sampling of the entire lesion or very superficial in depth. This type of biopsy may accurately render a definitive diagnosis of melanoma but may lack the histologic features needed to recommend an SLN biopsy. In this situation, the entire lesion should be narrowly removed as an excisional biopsy for complete histologic evaluation.

PREOPERATIVE RADIOGRAPHIC STUDIES

- Although *symptom-directed* preoperative radiographic imaging is a good practice in patients with newly diagnosed melanomas, generally speaking, most newly diagnosed early stage patients are asymptomatic; therefore, no special radiographic imaging is required or recommended prior to performing an SLN biopsy for most primary melanoma patients.[19] In the asymptomatic patient, extensive radiographic staging is more likely to result in false-positive rather than true positive findings. One possible exception would be the patients with both very thick (>4 mm) and ulcerated primary lesions. Many surgeons would obtain complete radiographic staging inclusive of computed tomography (CT) of chest/abdomen/pelvis or positron emission tomography (PET) scan and magnetic resonance imaging (MRI) of the brain routinely for this high-risk group.[19]
- In contrast, in patients with a locally metastatic lesion or a limited number of in-transit metastases for whom an SLN biopsy is being considered as part of the definitive surgical management, a thorough preoperative radiographic staging evaluation should be performed.[19]
- As mentioned earlier, ultrasound examination should be performed in patients with suspicious palpable nodes. Furthermore, ultrasound evaluation of the regional nodal basins should also be used as an adjunct to physical examination particularly of the axilla, in obese patients, with thick and ulcerated melanomas to evaluate for the presence of macroscopically involved nodes. In these situations, the sensitivity of physical examination is low and the risk of harboring synchronous macroscopically involved nodes is relatively high. Ultrasound examination suspicious for nodal involvement can be confirmed with an ultrasound-guided fine needle aspiration (**FIG 3**).
- The success of any SLN program is dependent on the preoperative determination of the lymphatic drainage patterns from the primary melanoma site. Although the nodal basins at risk in extremity melanomas are relatively predictable, such is not the case for head and neck and trunk melanomas where lymphatic drainage patterns are considered ambiguous or unpredictable. Preoperative identification of lymphatic drainage patterns is accomplished with *lymphoscintigraphy*.[20,21]

FIG 3 ● Ultrasound-guided fine needle aspiration of a suspicious nonpalpable lymph node. A static ultrasound image of biopsy needle *(black arrow)* within the node *(red arrow)* is shown.

PREOPERATIVE LYMPHOSCINTIGRAPHY

- Once the decision is made to perform an SLN biopsy, the most important preoperative decision is whether or not to perform a lymphoscintigraphy.
- The technique of cutaneous lymphoscintigraphy provides an objective description of the lymphatic drainage pattern from a primary cutaneous lesion to the nodal basin(s) that receive direct afferent lymphatic drainage. Through the use of external gamma camera images, the migration of the radioactive tracer that is injected intradermally (where the invasive melanoma cells are located) at the site of the primary tumor can be visualized to determine the following: (1) the major lymph node basin(s) receiving direct lymphatic drainage, (2) number and relative location of sentinel nodes within the basin, and (3) the existence and location of SLN(s) located outside of a formal lymph node basin, referred to as either "interval" or "in-transit" SLNs that are located in the subcutaneous tissues between the primary tumor and the formal nodal basin or *ectopic* in completely unpredicted anatomic locations.[22] The lymphatic drainage patterns mimic how melanoma cells metastasize within the lymphatic compartment. Approximately 5% to 10% of the time, an interval or in-transit SLN pattern will be identified during lymphoscintigraphy on the trunk; these nodes are just as likely to be involved with metastatic disease as the SLNs in the formal nodal basins.[22] **FIG 4** provides a simplified schematic of potential lymphatic drainage patterns.
- Two radiopharmaceutical agents are now available in the United States to be used for lymphoscintigraphy and for intraoperative SLN localization, both using a dose of 0.5 to 1.0 mCi of the radiotracer technetium-99m. Radiolabelled sulfur colloid has been the historical standard and is still used commonly, to date, but not specifically approved for

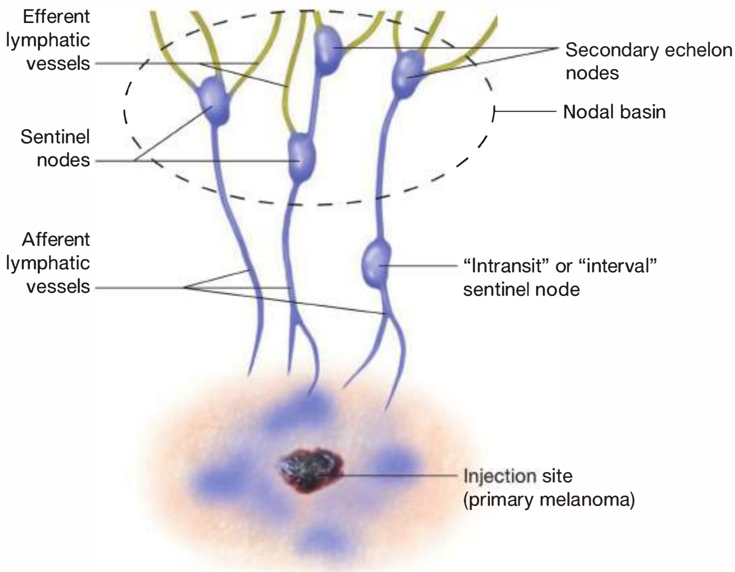


FIG 4 • Lymphatic drainage patterns. A schematic of potential lymphatic drainage patterns from the primary site to the regional nodal basin is shown. The first (primary echelon) node of drainage from a specific afferent lymphatic vessel is defined as an SLN. Up- or downstream drainage from the SLN to another node via efferent lymphatic vessels are considered secondary echelon nodes. Occasionally, primary lymphatic drainage is to a lymph node proximal to the formal basin in the subcutaneous tissue and termed as either an "interval" or "in-transit" SLN.

this use. Recently, the U.S. Food and Drug Administration (FDA) has approved the use of Tilmanocept,[23] which is a formulation of a dextran framework with several attached mannose residues and a technetium-99m binding site.

- In theory, the sulfur colloid particles migrate from the injection site through the afferent lymphatic vessels and are actively taken up by the macrophages in the first draining nodes (the sentinel nodes). Similarly, Tilmanocept migrates to the sentinel nodes from the injection site but is then covalently bound to the macrophages in the sentinel node as a result of the mannose residues, limiting significant pass through to secondary echelon nodes.
- Two types of images can be created. The routine examination is termed "planar" and provides images in two perpendicular planes: posterior–anterior (P-A) and/or anterior–posterior (A-P), or both, and lateral views[20] (**FIG 5**). These images visualize the injection site, the afferent lymphatic channels, and the accumulation of the radiotracer in the SLNs. The A-P and P-A views give the clinician medial and lateral as well as superior–inferior orientations, whereas the lateral views provide anterior and posterior localizations and also superior–inferior localizations. A transmission scan adds the contour of the body to the image and provides additional anatomic localizing information. When radioactive tracer injection sites (primary melanoma site) overlies or is in close proximity to a draining lymph node basin in at least one visual plane, the radioactivity in the sentinel node will not be visualized in that plane. Perpendicular images are necessary in order to visualize the sentinel activity separate from the injection site activity.

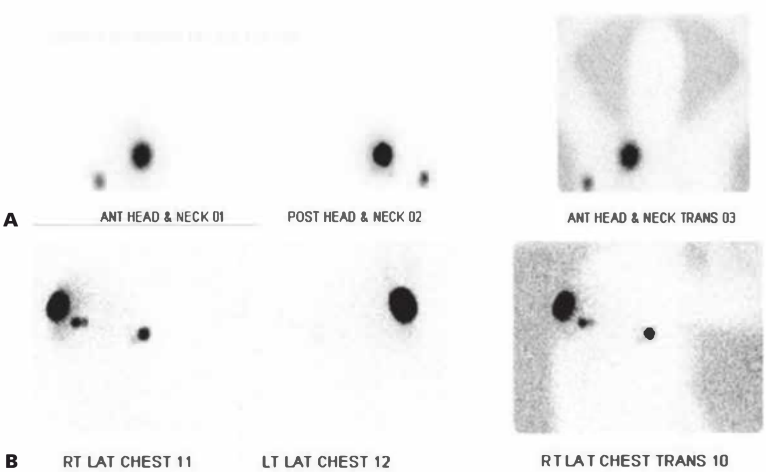


FIG 5 • Planar lymphoscintigraphy. Typical example of a cutaneous lymphatic drainage scan, obtained by injecting the technetium-99m–labelled tracer in the intradermal location at the primary melanoma site, is shown. The injection site, the afferent lymphatic vessels, and the SLNs in the regional basin nodal are visualized. A-P and P-A **(A)** as well as right and left lateral images **(B)** are taken to visualize the drainage pattern in perpendicular visual planes. The last image in both rows is the transmission scan that outlines the contour of the body to facilitate anatomic localization.

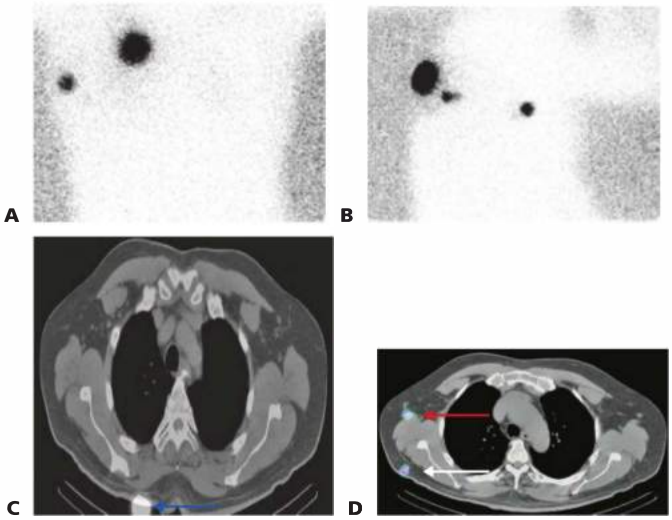


FIG 6 ● SPECT-CT lymphoscintigraphy. Planar lymphoscintigraphy of primary melanoma is shown in the top row, with anterior view in **(A)** and lateral view in **(B)**. Selected SPECT-CT images of the same patient are seen in the bottom row. Only the axillary SLN is seen in **(A)** and an additional SLN is seen in **(B)**, which was obscured by the overlying activity transmitted to the axilla from the injection site. The additional SLN in **(B)** is likely an in-transit node, the exact anatomic location of which is better visualized in the transaxial view of the SPECT-CT image in **(D)**. In **(C)**, the *blue arrow* indicates the injection site and in **(D)**, a few cross-sectional images inferior the *white arrow* identifies the in-transit SLN and the *red arrow* the axillary SLN, both of which are located in the same A-P visual plane.

- More recently, single-photon emission computed tomography–computed tomography (SPECT-CT) lymphoscintigraphy[21] has been developed, providing more exact anatomic localizations. With this method, serial cross-sectional, axial, coronal, and sagittal images are obtained and fused with the nuclear images. Relatively precise locations of the SLN and injection sites can be accomplished and is therefore particularly helpful in primary tumor locations such in the head and neck regions where multiple SLNs may be present or in locations where the potential nodal basins, and therefore the SLNs, may be in close proximity to the injection's site and lie within one of the same visual planes as the injection's site. In this latter situation, the SLN radioactivity will be obscured by activity within the injection site in one or more planes and therefore possibly go undetected on a "planar" study. Although obtaining a perpendicular image may visualize the SLN activity in a different line of sight, as described earlier, the SPECT-CT provides consistent three-dimensional imaging. The SPECT-CT images are also better at determining the presence of and delineating the location of interval or in-transit SLNs (**FIGS 6** and **7**).
- In the management of primary tumors located in cutaneous regions predicted to have ambiguous lymphatic drainage, such as in the head and neck and trunk, a preoperative lymphoscintigraphy is mandated. The extent of ambiguous cutaneous lymphatic drainage includes a very large area of the trunk and head and neck regions and is underestimated by the original classic descriptions of lymphatic drainage patterns. **FIG 8** illustrates the actual regions of ambiguous drainage. **FIG 9** demonstrates an example of ambiguous drainage.
- For extremity lesions, a formal lymphoscintigraphy is not essential as the basins at risk are predictable and intraoperative scanning can be performed with the handheld gamma probe. Some clinicians, however, will obtain a preoperative study for extremity lesions as well, particularly if the primary tumor is located distal to the knee or elbow to have a preoperative assessment for the presence of popliteal (**FIG 10**) or epitrochlear drainage patterns. Even in the proximal extremity locations, a preoperative lymphoscintigraphy can provide useful information in determining whether any upstream drainage from the thigh to the pelvis or the upper arm to the neck is primary (sentinel) or secondary echelon.
- Whereas some clinicians will schedule the lymphoscintigraphy on a day prior to the surgical procedure, others will obtain the study on the day of the surgery. In the latter scenario, the injection of the technetium-99m–labeled radiotracer that is used for the scan can be used for the gamma probe–directed intraoperative localization of the SLN. Because the half-life of technetium-99m is only 6 hours, when the lymphoscintigraphy is performed on a day remote from the surgery, another injection is required on the day of surgery unless a larger (three times) dose of the radiotracer is given the evening before the surgery.
- The lymphoscintigraphic images should be viewed by the surgeon and displayed in the operating room (OR) at the time of the SLN biopsy surgery to facilitate operative positioning, the intraoperative identification of the SLNs, and subsequent removal of all of the SLNs.

SURGICAL MANAGEMENT

Preoperative Planning

- Except in situations when the patient has already undergone a wide excision of the primary melanoma and then is referred for SLN biopsy, the SLN biopsy is carried out in the same operative setting as the definitive wide excision of the primary site.
- The surgery is performed as a day surgery, most conveniently in an ambulatory OR setting, under general anesthesia or with local anesthesia supported with intravenous sedation. Therefore, the patient should be nil per os (NPO) after midnight.
- Because frequently the entire index clinical lesion has been removed with either the shave or excisional diagnostic biopsy, identifying the correct site at the time of

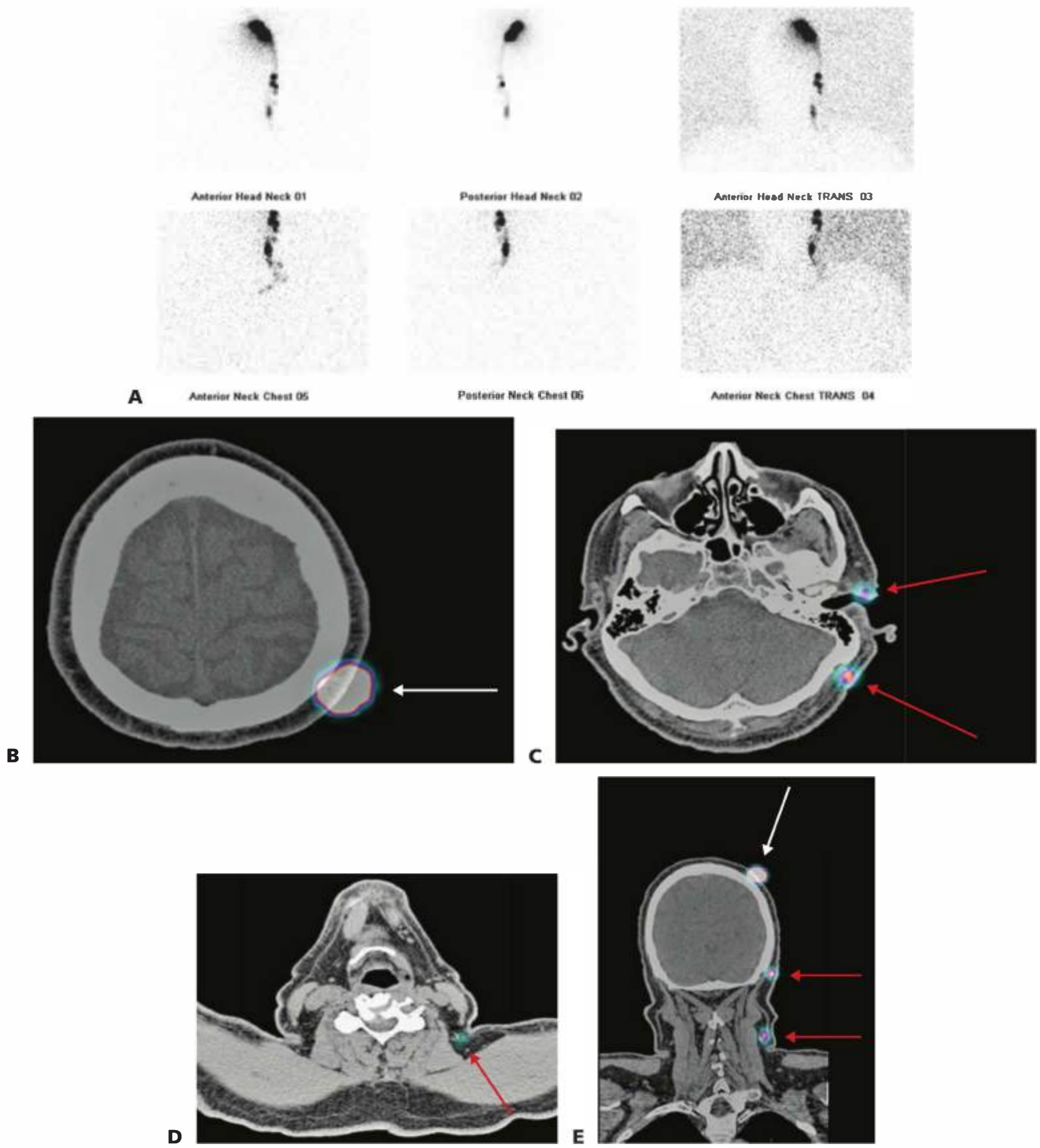


FIG 7 • SPECT-CT lymphoscintigraphy. Planar lymphoscintigraphy of a primary melanoma on the left scalp is shown in **(A)**, demonstrating multiple SLNs, the anatomic locations of which are difficult to define. In **(B–D)**, the SPECT-CT images are shown, with the *white arrows* indicating the injection site and the *red arrows* the SLNs, providing more exact localization with the use of cross-sectional (**B** and **C**) and coronal views in **(E)**.

lymphoscintigraphy or surgical procedure may be difficult. This is further complicated by the fact that these patients frequently have undergone other biopsies of skin lesions either prior to or at the time of the melanoma diagnosis. Because the accuracy of the SLN biopsy is dependent on injecting the correct site, careful documentation of the primary melanoma biopsy location to be injected should be carried out during the first clinic visit when the decision to perform the SLN biopsy is made. Digital images of this site can be obtained and downloaded in the patient's electronic medical record.

- Once the index lesion has been identified and clearly marked in the preoperative holding area and confirmed by the patient and/or family member, the patient can go to nuclear medicine for the radiotracer injection followed by the lymphoscintigraphy if not already completed on a day remote from the actual surgical procedure. The radiotracer is injected intradermally in the normal skin, just adjacent and as close as possible to the intact residual lesion (if present) or the biopsy site by the radiologist or technician. A four-point injection technique surrounding the lesion is employed with a 30-gauge needle attached to a 1-cc syringe (**FIG 11**).

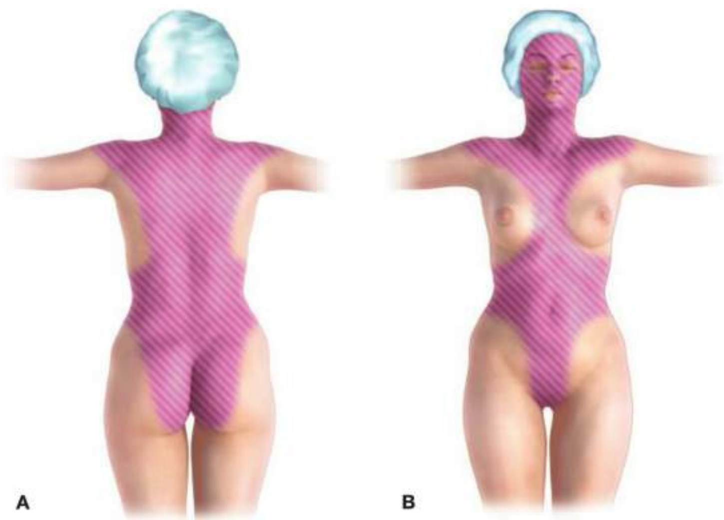


FIG 8 ● Areas of ambiguous lymphatic drainage. The regions of ambiguous (unpredictable) cutaneous lymphatic drainage include broad areas of the posterior **(A)** and anterior **(B)** trunk and the entire surface area of the head and neck.

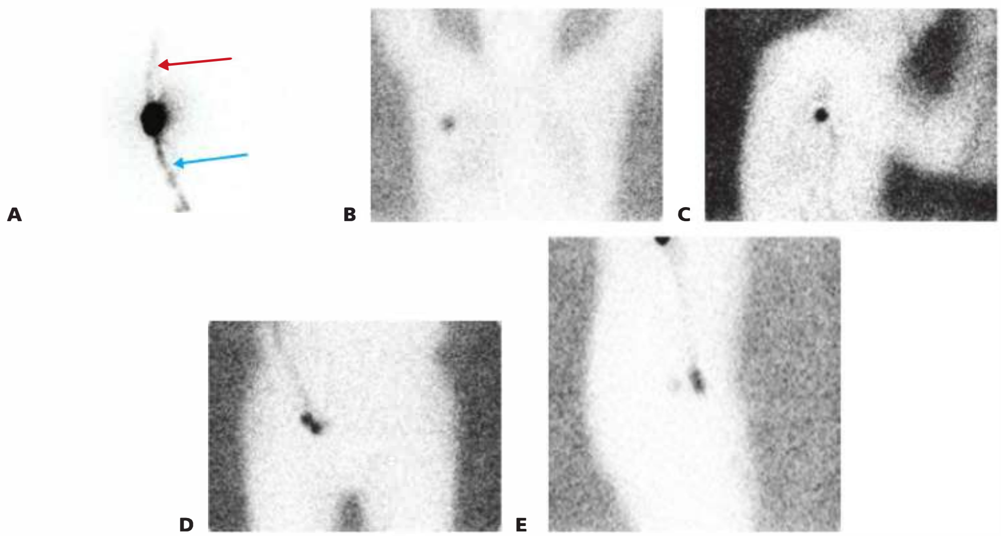


FIG 9 ● Ambiguous lymphatic drainage. Lymphoscintigraphy of melanoma on the right flank is displayed. The primary injection site is shown in **(A)**, demonstrating afferent lymphatic vessels draining in a bidirectional fashion to the ipsilateral axilla *(red arrow)* and groin *(blue arrow)*. In **(B)** and **(C)**, the axillary SLN is visualized in two perpendicular planes. In **(D)** and **(E)**, the inguinal SLN is visualized in two perpendicular planes.

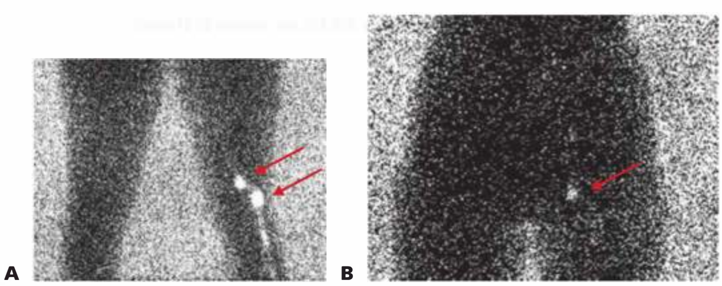
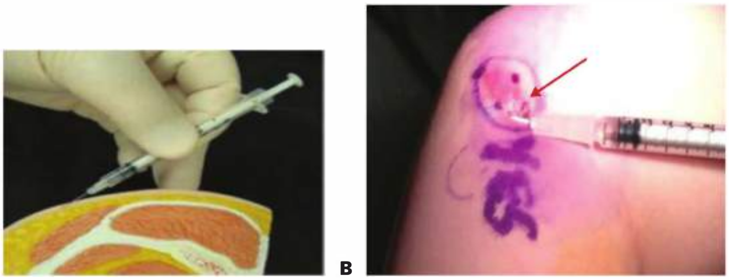


FIG 10 ● Visualization of popliteal SLN. Lymphoscintigraphy of melanoma on the plantar surface of the calcaneus demonstrating both popliteal **(A)** and inguinal **(B)** SLNs *(arrows)* is shown.



A B

FIG 11 ● Radiotracer injection technique. The correct technique and needle location for an intradermal injection is shown using a soft tissue model in **(A)**. An actual intradermal injection of the radiotracer at the primary melanoma site using a 1-cc syringe and a 30-gauge needle is shown in **(B)**. Note the wheal formation *(arrow)* confirming the intradermal location.

The usual dose of the radiotracer is 0.5 to 1 mCi of technetium-99m. For extremity lesions, the surgeon may choose not to obtain a lymphoscintigraphy (see earlier discussion) and have the patient return to the preoperative holding area directly after the injection. Also for extremity primaries, if permissible by the nuclear medicine department and if a lymphoscintigraphy is not going to be obtained, the surgeon can perform the injection of the radiotracer in the OR just prior to injecting the blue dye.

- Generally speaking, scheduling the injection that will be performed by the nuclear medicine staff approximately 1 hour prior to the surgery start time is adequate, but 2 or 3 hours may be required if a SPECT-CT lymphoscintigraphy is planned.
- Open communication with anesthesia personnel should take place prior to arrival in the OR to make sure the IV is placed thoughtfully at a site removed from the planned sites of the surgical procedures.
- The patient should be administered appropriate broad-spectrum antibiotic prophylaxis to reduce the risk of surgical site infection.
- The handheld gamma probe should already be in the OR.
- If the plan is to use the vital blue dye as another SLN localizing agent, this should be drawn up in 1-cc aliquots in the OR prior to the arrival of the patient.

Operative Positioning

- Thoughtful operative positioning is more of an art than a science but is an important step that will reduce operative times, limit the number of position changes, facilitate intraoperative scanning with the handheld gamma probe, and more importantly, optimize the complete identification and removal of all SLNs.
- The lymphoscintigraphic images should be displayed in the OR.
- Once in the OR, the gamma probe is used to transcutaneously scan all the planned nodal basins and SLN locations to be explored to make sure that the radiotracer has migrated. Alternatively, the patient can be scanned with the handheld gamma probe in the holding area prior to entering the OR to make sure the radiotracer has migrated in the event that a lymphoscintigraphy was not performed on the day of the surgery or not needed (i.e., for extremity primary).
- The gamma probe should also be used to scan potential additional sites that may not have been specifically identified on the lymphoscintigraphy, such as in the epitrochlear and popliteal regions for primary lesions distal to the elbow and knee respectively, all of the major regional nodal basins in the neck for head and neck and upper trunk primaries close to the midline, contralateral axilla for mid and upper back and chest lesions close to the midline, contralateral inguinal basin for lower abdomen and lower back primaries close to the midline, and ipsilateral axilla and inguinal regions for lateralized flank primaries. Additional SLN sites may be identified and these findings may influence operative positioning and the regions to be prepped and draped. The arm(s) and leg(s) when performing SLN biopsies in the axillae and groins, respectively, should be circumferentially prepped and draped so position changes can be performed sterilely to facilitate adequate exposure of the lymph node basins intended for biopsy. Moreover, primary lesion(s) intended to undergo wide local excision should also be clearly visible and accessible.
- Whenever possible, patients should be positioned in a way to expose both the SLN and wide excision sites in one supine or lateral position. This will allow one session of prepping and draping and avoid the time it takes to change positions. This can usually be accomplished when the primary lesion is on one of the extremities, anywhere on the trunk or head and neck locations when all of the SLN sites are on the ipsilateral side of the primary, and anywhere on the anterior trunk and anterior head and neck regions even when the draining nodal are bilateral. In contrast, the most problematic locations are posterior neck and trunk lesions close to the midline when bilateral nodal basin (i.e., both axillae, both cervical, or both inguinal) drainage is identified or two or more different basins on opposite sides of the body (i.e., left axilla and right neck) contain SLNs. In these latter scenarios, at least one position change will be required.
- When foot/lower leg cutaneous lesions localize SLN(s) to the popliteal fossae, prone positioning is best suited for such patients for adequate visualization and access to the SLN(s). The patient may then be subsequently repositioned in the supine or lateral decubitus position for excision of corresponding primary lesions if that site is not accessible in the prone position. Another option for this scenario would be to place the patient in the lateral decubitus position, avoiding a position change.
- The patient should also be positioned to facilitate the surgeon in scanning the nodal basin and the intervening tissues with the handheld gamma probe positioned perpendicular to or in a direction pointed away from the injection site to limit the "shine-through" radioactivity emanating from the injection site that may obscure the radioactivity in the SLN and in turn hamper ones ability to discriminate SLN radioactivity from the injection site activity.
- After the patient is positioned, multiple steps are carried out to accomplish a complete and accurate sentinel lymphadenectomy.[24]

INJECTION OF BLUE DYE

- Once the patient is positioned, the vital blue dye is injected at the primary site using a similar four-point intradermal injection technique that was used for injecting the radiotracer. Approximately 2 to 3 cc of blue dye is injected using 1-cc tuberculin syringes and a 25-gauge needle (**FIG 12**).
- Although it is not mandatory that the blue dye be used, most surgeons feel that the two localizing agents complement each other in successfully identifying and removing the SLNs.
- The blue dyes most commonly used are isosulfan blue and methylene blue in the United States and patent Blue V in Europe and Australia. The isosulfan seems to concentrate in the SLNs in a more uniform manner compared to methylene blue, making it easier to visualize. Some surgeons prefer to use methylene blue because of the potential, albeit very low risk, of an allergic reaction to isosulfan blue.[25] However, at least one report documents increased postoperative complications with the use of methylene blue.[26]
- After the blue dye is injected, the patient is then appropriately prepped and draped. The time that transpires during the prepping and draping is long enough for the blue dye to travel through the lymphatic vessels to the SLNs.

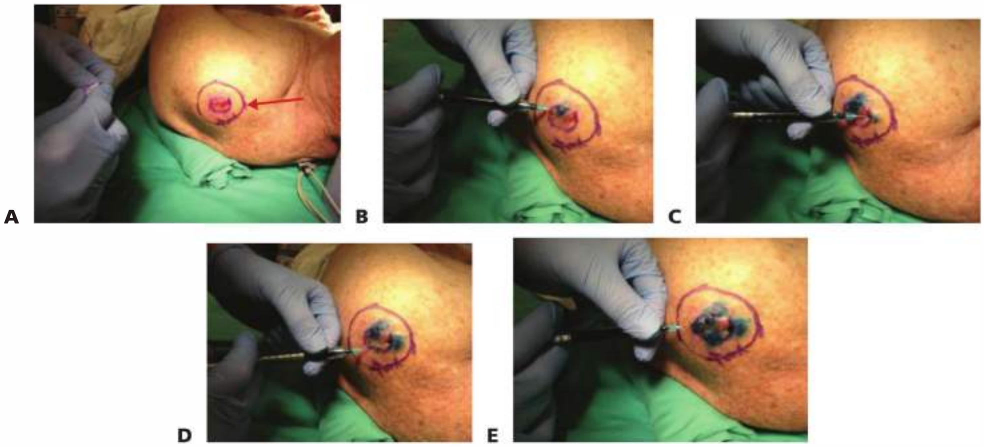


FIG 12 ● Blue dye injection technique. The primary melanoma is shown **(A)** with planned margins measured and drawn *(arrow)*. The four-point intradermal injection of the blue dye is shown in images **(B–E)**.

INTRAOPERATIVE LOCALIZATION AND SURGICAL EXCISION OF THE SENTINEL NODES

- Most commonly, both the SLN biopsy and the wide excision of the primary site will be performed in the same operative setting. Generally, if the blue dye is used, the nodal basin exploration and removal of the SLN is approached first in order to take advantage of the visualization of the SLN afforded by the blue dye. If the wide excision is performed first, the blue dye will be removed as well, limiting the continued flow of dye to the SLN and in turn the visualization of the SLN.
- The use of the handheld gamma probe is central to this procedure. The probe is placed within a sterile ultrasound cover after the patient is prepped and draped.
- If the planned wide excision site (injection site) is in close proximity to the nodal basin, the shine-through activity may be greater than the sentinel activity. The following maneuvers are used to discriminate SLN activity from the shine-through activity: As the gamma probe is transcutaneously passed from the injection site to the nodal basin, the counts will diminish in proportion to the distance from the injection site. A sentinel node area is identified when the radioactive counts increase as the probe is moved further away from the injection site compared to a location that is closer to the injection site (**FIG 13**). The radioactive counts should again decrease as the gamma probe is passed further beyond the sentinel node. The use of a removable collimator can be helpful in reducing shine-through activity. Make sure that when passing the probe from the injection site to the nodal basin, the probe is positioned perpendicular to or directed away from the injection site. If none of these maneuvers are successful, the wide excision can then be performed first, which very effectively removes the background shine-through counts. This maneuver will also remove the blue dye and stop the continued flow of dye to the nodal basin and in turn significantly reduce the ability to use the blue dye as an aid in identifying the SLN.
- If the patient is positioned correctly, the surgeon will be able to transcutaneously localize the epicenter of the SLN activity with the handheld gamma (which represents a small percentage of the radioactivity at the injection site)

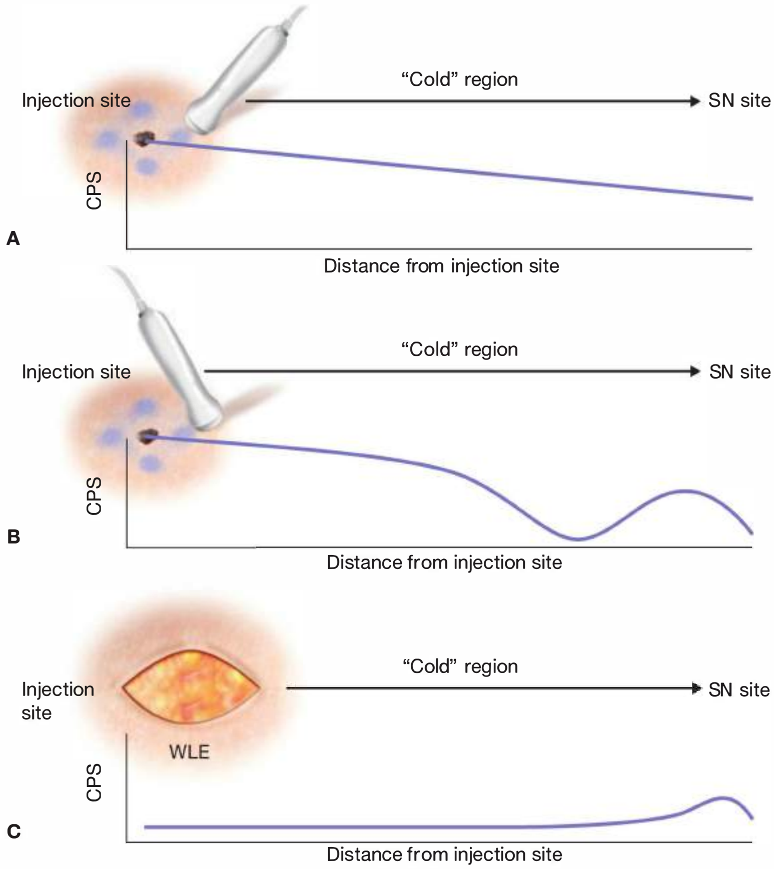


FIG 13 ● Conceptualization of intraoperative SLN scanning. Three conceptual graphs are shown, with the x-axis representing radioactive count per second (CPS) and the y-axis distance of the SLN from the injection site. The amount of radioactivity that travels to the SLN is a small percentage of the radioactivity injected. Shine-through radioactivity from the injection site may obscure the ability to detect to the radioactivity in the SLN, particularly if the injection is close to the nodal basin and/or SLNs. Although placing a collimator on the end of the probe may block out much of the shine-through activity and allow the detection of the SLN, it also narrows the exposed area of radioactivity detection crystal on the probe and in turn reduces the counts detected from the node. In **(A)**, scanning for the SLN is performed with the probe pointed at the injection site. Even though the probe is moving away from the site, shine-through counts detected may be greater than the counts in the SLN, limiting the ability to discriminate SLN activity versus shine-through injection activity. In **(B)**, the same maneuver is performed, now with the probe pointed away from the injection site, allowing the detection of a step-up in activity as one reaches the SLN. In **(C)**, the wide excision has been performed, essentially removing any shine-through activity and in turn facilitating the detection of the SLN activity. This latter maneuver is often used when trying to find the remaining SLNs with less radioactivity after the first, most radioactive SLN has been identified and removed.

within the nodal basin without too much difficulty especially if the injection site is at some distance from the nodal basin (**FIG 14**).

- The epicenter of SLN activity is marked with a sterile marking pen and used for surgical incision planning.
- The nodal basin is approached with a small biopsy incision directed by the handheld gamma probe over the epicenter of radioactivity. We make sure that this biopsy incision can be easily incorporated and excised en bloc as part of a formal lymphadenectomy incision if that is required at a later date should the sentinel node reveal metastases (**FIG 15**).
- The dermis and subcutaneous tissue is divided with cautery, advancing deeper for approximately 1 to 2 cm at a time between pauses during which time the trajectory of the line of dissection toward the radioactive signal may be confirmed with the gamma probe. Using this technique, the surgeon is able to localize and directly advance to the targeted SLN(s) with minimal tissue disruption (**FIG 16**).
- In most situations, the SLNs are deep to the subcutaneous investing fascial layer (i.e., Scarpa's in the groin and platysma in the neck), which needs to be incised in order to enter the nodal basin proper (**FIG 16C**).

FIG 14 ● Thoughtful positioning in the OR. The left lateral position is correctly chosen in this patient with a primary melanoma on the right midback with a lymphoscintigraphy showing drainage to the right axilla and a probable in-transit node over the scapula. This position facilitates not only performing the SLN biopsies and the wide excision without a position change but also scanning for the SLN nodes perpendicular to and directed away from the injection site. Under each frame, the numbers represent the counts per second of radioactivity where the gamma probe is placed. Note that the highest count is over the injection site, then counts decrease moving away from the injection until they increase to identify the in-transit node, then decrease again as the in-transit node is passed, then increase again in the axilla. The last frame in the second column shows the SLN sites marked and in the last column on the right the two frames show the in-transit SLN and the axillary SLN.

A B

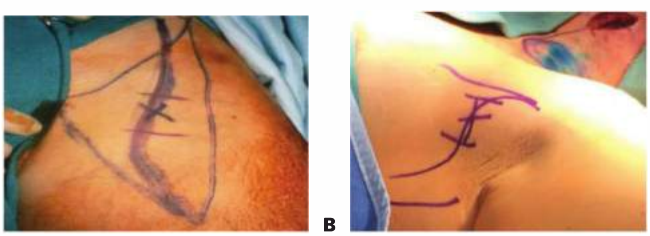
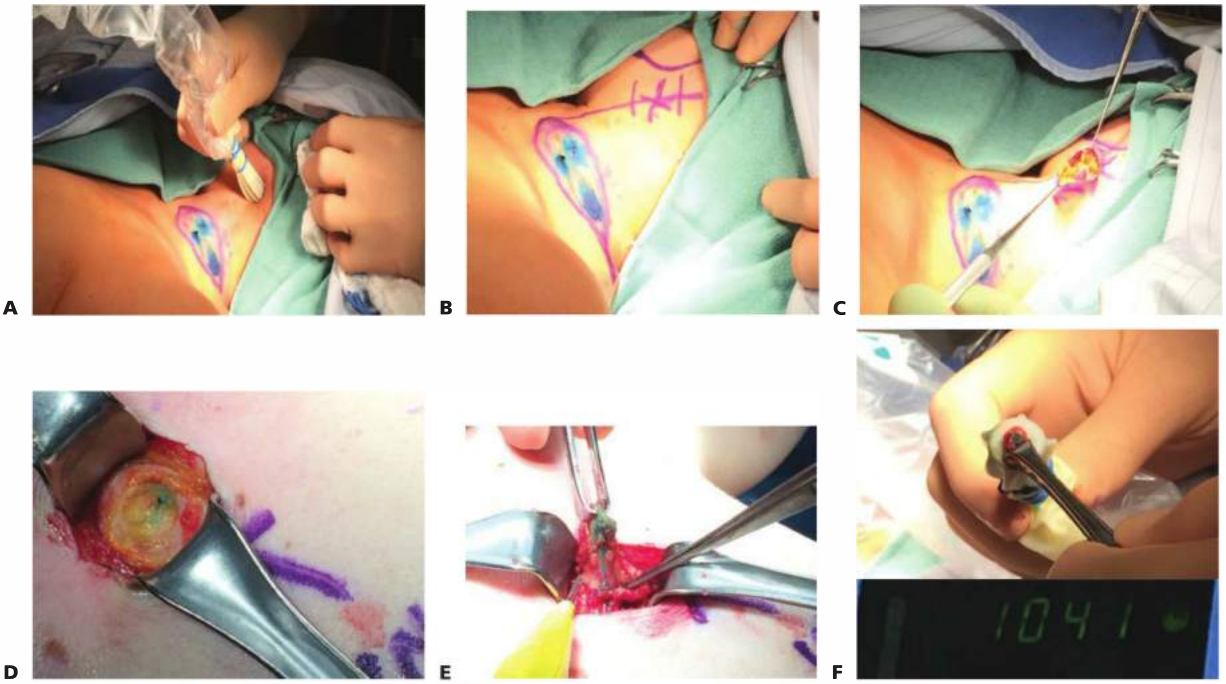


FIG 15 ● Skin marking and planned SLN biopsy incision. Examples of transcutaneous SLN localization with the gamma probe in two nodal basins: **(A)** inguinal and **(B)** axillary. In each frame, the SLN biopsy incision is drawn to incorporate the location of the SLN, marked with an "X" as well as a future formal lymphadenectomy should that be required.



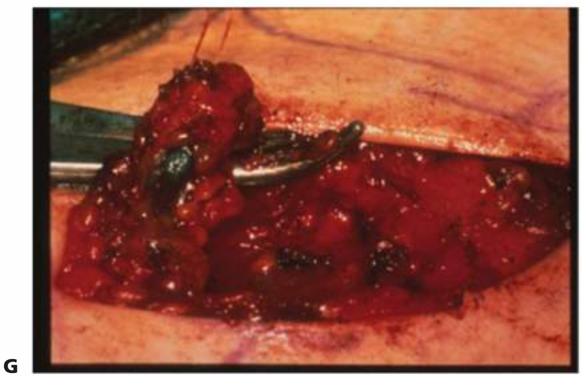


FIG 16 ● Steps in excising the SLNs. The surgical steps used in the actual removal of the SLNs. (**A**) Transcutaneous localization, **(B)** marking the epicenter of radioactivity and planning the incision, **(C)** making the incision, incising the dermis and the subcutaneous tissue to expose the fascia, **(D)** incising the fascia to enter the nodal basin proper, **(E)** dissecting the SLN from the surrounding tissue, delivering the node into the wound, then removing the node after clipping or clamping then cutting the afferent vessels and vascular pedicle to remove the node, **(F)** ex vivo counting of the SLN, **(G)** rechecking the nodal basin for significant residual radioactivity, and removing additional SLNs.

- Skin hooks, handheld Richardson-type retractors, or blunt self-retaining retractors can be used for exposure (**FIG 16D**).
- Once the nodal basin is entered, the localization of the SLN may be further facilitated by either following a blue-stained lymphatic channel toward the blue node or by direct visualization of the blue-stained lymph node (**FIG 16E**).
- The visualization of the blue dye is helpful in rapidly identifying which lymph node has accumulated the radiotracer, discriminating the SLN from the other nonstained surrounding nodes that are usually in close proximity.
- The SLN is then dissected free from the surrounding tissues. This is facilitated by gently grasping the node with a pickup and then delivering the node to a more superficial location in the basin. We prefer to use a pickup with broad and blunt jaws such as Hayes-Martin, rather than a DeBakey or Adson, to avoid tearing the node. Some surgeons place a figure-of-eight stitch in the node for this maneuver, but this can also carry the risk of tearing the node. Once mobilized and delivered, the intervening lymphatic channels can be identified because of the blue dye and are clipped or tied to limit the development of a postoperative seroma. The vascular pedicle is then clamped, cut, and then tied.
- Ex vivo counts of the node are then documented with the handheld gamma probe and recorded (**FIG 16F**). After removing the initial SLN, the nodal basin is then scanned for residual radioactive counts with the gamma probe pointed away from the injection site. If the background activity in the nodal basin is still high because of close proximity to the injection site, the wide local excision of the primary site may be performed. This removes any significant background activity (shine through) and

allows for a more complete evaluation of residual SLN counts within the nodal basin.

- Additional nodes identified by the presence of high residual radioactivity and/or blue dye staining are then removed and labeled as sentinel nodes, with numbers assigned sequentially in the order of identification. Nodes are defined as sentinel if they are blue and/or contain radioactivity significantly above background. Nodes are removed and labeled as "sentinel" until no focal basin radioactivity is greater than 10% of the "hottest" sentinel node removed.
- The skin and soft tissue between the injection site and nodal basin(s) should also be scanned to identify and subsequently remove any "in-transit" or "interval" SLNs. Similarly, if the background counts are too high because of proximity to the injection site, the wide excision can be performed to decrease the shine through and facilitate the exploration for the in-transit SLNs.

CLOSURE

- Hemostasis should be ensured and divided fascial layers closed with interrupted 3-0 absorbable sutures. Drains are usually not needed.
- Skin may then be approximated using interrupted, buried absorbable sutures in the dermis followed by a running subcuticular stitch with a 4-0 absorbable monofilament suture. Steri-Strips or a skin adhesive may then be applied.

PATHOLOGIC EVALUATION OF THE SENTINEL NODES

- A dedicated dermatopathologist should process the node and read the pathology slides.
- The SLN are serially sectioned using either along the long axis of the node or a bread-loafing technique across the short axis of the node (**FIG 17**). The width of the serially sliced sections is partly dependent on the size of the node but usually are made in 2-mm intervals.
- Frozen section evaluation of the SLNs are not recommended out of concern of leaving behind nodal tissue with small-volume diseases in the cryostat and therefore will go undetected. Such events could reduce the accuracy of the pathologic evaluation of the SLN.[27]
- The tissue slices are embedded in paraffin blocks for permanent section evaluation. All the blocks are stained with hematoxylin and eosin. If these are negative, additional sections are taken for immunostaining.

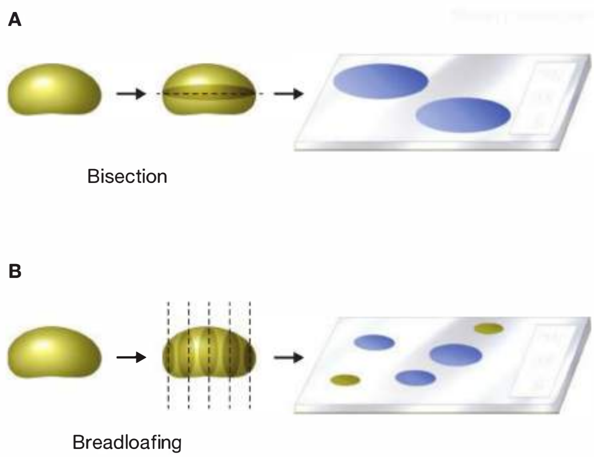


FIG 17 ● Histologic examination of the SLN. Schematic representation of sectioning of lymph nodes, with routine bisection in **(A)** creating two samples to be stained and serial sectioning in **(B)**, resulting in multiple sections for staining.

COMPLICATIONS

- No identifiable drainage to SLN(s)
- Removing the "wrong" node and leaving behind the true SLN
- Hematoma
- Seroma
- Infection (cellulitis or infected seroma)
- Paresthesias
- Lymphedema

TECHNIQUES

POSTOPERATIVE CARE

- Always examine the patient before discharge to make sure a hematoma has not developed.
- Instruct the patient what to look for in terms of seroma and surgical site infection.
- Remind them about the blue dye in the urine.
- Keep the SLN site dry for 48 hours.

OUTCOMES

- Using the dual localizing technique of radiotracer and blue dye injections, the SLN identification rate approaches 100%.[3]
- The frequency of a false-negative event defined as the development of clinical nodal disease in the same nodal basin subsequent to the removal of a negative SLN is 3% to 5%.[28] A false-negative event is most commonly a result of very small volume disease undetected by the original pathologic evaluation of the SLN removed, and therefore, a formal lymphadenectomy was not performed. For such an event to occur, another lymph node with subclinical disease was likely present in the same nodal basin at the time of the SLN procedure as the source of the subsequent clinical nodal recurrence. Another reason for a false-negative event leading to a nodal recurrence is the inaccurate identification of the SLN and removing a node that was not sentinel and leaving behind the true SLN that harbored microscopic disease.[28]
- Lymphedema, although rare, can occur and is most common following an SLN biopsy in the groin in conjunction with a wide excision on the thigh or lower leg.

PEARLS AND PITFALLS

Head and neck primaries	■ The lymphatic drainage from these primary lesions is the most ambiguous and least predictable. Therefore, a SPECT-CT lymphoscintigraphy is strongly encouraged. ■ Due to the close proximity to important structures when treating melanomas of the face, the excision margins for the primary lesion may have to be selectively narrowed to avoid injury to these structures and any associated functional or cosmetic impairments (see Part 5, Chapter 26). It is important to note that injected blue dye at the primary site left behind in the remaining skin after the wide excision can tattoo the skin for long periods of time. Therefore, excision margins are clearly delineated with a marking pen prior to the injection of the blue dye. In this way, the volume of dye injected can be adjusted to ensure that the blue staining is limited to the skin to be excised. ■ The SLNs in the neck are surprisingly small; the use of blue dye is particularly helpful. ■ The lymphatic drainage in the head and neck region is very rapid and the flow of blue dye can be diluted out if too much time transpires between the injection and the exploration of the nodal basin for the SLN. Therefore, in contrast to other primary sites, the blue dye is injected under sterile conditions after the patient is prepped and draped. ■ The SLNs in the neck region are often adjacent to important nerves, such as the spinal accessory, great auricular, and branches of the facial nerve.
Injection of blue dye	■ An injection performed in the intradermal location creates some resistance and can result in the needle becoming separated from the syringe, splattering blue dye on oneself, the patient and OR staff. Therefore, the use of 1-cc Luer lock–type syringes is recommended. ■ Remember to tell patient that his or her urine will be blue/green colored for 24 hours. ■ Any blue dye staining of the skin not removed by the wide excision may take several months to completely fade away. ■ If the patient has already had a wide excision, a preoperative discussion should take place about whether or not to use the blue dye for the planned SLN biopsy. Another excision should not be performed just to remove the blue dye to avoid a tattooing effect. The only time that another excision should take place is when it is necessary to remove the injection site radioactivity that is obscuring your ability to adequately scan the nodal basin for the SLN.

Complications	■ **No drainage observed from the injection site** to an SLN is almost always a result of an error in injection technique. The appropriate technique involves an intradermal injection that raises a wheel and causes some discomfort to the patient. The most common error is injecting the radiotracer too deep into the subcutaneous tissues where the concentration of lymphatic vessels is low or directly into the excisional biopsy site. Hallmarks of a subcutaneous injection include lack of pain during the injection, radiotracer activity seen in the liver on the lymphoscintigraphic images, and no drainage to a nodal basin. ■ **Recurrent seromas** at the SLN biopsy site are conveniently handled by using a "seroma cath" system, composed of a percutaneously placed angiocatheter, a clear tubing, and a small suction bulb. This technique can also be used to treat infected seromas along with antibiotics rather than opening up the wound. ■ **Incorrect identification of the SLN** can lead to leaving behind microscopic nodal disease, which will be the source of subsequent clinical lymph node recurrence. One important maneuver to minimize the frequency of such events is to always view the lymphoscintigraphic images prior to the surgery and display the images in the OR rather than depending on the reading by the radiologist.

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Chapter 28

Axillary Lymph Node Dissection for Melanoma

Michael S. Sabel

DEFINITION

- Axillary lymph node dissection (ALND) involves the surgical excision of the lymph node–bearing tissue from the axilla. For melanoma patients, a complete ALND is considered the standard of care for patients with both micrometastatic disease, as demonstrated on sentinel lymph node (SLN) biopsy and clinically evident disease.
- The axilla is divided into anatomic levels based on the relationship of the nodes to the pectoralis minor muscle (**FIG 1**). Level I nodes are located lateral to the pectoralis minor, level II nodes are seated deep to the pectoralis minor, and the level III nodes are medial to the pectoralis minor. For patients with clinical evident axillary disease, a level I-III dissection is recommended. For patients with a positive axillary SLN biopsy, a level I-III dissection is often performed, but a level I-II dissection may be adequate.[1,2] This chapter will describe an ALND encompassing levels I, II, and III.

PATIENT HISTORY AND PHYSICAL FINDINGS

- The history should focus on the patient's melanoma history, including the histology of the primary tumor, disease-free interval between the primary diagnosis and the diagnosis of regional metastases, and the extent of both locoregional and distant disease. The history should also focus on comorbidities, past medical history, and medications that might impact the patient's surgical candidacy.
- The history should also include a thorough review of systems, specifically looking for symptoms suggestive of distant disease. Patients with symptoms worrisome for stage IV disease should have body imaging before proceeding with surgery.
- A complete physical examination should pay particular attention to signs of local, regional, and distant disease. The site of the primary tumor and the skin between it and the regional basin should be examined for signs of in-transit recurrences. A complete lymph node exam should be performed. This should not just be limited to the axilla of concern but bilateral cervical, supraclavicular, epitrochlear, axillary, and inguinal basins. Suspicious nodes outside of the draining basins may represent stage IV disease.
- For the involved axilla, the exam should focus on the extent of disease, including the size of the involved nodes and fixation. The ipsilateral arm should be examined for lymphedema, weakness, or sensory deficit, as these may be indicative of involvement of the axillary vein or brachial plexus. You should also document any conditions affecting the shoulder or upper extremity, which limits range of motion.
- For patients who had an SLN biopsy or excisional biopsy, it is important to document any sensory or motor deficits that may have occurred at the first surgery as well as any seroma, hematoma, or infection. It may also be helpful to note the orientation of the incision, as this may impact the orientation of the ALND incision.
- It is important to review with patients the expected postoperative course including drain management and arm exercises, as well as short-term and long-term morbidity, including the risk, prevention, and management of lymphedema.

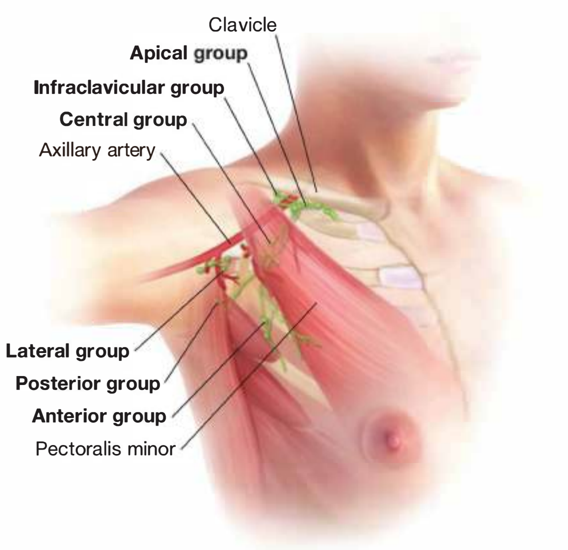

FIG 1 ● Levels of axillary lymph nodes. The level I nodes are located lateral to the pectoralis minor muscle, the level II nodes are located deep to the pectoralis minor, whereas the level III nodes are located medial to the pectoralis minor.

IMAGING AND OTHER DIAGNOSTIC STUDIES

- For asymptomatic patients with micrometastatic disease identified on SLN biopsy, there are no imaging studies necessary before proceeding with ALND.[3] For patients with thick, ulcerated tumors (American Joint Commission Center [AJCC] stage T4b) and a positive SLN, the risk of distant disease may justify preoperative body imaging, with either a computed tomography (CT) scan or positron emission tomography (PET)/CT.[4] However, for patients with micrometastatic disease, preoperative staging studies have a high false-positive rate, may lead to unnecessary follow-up studies or biopsies, and rarely alter surgical decision making.
- Patients with symptoms concerning for metastatic disease should undergo staging with either a CT of the chest, abdomen, and pelvis or a PET/CT and a magnetic resonance imaging (MRI) of the brain. Patients with clinically evident regional disease should also undergo distant staging, as there

is a higher chance of detecting metastatic disease that might alter surgical decision making.[3]

- For patients with fixed, matted lymph nodes; skin involvement; or neurovascular symptoms of the involved arm (paresthesias, motor and sensory deficits, lymphedema, limited range of motion), MRI of the chest wall can be helpful in determining resectability. Unresectable or borderline resectable patients could be considered for neoadjuvant therapy with newer biologic and targeted therapies.

SURGICAL MANAGEMENT

Preoperative Planning

- In the preoperative area, the side of the ALND should be clearly marked and confirmed with the patient before proceeding to the operating room (OR).
- Intravenous (IV) antibiotics are indicated for ALND.[5] Sequential compression devices (SCDs) should be used for deep venous thrombosis (DVT) prophylaxis. Patients with a history of DVT or genetic predisposition toward clotting should receive subcutaneous heparin.
- Many surgeons prefer the use of short-acting neuromuscular blocking agents during induction, so that the patients are not paralyzed during the procedure. This allows identification of the thoracodorsal, long thoracic, and medial and lateral pectoral nerves by mechanical stimulation. However, this is not essential and some surgeons prefer paralysis with a long-acting neuromuscular blocking agent to prevent muscular contraction and allow for retraction of the pectoralis major and minor muscles. Either way, this should be discussed with the anesthesiologist prior to the case.

Positioning

- The patient should be positioned supine on the OR table, toward the edge of the side of the ALND so that the posterior axillary line is in-line with the edge of the table. The ipsilateral arm is abducted at 90 degrees on a padded arm board. It is important not to extend the arm past 90 degrees to avoid brachial plexus injury.
- The endotracheal tube should be located away from the involved arm and adequate space should be preserved above the arm for the surgical assistant.
- The chest wall, lower neck, and entire arm should be prepped and draped into the surgical field using a sterile stockinette and Kerlix wrap. This allows the arm to be rotated over the chest, relaxing the pectoralis major and minor (**FIG 2**).

FIG 2 ● Preoperative positioning and draping for an ALND. The arm should be prepped into the field with a stockinette and Kerlix wrap so it can be rotated over the chest during the procedure.

INCISION

- Typically, a "lazy S" incision is used along the pectoralis major muscle, extending posteriorly at the level of the axillary hair line, and then inferiorly along the latissimus dorsi muscle (**FIG 3**). For patients with a prior excisional or SLN biopsy incision, this should be encompassed into the ALND incision, and thus might impact the choice of incision. For patients with bulky adenopathy, particularly those with nodes close to the skin, the skin overlying the nodes should be included with the specimen. Be sure there is adequate skin to allow for a tension-free closure.
- After incising the skin with a scalpel, electrocautery is used to divide the subcutaneous tissue and elevate skin

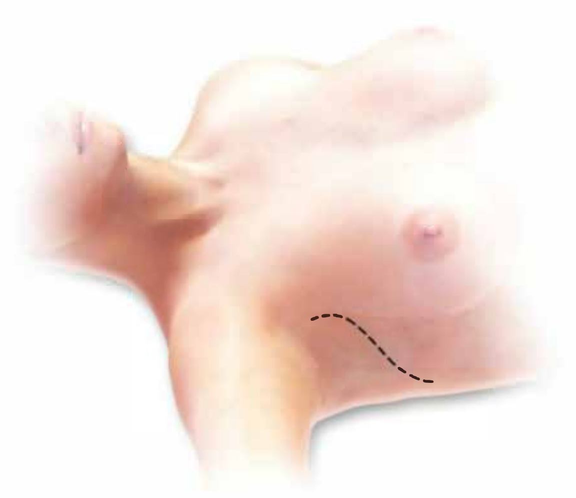

FIG 3 ● The "lazy S" incision for an ALND. One can begin with the transverse incision and extend the pectoralis and latissimus arms as needed.

TECHNIQUES

flaps. Unless mandated by the presence of bulky disease, the skin flaps should not be too thin and get progressively thicker as they are raised. Thin skin flaps will increase the risk of wound complications and give the axilla a sunken-in appearance.

- The skin is elevated using skin hooks or sharp rakes. It is important that the surgical assistant holds the flaps straight up and not retract them back (which residents will sometimes do in order to get a better view). The surgeon retracts the tissue with the opposite hand in order to apply strong countertraction and identify the appropriate tissue plane.
- Surgeons are often hesitant to go too far or too deep while elevating the inferior skin flap at this initial point of the operation for fear of injuring the long thoracic nerve. However, raising an adequate inferior flap allows for greater mobility of the specimen and easier dissection. The inferior flap should be raised to approximately the level of the 5th rib.
- Once the flaps are elevated, the next step will be to identify some of the borders of the axilla: the pectoralis major and minor muscles, the latissimus dorsi muscle, and the axillary vein. Although individual surgeons have their preferences, there is no correct order, and the presence of large lymph nodes might mandate changing your approach. In this chapter, we will describe a medial-to-lateral approach.

IDENTIFICATION AND RETRACTION OF THE PECTORALIS MAJOR AND MINOR

- The pectoralis major muscle is usually the easiest margin to begin with, as it is often easily palpable upon raising the flaps (and may become apparent while elevating the superior flap). Once the pectoralis major is identified, the length of the lateral border should be exposed (**FIG 4**).
- Once the pectoralis major muscle is freed, it is retracted anteriorly and medially to expose the interpectoral nodes and the pectoralis minor muscle. This, and the remainder of the operation, is facilitated by the use of a Thompson retractor (**FIG 5**).
- The tissue between the pectoralis major and minor muscle that contains the interpectoral (Rotter's) nodes is included with the specimen, dissecting it off the pectoralis minor muscle. As the dissection proceeds onto the pectoralis minor, the medial pectoral bundle can be observed coming either through or lateral to the pectoralis minor (**FIG 6**). This should be preserved. There is often an accompanying vein with a branch going into the specimen. This will need to be clipped, taking care not to clip the medial pectoral nerve.

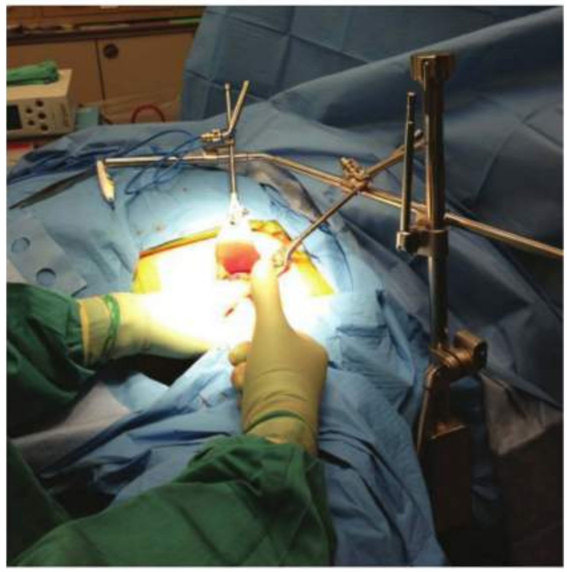

FIG 5 ● The Thompson retractor provides excellent exposure for an ALND.

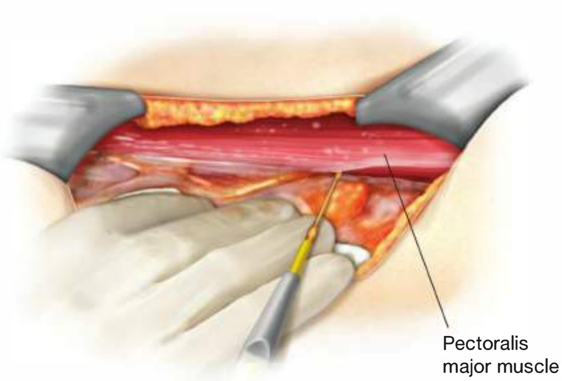

FIG 4 ● The pectoralis major muscle is identified and cleaned off along the lateral edge.

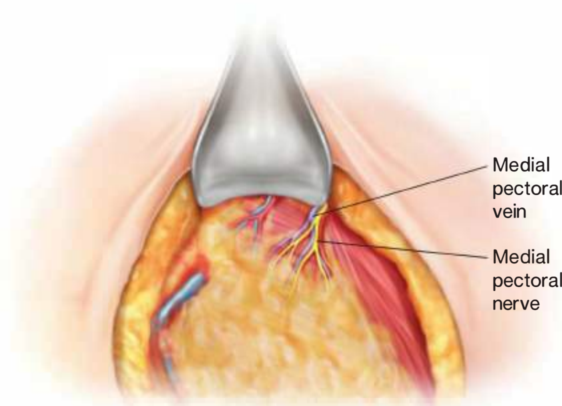

FIG 6 ● The medial pectoral nerve.

- For patients undergoing an ALND for a positive SLN, the pectoralis minor can be preserved. The lateral edge of the pectoralis minor muscle is freed by dividing the axillary fascia (FIG 7). The axillary fascia is an extension of the clavipectoral fascia that divides the subcutaneous fat from the axillary fat. Upon dividing the fascia, you will notice the protrusion of a more yellow, globular fat. This is the lymph node–bearing tissue that needs to be excised.
- The axillary contents are now swept laterally and the pectoralis minor muscle exposed along its length. Once this is done, the Thompson retractor can be repositioned so that both the pectoralis major and minor can be retracted anteriorly.
- If there is bulky adenopathy and exposure of the upper axillary lymph nodes is difficult, it may be necessary to divide the pectoralis minor muscle, and this is described subsequently.

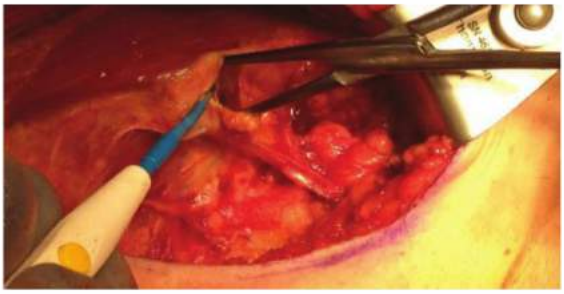

FIG 7 ● The axillary (clavipectoral) fascia is divided with cautery, revealing the axillary fat underneath.

IDENTIFICATION OF THE AXILLARY VEIN

- The vein often becomes visible medially during the elevation of the pectoralis musculature. If not, its general location can be anticipated by identifying the underarm dimple at the inferior aspect of the upper arm and tracing it toward the chest wall (FIG 8). Dissection down to the vein should not be performed directly with cautery to avoid an inadvertent injury, but rather, a careful dissection is recommended (FIG 9). Small venous branches and lymphatics should be clipped or suture ligated. It is also important not to find yourself superior to the vein, as the axillary artery and brachial plexus can be injured. Once the vein has been identified, the inferior margin should be cleared. It is not necessary to skeletonize the vein.

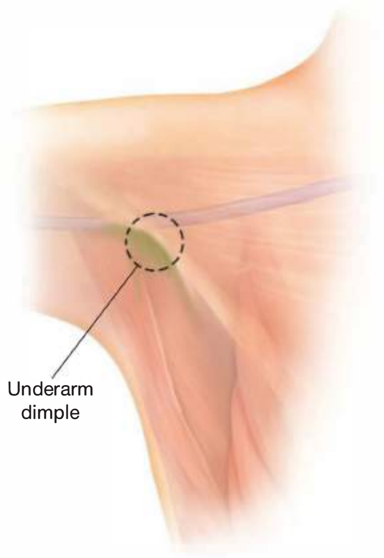

FIG 8 ● The position of the axillary vein in the axilla can be estimated by locating the underarm dimple and tracing this back toward the chest wall.

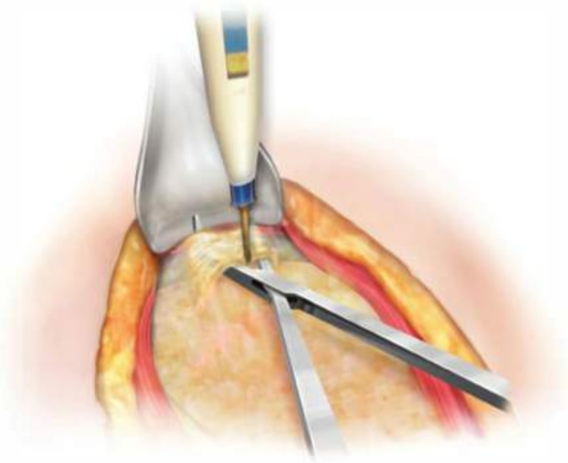

FIG 9 ● Exposure of the axillary vein is accomplished by careful dissection with a right angle and cautery.

THE LATISSIMUS DORSI MUSCLE

- The final boundary to identify is the latissimus dorsi muscle. Again, this is often seen during the elevation of the inferior flap. If not, the lateral skin should be retracted laterally using skin hooks or sharp rakes, and the axillary contents retracted medially. Dissection down through the subcutaneous fat will identify the muscle (FIG 10). In obese patients, be careful not to overestimate how lateral the muscle is, as you may dissect past it and raise an unnecessary posterolateral flap. Likewise, being too medial puts the thoracodorsal bundle at risk. Once identified, it should be cleared by staying on the anterior surface of the muscle.

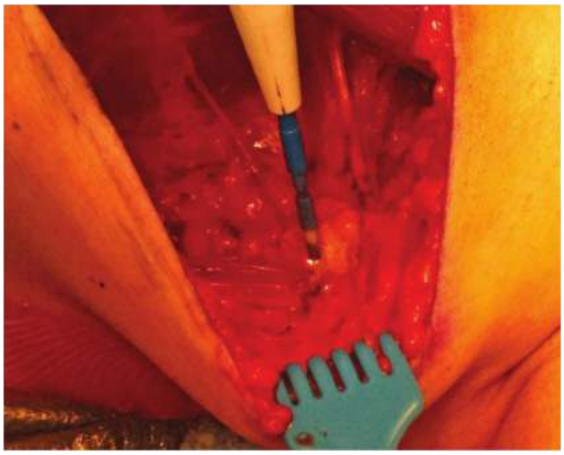

FIG 10 ● With lateral traction on the skin, the latissimus dorsi muscle is exposed and cleared on its anterior surface.

- In a small percentage of cases (approximately 5% to 7%), you may identify a more superficial muscle extending from the latissimus dorsi muscle to the pectoralis muscle, over the axillary vein. This is a muscular–tendinous structure known as a Langer's arch (**FIG 11**). This can often be disorienting, so it is important you be aware of this possibility and continue to dissect laterally to identify the latissimus dorsi. The Langer's arch, if present, will need to be divided and excised with the specimen.
- The latissimus muscle should be cleared up to the point where the tendinous insertion is reached beneath the axillary vein.

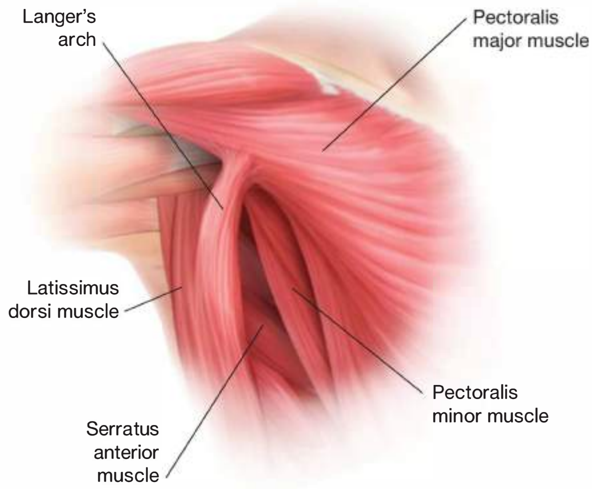

FIG 11 ● Anatomy of a Langer's arch.

THE THORACODORSAL NEUROVASCULAR BUNDLE

- Once the intersection between the vein and the latissimus is identified, the axillary contents are freed from lateral to medial. Lymphatics should be clipped rather than cauterized. The intercostobrachial nerve will be in this tissue, extending toward the arm and is commonly sacrificed during this operation. It is important to note that the intercostobrachial nerve does not need to be sacrificed. It can be dissected free by bivalving the specimen and freeing the nerve. However, this is not commonly done when an ALND is being performed for known cancer.
- It is important not to divide the axillary tissue to identify the thoracodorsal vein, but rather, make sure all the tissue between the latissimus dorsi and thoracodorsal bundle is dissected and included with the specimen. Failure to do this, for example, making the thoracodorsal bundle the lateral margin, will leave behind several lymph nodes. As these nodes primarily drain the arm, this is particularly important in melanoma.
- As the axillary vein is cleared medially, the thoracodorsal vein can be identified. The thoracodorsal vein comes off the posterior aspect of the vein. The other large tributary off the axillary vein is the lateral thoracic vein, but this comes off inferiorly, which serves as an important clue that it is not the thoracodorsal vein (**FIG 12**). Although the lateral thoracic vein will need to be ligated, this should not be done until the thoracodorsal vein is clearly identified. The thoracodorsal nerve may be directly behind the lateral thoracic vein, so take care when ligating it.
- Once the thoracodorsal vein is visualized, the artery can usually be seen pulsating in close proximity. The nerve, however, at this level, does not run next to the

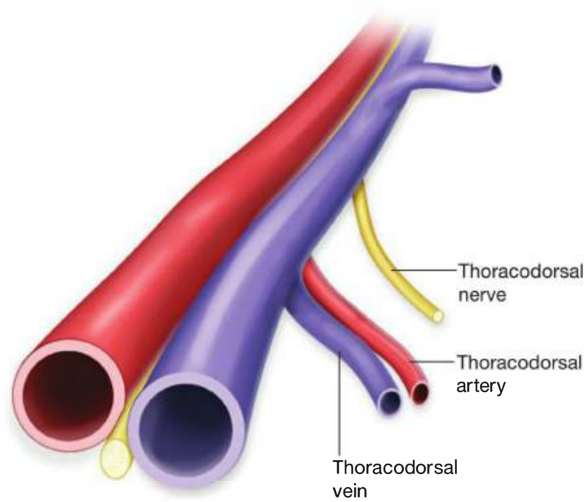

FIG 12 ● Whereas the lateral thoracic nerve enters the axillary vein on the inferior surface, the thoracodorsal vein tends to enter more posteriorly. This can be an important clue as to which vein you are looking at.

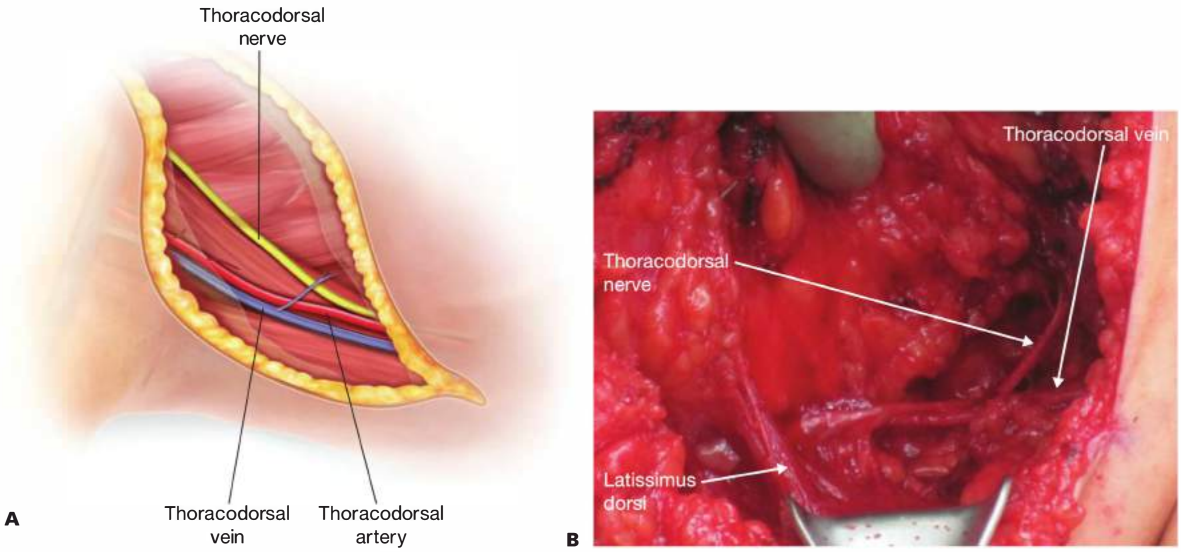

FIG 13 ● **A.** Relationship of the thoracodorsal nerve to the artery and vein. **B.** Intraoperative photo showing the nerve medial to the vein and artery and then joining the bundle inferiorly.

vein but is usually seated more medial, joining the vein and artery 1 to 2 cm inferiorly (**FIG 13A,B**). The nerve can easily be damaged by assuming it is next to the vein and dividing the more medial tissue. Careful dissection, avoiding the electrocautery, should be used to identify the nerve and trace it inferiorly until it joins the bundle.

- Although these anatomic relationships are generally true, the anatomy can be distorted by both bulky adenopathy and prior surgery. These can distort the relative positions of these structures, and this should be considered when having difficulty identifying them.
- Once the thoracodorsal nerve, artery, and vein are identified, they can be traced and dissected free down to their insertion into the latissimus dorsi. This can be facilitated by retracting the axillary contents anteromedially (which can sometimes be done with the long blade of the Thompson retractor). Although this step can be completed later, we prefer to free the entire bundle now, when visibility is optimized (**FIG 14**). There will be branches off of the thoracodorsal toward the specimen that will need to be clipped or ligated.

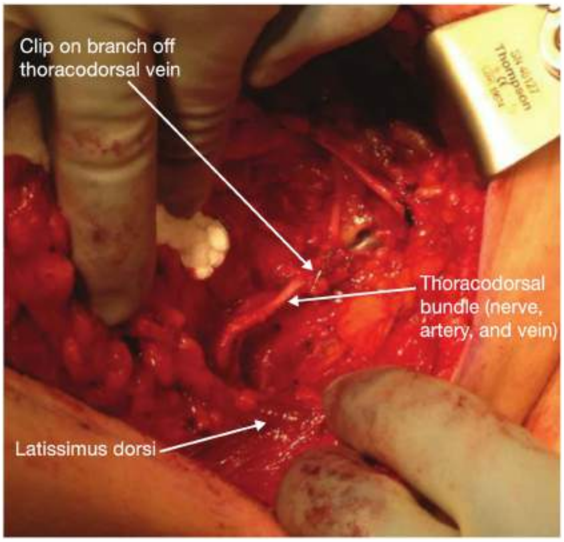

FIG 14 ● With the axillary contents swept medially from the latissimus dorsi, the entire bundle is visualized.

DISSECTION OF THE LEVEL II AND LEVEL III NODES

- Once the thoracodorsal is free, the axillary contents are released and the pectoralis major and minor once again retracted medially and anteriorly. The serratus anterior is identified and you will notice the yellow axillary fat extending up along the serratus, under the pectoralis minor, and along the axillary vein, like the top of a pyramid. This tissue bears the level II and III nodes. The axillary contents are dissected off of the serratus anterior. There is often a large vein that will need to be ligated.
- The intercostobrachial nerve can be seen exiting from the serratus anterior. Although this was likely ligated laterally, it needs to be divided again. The nerve should be cut with scissors flush with the muscle. This minimizes the chance of a neuroma and postoperative neuropathic pain, which is more likely if the nerve is divided with cautery or clips.
- The axillary fat is dissected off of the axillary vein. If you haven't already, you will note the axillary fat extending

superior to the vein, overlying the brachial plexus. This fat should be included with the specimen. There is a plane of tissue between the fat and the brachial plexus that allows this fat to be retracted inferiorly and can be easily dissected free, dividing only some loose areolar tissue (**FIG 15A,B**). Excessive cautery near the brachial plexus is strongly discouraged, and care is taken to clip or suture ligate any small vessels.

- Dissection of the upper axillary lymph nodes is facilitated by adducting the arm over the chest and held by an assistant. This allows the surgeon to reposition the Thompson retractor and gain more medial-anterior retraction, opening the axilla. The level II, and in some patients, the level III nodes, can be accessed this way and dissected from the thoracic inlet off the chest wall. It is important to carefully ligate the specimen and any small vessels, as this is a difficult area to return to in the case of bleeding.
- In many patients, based on body habitus or in the presence of bulky adenopathy, it is not possible to completely dissect the upper axillary lymph nodes just by adducting the arm over the chest. In this case, there are two options. The pectoralis minor muscle can be divided or an infraclavicular approach can be taken.

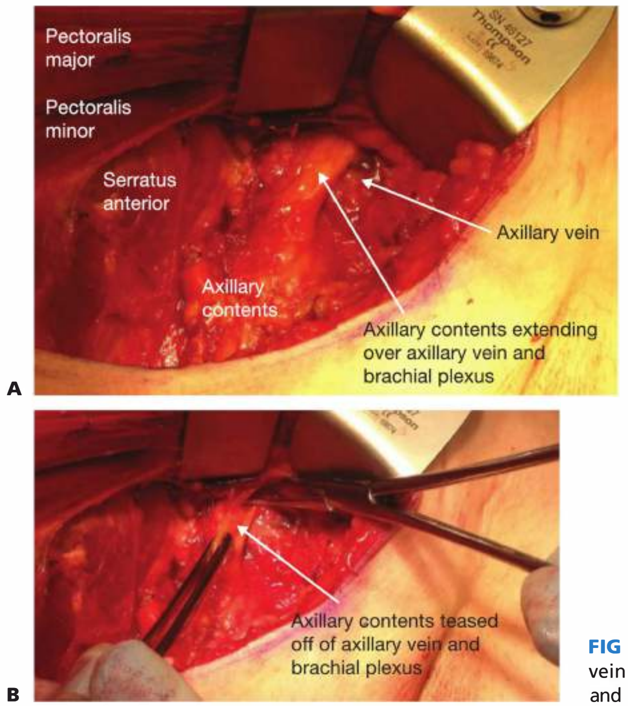

FIG 15 ● **A.** Axillary contents extending superiorly over the vein and brachial plexus. **B.** This is teased down with a forceps and included with the specimen.

DIVISION OF THE PECTORALIS MINOR MUSCLE (PATEY PROCEDURE)

- In some cases, there may be direct involvement of the pectoralis minor muscle by tumor. In this case, the pectoralis minor should be resected en bloc with the axillary contents, dividing the muscle at the insertion point on the coracoid process and dividing it off the chest wall inferiorly (**FIG 16**). This greatly facilitates the removal of the level III lymph nodes.

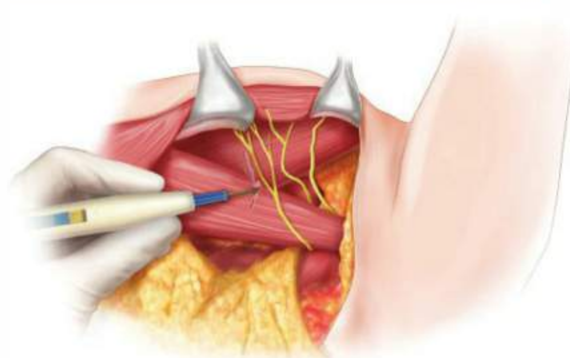

FIG 16 ● The pectoralis minor muscle is divided to obtain easier access to the level III lymph nodes, taking care not to injure the pectoral nerves.

INFRACLAVICULAR APPROACH

- An alternate approach is to make a second transverse incision, approximately 2 cm below the clavicle, and then separating the clavicular from the sternal heads of the pectoralis major (**FIG 17**). The level III nodes can then be excised, taking care not to injure the neurovascular structures. Division of the pectoralis minor is adequate in the great majority of patients, but the infraclavicular approach can be extremely beneficial in patients with bulky adenopathy at the confluence of the cephalic and axillary veins and in patients who recur in level III after a prior level I and II ALND.

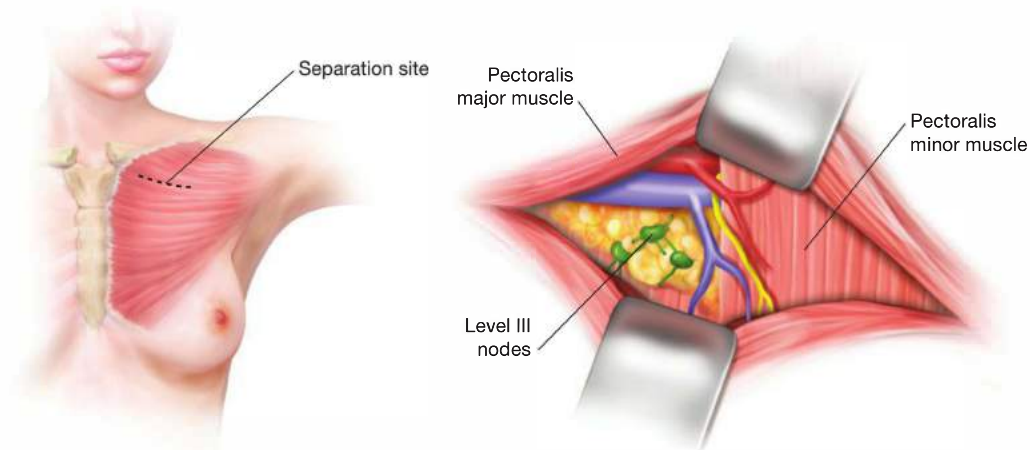

FIG 17 ● An alternate approach to the level III axillary nodes is to make an incision 2 cm below the clavicle and separate the clavicular and sternal heads of the pectoralis major.

EXPOSURE OF THE LONG THORACIC NERVE

- Once the level II and III nodes are free, they are brought laterally. The final structure to identify will be the long thoracic nerve. The nerve is commonly described as running along the serratus anterior, but this is incorrect. It is actually outside the fascia of the serratus, and this is exaggerated by the lateral retraction. Therefore, dissection directly on the serratus anterior will not identify the nerve and may lead to inadvertent injury. Dissection should be performed slightly laterally to the chest wall (**FIG 18**), and cautery should be used sparingly.
- Two anatomic landmarks can often help identify the nerve or estimate its position. First, the long thoracic and thoracodorsal nerve are roughly in the same anteroposterior (AP) plane. Therefore, by noting the location of the thoracodorsal nerve, you can estimate where you should be looking for the nerve. As before, this relationship can be altered by bulky disease or prior surgery. Second, the thoracodorsal vein often gives off a crossing branch toward the chest wall. This usually enters the chest wall at the level of the nerve.
- Once identified, the specimen is separated from the long thoracic nerve by carefully dissecting laterally to the nerve, allowing the nerve to move medially along the chest wall. This can often be done bluntly, but care should be taken not to stretch the nerve too much, as this can lead to injury and a temporary winged scapula.

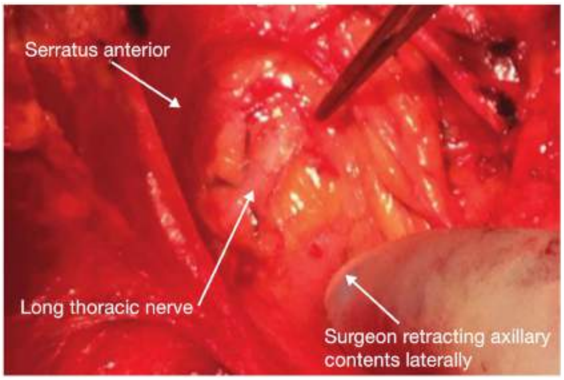

FIG 18 ● The long thoracic nerve is identified just lateral to the serratus anterior, which is emphasized by lateral retraction of the specimen.

REMOVAL OF THE SPECIMEN

- With both nerves free, the next step is to remove the tissue from between the nerves off of the underlying subscapularis muscle. At the level of the axillary vein, the fibrofatty tissue between the nerves should be clamped, taking care to be sure both nerves are free (FIG 19). The tissue is divided and tied off. This can be done in multiple steps. Once the subscapularis muscle is seen, the tissue can be easily divided off the muscle, constantly visualizing the nerves. Excessive lateral retraction can sometimes pull the serratus and the nerve, leading to accidental injury. This dissection should be carried inferiorly, past the point where both nerves enter their respective muscles. This can be facilitated by repositioning of the Thompson retractor.
- At this point, the specimen may still be attached inferiorly. Other than some veins going to the specimen, which can be suture ligated, this tissue can be divided with cautery, releasing the specimen, which is sent to pathology.

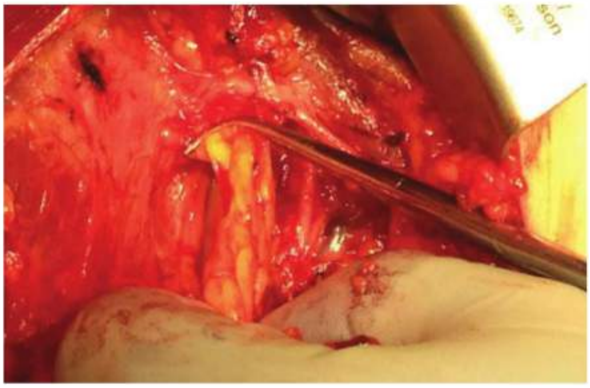

FIG 19 ● The axillary tissue below the vein and between the long thoracic and thoracodorsal nerve is clamped, being sure that both nerves are completely free. The tissue is divided and then taken off the subscapularis muscle.

DRAIN PLACEMENT AND INCISION CLOSURE

- The wound should be irrigated with saline or sterile water and thoroughly examined for hemostasis. This should include retraction of the pectoralis major and minor to explore this area. While assuring hemostasis, be careful not to use cautery near the long thoracic or thoracodorsal nerves.
- A single 10-mm flat channel drain is placed through a separate incision inferiorly and sutured to the skin. The drain should be cut so it just lies inferior to the axillary vein. The incision is closed using deep dermal 3-0 absorbable sutures and, for the typical closure, skin adhesive or absorbable monofilament suture. If a large amount of skin is needed to be excised, Nylon sutures may be appropriate.

PEARLS AND PITFALLS

Preoperative planning	■ A thorough neurovascular exam of the involved extremity is critical. Any suggestion of neurovascular involvement should prompt an MRI to assure resectability. ■ For patients who had prior axillary surgery, document any sensory or motor defects, as a nerve injury may have already occurred. ■ Be sure the patient is aware of what to expect postoperatively, including short-term and long-term lymphedema risk reduction and management.
Positioning	■ Having the arm prepped into the field so that it can be retracted over the chest is critical to performing a complete ALND.
Skin flaps	■ Avoid excessively thin flaps as this will lead to wound complications and a "sunken-in" appearance to the axilla. ■ Raise an adequate inferior flap early, as this allows better mobilization of the specimen and better exposure.
Elevating the pectoralis major and minor	■ Every attempt to preserve the medial pectoral nerve should be made. This requires care when mobilizing the pectoralis muscles.

Identifying the latissimus dorsi	■ Careful dissection should land you on the anterior surface of the latissimus dorsi. If you do not see it, slow down and use a right angle rather than continue to cauterize. If you are too medial, you could injure the thoracodorsal bundle. Be careful you are not too lateral (particularly in an obese patient).
Identifying the vein	■ Use the underarm dimple to estimate the location of the axillary vein. Being too far superior risks injury to the brachial plexus.
Thoracodorsal bundle	■ The thoracodorsal vein comes off the axillary vein posteriorly. If you find a vein coming off the inferior aspect of the axillary vein, it is probably the lateral thoracic, but do not ligate it until you have seen the thoracodorsal. ■ The nerve is usually medial to the vein at this level but not always. ■ If you can not locate the bundle, you can identify it at the level of the latissimus and trace it back toward the axillary vein.
Long thoracic nerve	■ Do not dissect directly on the serratus anterior—you will be medial to the nerve and mobilize it into your specimen. ■ Expect the long thoracic nerve in roughly the same AP plane as the thoracodorsal vein. ■ If you trace the thoracodorsal nerve along its length, a branch will head medially to the chest wall precisely where the long thoracic nerve lies.
Altered anatomy	■ Remember, bulky adenopathy or prior surgery (such as an SLN biopsy) can alter these relationships.

POSTOPERATIVE CARE

- The drain will remain in place until the output falls below 30 mL per 24 hours for 2 days in a row. The patient and their family should be shown how to care for the drain and record the drain output. A visiting nurse can be of assistance.
- Patients should be instructed to avoid repetitive activities with the arm or heavy lifting. Some surgeons also advise avoiding reaching over 90 degrees, particularly if the incision was excessively tight. However, patients should be encouraged to use the arm for normal activities and should be given exercises to maintain normal range of motion. Slings should not be given to patients.
- Once the drains are removed, physical therapy can be extremely helpful with returning to full range of motion.
- Patient education about the signs and symptoms of lymphedema and lymphedema prevention. Early recognition of lymphedema can improve the likelihood of management.
- Patients with stage III melanoma should be referred to medical oncology for a discussion of adjuvant therapies (high-dose interferon α-2b, biochemotherapy) or clinical trial. Patients with disease at high risk for relapse should also be considered for adjuvant radiation.

OUTCOMES

- For prospective trials, the adequacy of an ALND is often based on the number of lymph nodes identified within the axillary specimen. Morton et al.[6] in the MSLT-I trial recommended 15 or more nodes for an ALND, and this is a reasonable benchmark. However, this number will vary not only with surgical technique but also body habitus and the pathologist.
- For patients with AJCC stage IIIa disease, defined as having a nonulcerated primary with 1 to 3 nodes containing micrometastatic disease (diagnosed on SLN biopsy), the 5-year survival is approximately 78%, whereas the 10-year survival is 68%. For patients with AJCC stage IIIb disease, defined as either having an ulcerated primary with micrometastatic disease in 1 to 3 nodes or a nonulcerated primary with macrometastatic disease in 1 to 3 nodes, the 5-year survival is 59%, whereas the 10-year survival is 43%. For patients with AJCC stage IIIc disease, defined as an ulcerated primary with macrometastatic disease in 1 to 3 nodes, or any patient with 4 or more nodes, matted nodes, or in-transit disease and positive nodes, the 5-year survival is 40% and the 10-year survival is 24%. However, there can be considerable variability, as survival is impacted not only by the nodal status but also by age, gender, the Breslow thickness of the primary melanoma, the presence of ulceration, and the tumor mitotic rate.[7]
- Although data related specifically to ALNDs is limited, the reported regional recurrence rates after an ALND performed for a positive SLN biopsy are around 4% to 5%.[1,8,9]
- Regional recurrence after ALND is higher in patients with two or more positive axillary nodes, extracapsular extension, or any node greater than 3 cm in size. For patients with such high-risk features, axillary recurrence can be as high as 23% to 50%.[10–12] Although it does not appear to impact overall survival, the use of adjuvant radiation can reduce the risk of axillary recurrence by 50%.[13–15]

COMPLICATIONS

- Infection
- Hematoma
- Seroma
- Limited range of motion at the shoulder
- Axillary web syndrome
- Paresthesias of the axilla and upper inner arm
- Axillary vein thrombosis
- Lymphedema
- Winged scapula (injury to the long thoracic nerve)
- Latissimus dorsi paralysis (injury to the thoracodorsal nerve)
- Brachial plexus injury

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Chapter 29

Inguinal Lymph Node Dissection (Inguinofemoral and Ilioinguinal) for Metastatic Melanoma

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DEFINITION

- Inguinofemoral lymphadenectomy (or superficial inguinal lymph node dissection) is defined as the en bloc removal of all lymphatic tissue contained within the femoral triangle, as well as the node-bearing tissue superior to the inguinal ligament but superficial to the external abdominal oblique aponeurosis, up to the level of the anterior superior iliac spine (ASIS).
- The procedure can be combined with a pelvic (also known as deep inguinal) node dissection, in which case it is designated as an ilioinguinal lymphadenectomy, that includes the separate removal of the obturator and external iliac lymph nodes at least up to the level of the iliac bifurcation.
- The procedure has been used for the management of inguinal metastasis from penile and vulvar carcinoma as well as cutaneous malignancies such as squamous cell, basal cell, adnexal, and Merkel cell carcinoma, but it is most commonly used for metastatic melanoma, the focus of this chapter.

DIFFERENTIAL DIAGNOSIS

- Patients who present with a palpable inguinal mass with a history of melanoma should be considered to have metastatic melanoma until proven otherwise.
- Patients who present with a palpable inguinal mass without a known history of melanoma should be investigated for a primary malignancy with complete skin/mucosal surface physical examination including the vulva, penis and perianal skin/anal canal, and a digital rectal examination to evaluate for melanoma, nonmelanoma skin cancer (squamous cell, basal cell, Merkel cell, or adnexal carcinoma), vulvar, penile, and anal cancer.
- For patients presenting with a palpable groin mass but without history or physical evidence of skin/mucosal surface cancers, the differential diagnoses include inguinal/femoral hernias, femoral aneurysm, reactive/infectious lymphadenopathy (cat-scratch fever or posttraumatic), lymphoma, or metastatic cancer of unknown primary origin (including melanoma).

PATIENT HISTORY AND PHYSICAL FINDINGS

- Prompt diagnosis of inguinal metastasis by the least invasive means when possible is a good start to minimize the morbidity of subsequent inguinal node dissection.
  - Patients with clinically occult inguinal disease can be diagnosed with sentinel lymph node biopsy. Inguinofemoral lymphadenectomy for microscopic nodal disease identified with sentinel lymph node biopsy appears to be associated with less morbidity compared to lymphadenectomy for macroscopic nodal disease.[1]
  - Patients with palpable groin masses not determined to be an aneurysm or hernia should be considered for a percutaneous fine needle or core needle biopsy to establish the diagnosis. If the mass is difficult to palpate or characterize, a diagnostic ultrasound with subsequent ultrasound-guided biopsy could be considered. Open biopsy should be reserved for when percutaneous biopsy is nondiagnostic, as the resulting scar and biopsy cavity from an open biopsy of a palpable mass render subsequent lymphadenectomy technically more difficult and can often result in wider skin flaps than what otherwise would be necessary.[2]
- Although currently considered to be the standard of care, the role of completion inguinofemoral lymphadenectomy in patients with micrometastatic melanoma found on sentinel lymph node biopsy is under investigation. Nodal observation as a potential alternative to immediate completion lymphadenectomy in melanoma patients with a positive sentinel node is being evaluated in the ongoing Multicenter Selective Lymphadenectomy Trial II. The trial randomizes patients with a positive sentinel lymph node to either immediate lymphadenectomy or observation with serial clinical examinations and ultrasonography. The patients randomized to observation may undergo a delayed completion lymphadenectomy if there is regional recurrence or may avoid the procedure and its associated morbidity if there is no evidence of regional disease during follow-up.
- Ilioinguinal lymphadenectomy is typically warranted for patients with radiographic evidence of metastatic disease in the pelvis. Other indications for an ilioinguinal lymph node dissection have not been definitively established and therefore are controversial. The clinical benefit of ilioinguinal lymphadenectomy for clinically occult metastatic disease when the pelvic nodes appear to be radiographically normal has not been demonstrated in a randomized, prospective trial to date. However, there are indications that are generally considered but not yet established.
  - Relative indications for ilioinguinal lymphadenectomy include any palpable inguinofemoral disease or four or more micrometastatic lymph nodes found at the setting of prior sentinel lymph node biopsy.
  - A possible but not yet established indication is any positive inguinofemoral sentinel lymph node biopsy result where the lymphoscintigraphy indicated evidence of "hot" nodes in the pelvis that were not removed in the sentinel lymph node procedure.
  - Some surgeons advocate for the positive status of the so-called "Cloquet's node" as an indication for ilioinguinal lymphadenectomy. However, there is a lack of uniform definition of Cloquet's node, as well as known examples

of lymphoscintigraphy performed for sentinel node biopsy where there is direct drainage from low or mid-inguinal nodes to pelvic nodes, bypassing all high inguinal nodes that would include Cloquet's node. Due to these factors, we do not rely on the status of Cloquet's node in any way.[2]

- Inguinofemoral or ilioinguinal lymph node dissections are performed under general anesthesia; therefore, the patient should be assessed for perioperative cardiac risk factors and referred for preoperative testing including cardiac stress test when clinically warranted.
- Patients should be clinically assessed for any preoperative lymphedema and typically are referred for fitted gradient compression stocking measurements to be used in the postoperative period. Although proof of the value of compression therapy is lacking, it is thought that early institution of compression therapy might minimize the risk of lymphedema in the early postoperative period.

IMAGING AND OTHER DIAGNOSTIC STUDIES

- Prior to lymphadenectomy, patients who are diagnosed with palpable inguinal metastatic melanoma typically are recommended to undergo whole body imaging (positron emission tomography–computed tomography [PET/CT] plus brain magnetic resonance imaging [MRI] or equivalent). Surgery is typically pursued in the absence of biopsy-proven distant disease, whereas systemic therapy is typically pursued if biopsy-proven distant disease is found.
- Patients who are diagnosed with micrometastatic inguinal melanoma by sentinel lymph node biopsy are not routinely recommended to undergo imaging due to the relatively low frequency of findings that are truly positive.

SURGICAL MANAGEMENT

Preoperative Planning

- Preoperative planning for a complete lymphadenectomy starts with careful consideration of the diagnostic procedures required to establish the diagnosis of metastatic disease. Percutaneous needle biopsy where feasible should be considered for palpable disease as discussed above. Orientation of the sentinel node incision should be planned to facilitate a potential inguinal lymph node dissection that will include resection of the sentinel node biopsy scar and cavity.
  - When the sentinel node is mapped below the inguinal ligament, the sentinel node incision should ideally be vertically oriented and at least 0.5 cm distal to the groin crease (**FIG 1A**).
  - When the sentinel node is mapped to above the inguinal ligament (typically with a flank primary melanoma), the sentinel node incision should ideally be obliquely or transversely oriented and at least 0.5 cm proximal to the groin crease (**FIG 1B**).
- For planning the completion lymphadenectomy, the operative side and site should be identified with the agreement of the patient and/or the representative of the patient in the preoperative holding area.
- Patients with a prior history of deep vein thrombosis (DVT) or known genetic predisposition to thrombosis are given a prophylactic dose of low-molecular-weight heparin preoperatively.
- A first-generation cephalosporin such as cefazolin (or equivalent if allergic to cephalosporins or penicillin) are routinely given intravenously within 30–60 minutes of the creation of the skin incision.

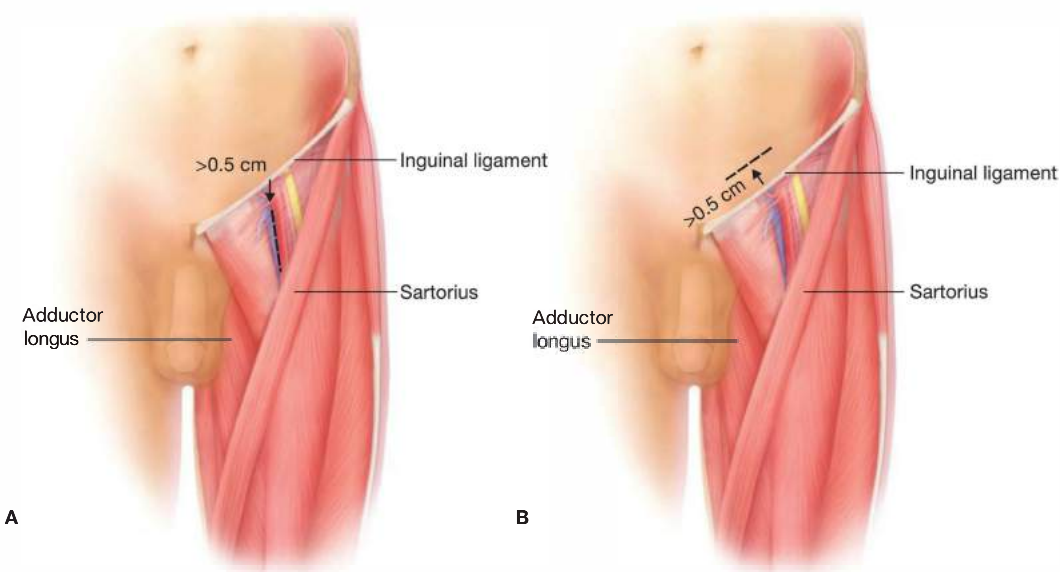


FIG 1 ● **A.** The recommended orientation for sentinel node biopsy incision when the draining nodes map to the region inferior to the groin crease. **B.** The recommended orientation for sentinel node biopsy incision when the draining nodes map to the region superior to the groin crease.

Positioning

- The patient is placed in the supine position on a standard operating table. A sequential compression device (SCD) (knee length ipsilateral and thigh length contralateral) should be placed for DVT prophylaxis prior to induction of anesthesia. General anesthesia is required using either a laryngeal mask or endotracheal tube for inguinofemoral lymphadenectomy, but endotracheal tube is preferred for ilioinguinal dissections. Long-acting paralytic agents at induction are often avoided to allow for motor nerve stimulation to be evident during the course of the procedure. A urinary catheter is inserted for ilioinguinal dissections but may potentially be omitted for inguinofemoral dissections at the discretion of the surgeon. The patient is placed in a slight frog-leg position with all pressure points padded. The operative field should be prepared from the abdominal wall at the level of the umbilicus to the level of the knee. A groin towel secured with a sterile adhesive drape can be used to cover and exclude the genitalia from the field.

INGUINOFEMORAL (OR SUPERFICIAL) LYMPHADENECTOMY

Skin Incision and Raising of Flaps

- As stated previously, a well-placed node biopsy incision, or avoiding the creation of a preexisting incision by percutaneous instead of open biopsy of palpable metastasis, is important to minimize the area of required skin flaps.
- For a positive sentinel node where the sentinel node scar is below the inguinal crease, a curvilinear incision is made in a vertical orientation with an ellipse of skin to facilitate excision of the previous cavity of dissection (**FIG 2A**). For a positive sentinel node where the sentinel node scar is above the inguinal crease, a transversely or obliquely oriented incision is made to excise the previous cavity of dissection. A second counterincision can be made below the inguinal crease to reach the remaining femoral nodes (**FIG 2B**). In thin individuals, retraction can frequently allow for the extirpation of the femoral nodes distal to the inguinal crease without the need for the second incision.
- For palpable disease without a pre-existing biopsy scar, a skin incision is configured in a lazy "S" fashion (**FIG 2C**). If the tumor is close to the skin, an ellipse of skin overlying the palpable tumor should be included. The incision should also include any scar from prior node biopsy procedure if applicable. This incision can be extended in a cranial direction if needed for an ilioinguinal lymphadenectomy.
- Skin flaps are raised in order to clear the anticipated boundaries of the dissection (below) without being so thin to cause postoperative skin necrosis. Limiting the extent of the flaps to the borders of the femoral triangle avoids an unnecessarily wide field of dissection and therefore may be associated with a reduction in morbidity.
- The dissection is continued to the level of the muscular fascia with the following boundaries (**FIG 2D**):
  - Anterior superior iliac spine (ASIS) superolaterally
  - Pubic tubercle superomedially
  - The superior extent of dissection should encompass the tissue from the ASIS to the pubic tubercle resulting in approximately 3–5-cm clearance above inguinal ligament while leaving external oblique fascia intact.
  - Sartorius muscle laterally, incising the fascia
  - Adductor longus medially, incising the fascia
  - Crossing of the sartorius and adductor longus distally (the so-called apex of the femoral triangle)
- It should be noted that while there have been isolated reports suggesting that incising the fascia of the sartorius and adductor longus may increase lymphedema, this has not been established in large series and most surgeons incise the muscle fasciae as described earlier.
- During the course of the dissection, tissue that potentially contains lymphatic vessels should be clipped, tied, or sealed with harmonic shears.[3]
- A key point of the upper extent of the dissection on the abdominal wall is that the lymphadenectomy clears the subcutaneous and node-bearing tissue down to the external oblique fascia from the boundary of the ASIS to the pubic tubercle proximally and down to the inguinal ligament distally (**FIG 3**). The dissection can typically preserve the spermatic cord in males, but the round ligament can be divided, if necessary due to the presence of disease, in females.

Dissection of the Saphenous Vein Distally

- The distal portion of the saphenous vein is encountered along the medial boundary of the dissection approximately 3–5 cm proximal to the apex of the femoral triangle. In most cases, the saphenous vein is tied off distally with 2-0 silk and divided. The saphenous vein can potentially be preserved in select cases where the procedure is performed for micrometastatic disease, when and if any existing seroma cavity and scar tissue is separate from the vein.[1,4] Although saphenous vein preservation might theoretically reduce the likelihood of postoperative DVT and lymphedema, this maneuver has never been definitively shown to reduce postoperative complications in any prospective, randomized study. Therefore, saphenous preservation should only be considered in select cases performed for micrometastatic disease, where the vein is not involved with scar or seroma cavity, and the maneuver should never compromise the extent of dissection.

Dissection of the Femoral Vessels

- The superficial femoral artery is identified at the distal aspect of the dissection at the apex of the femoral triangle. At this level, the femoral artery lies anterior to the femoral vein. As the dissection proceeds distal to proximal, the femoral artery courses laterally while the femoral vein courses medially. The anterior surfaces of the femoral vessels are skeletonized, and the dissection is extended laterally at the same depth as the vessels to avoid injury to the femoral nerve, which is generally not directly visualized. The relationship of the femoral vessels to the boundaries of the femoral triangle is shown in **FIG 4**.

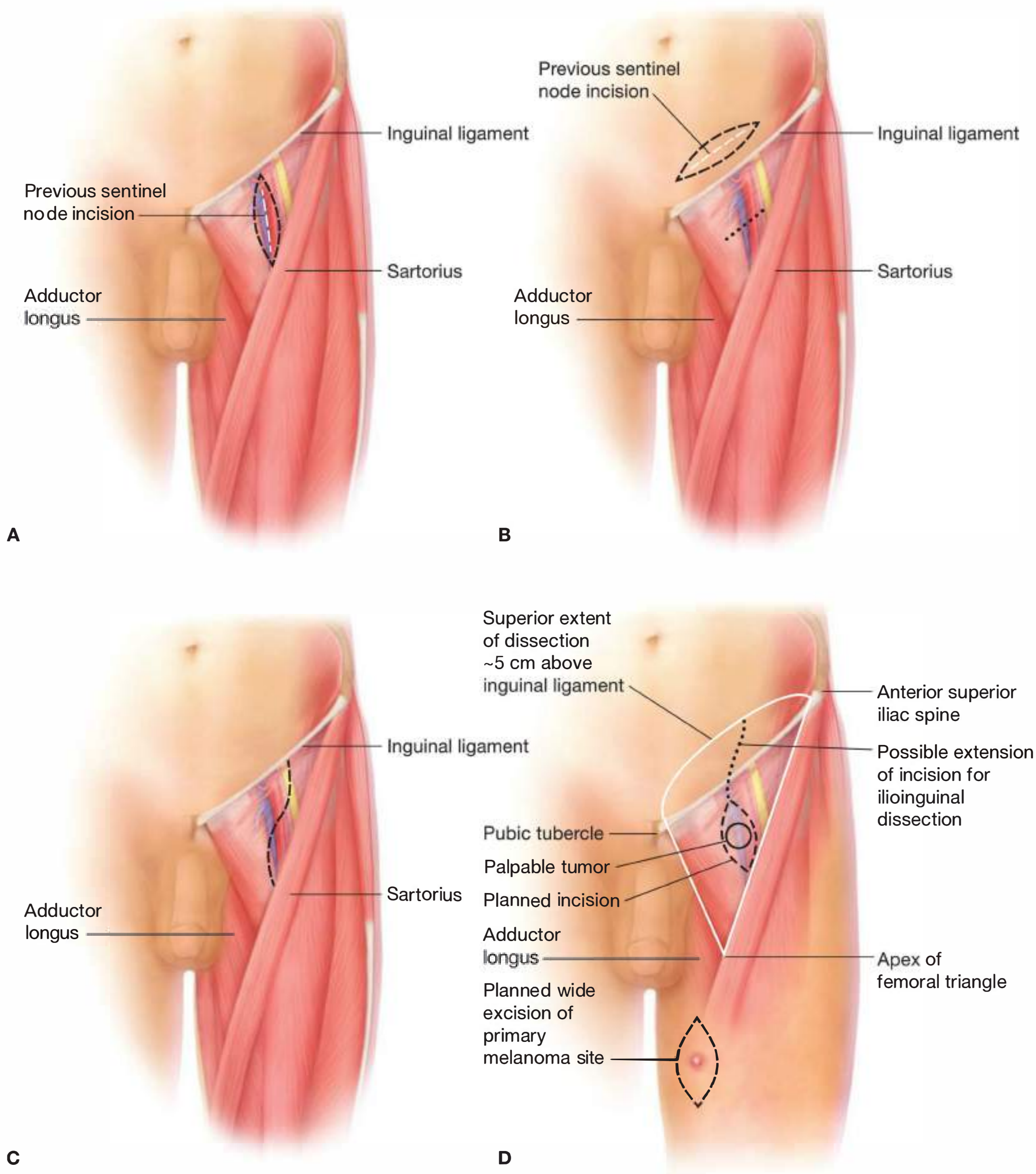


FIG 2 ● **A.** The recommended orientation of a curvilinear incision for the indication of a positive sentinel node that mapped to the region inferior to the groin crease. **B.** The recommended orientation of an elliptical incision above the groin crease combined if necessary with a linear incision inferior to the groin crease. **C.** The recommended orientation of a lazy S incision that can include an ellipse of skin overlying palpable disease. Of note, to facilitate exposure for an ilioinguinal lymphadenectomy, it may be required for the incision to cross the groin crease. **D.** The operative field with denoted boundaries of the extent of inguinofemoral lymphadenectomy (white line) in a patient with an intact primary melanoma and clinically evident nodal disease. Note that the planned incision includes the palpable metastasis and that the incision can be optionally extended onto the abdominal wall for an ilioinguinal lymphadenectomy.

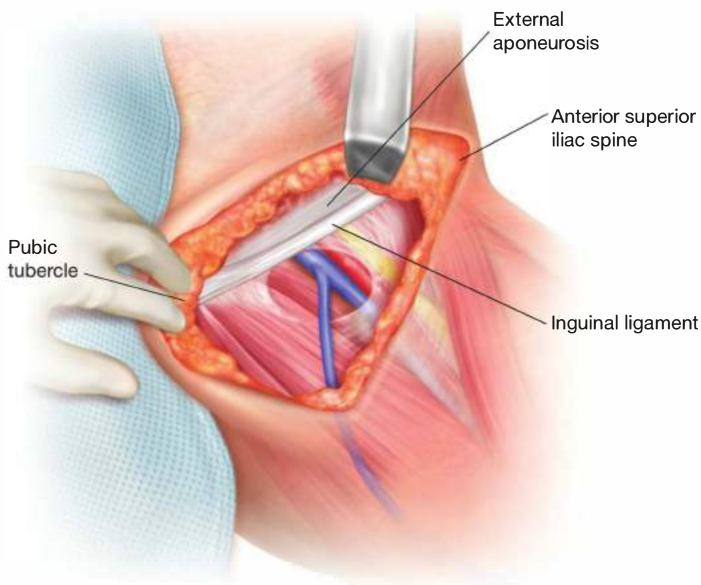


FIG 3 ● The superior extent of dissection clears all subcutaneous tissue 3–5 cm proximal to the inguinal ligament to a depth bounded by the underlying external oblique aponeurosis.

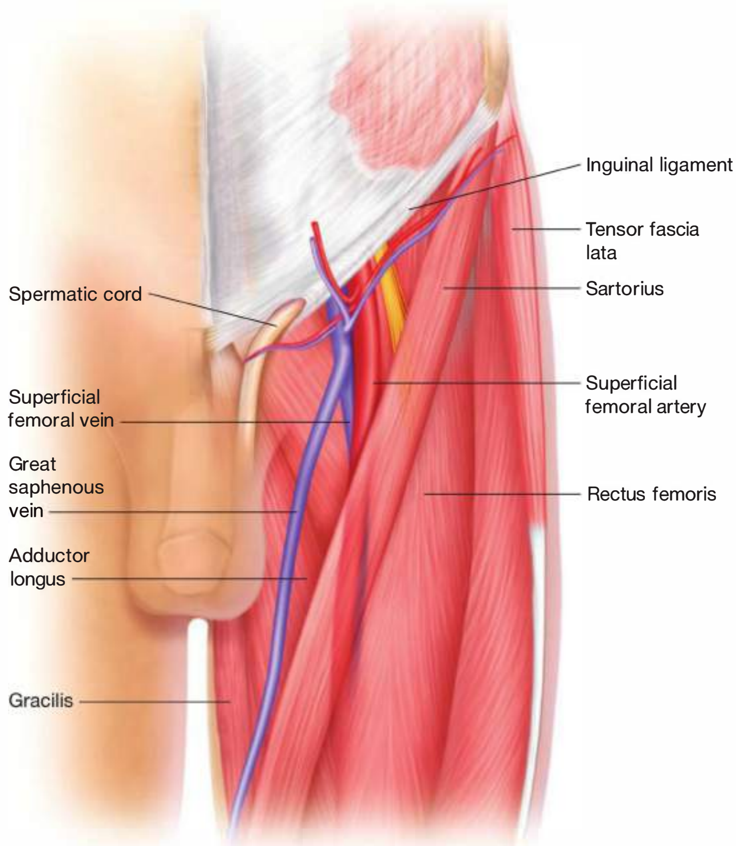


FIG 4 ● The relationship of the femoral artery and vein to the boundaries of the femoral triangle. Note at the distal apex of the femoral triangle, the femoral artery lies superficial to the femoral vein.

Completion of the Dissection and Ligation of the Saphenofemoral Junction

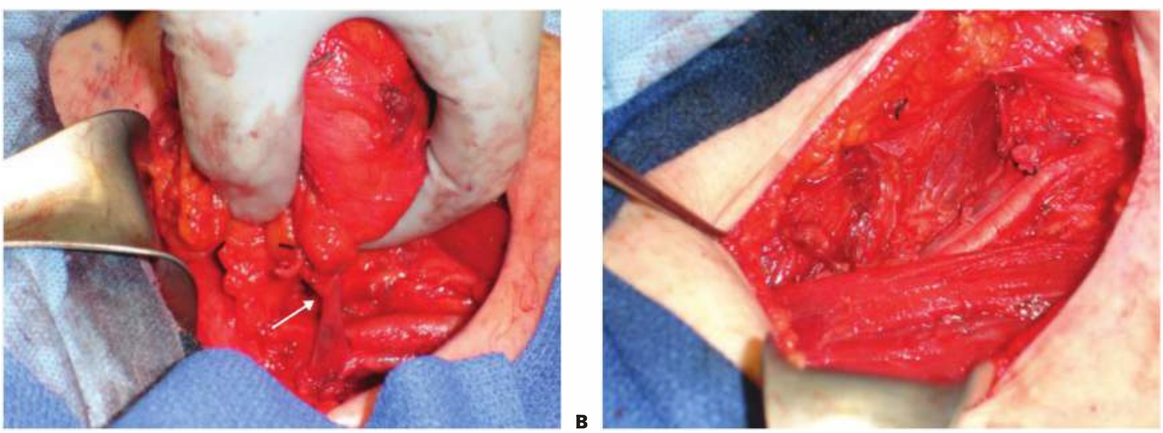
- The dissection continues in a distal to proximal direction up to the level of the saphenofemoral junction. If the saphenous vein is to be preserved, it is fully freed from the specimen; generally, several small- to medium-sized tributaries draining the specimen need to be divided and ligated individually. Otherwise, the entirety of the saphenous vein is included in the specimen and the remaining soft tissue is circumferentially dissected so that the specimen remains adherent only by the saphenofemoral junction (**FIG 5A**).
- The saphenous vein is doubly ligated at the level of the saphenofemoral junction, usually with a 3-0 silk suture ligature and a 2-0 silk tie, taking care not to narrow the femoral vein (**FIG 5B**). A formal closure of the stump with vascular suture is not routinely required but may be necessary if the saphenofemoral junction is very broad or if palpable tumor extends in close proximity to the femoral vein itself.

Sartorius Muscle Transposition Flap

- Sartorius muscle transposition is used to cover the exposed femoral vessels in the groin whenever there is concern about the integrity of the overlying skin flap closure. Some surgeons routinely perform this in all cases, whereas others do it selectively or not at all.[1,5] We use it in most cases but routinely omit it when the incision is placed high in the groin (i.e., not directly overlying the exposed vessels) and in selected younger patients, including children, especially athletes or other very active individuals.
- The tendinous portion of the sartorius muscle is taken off its point of origin at the ASIS with electrocautery. It is important to divide the muscle as high as possible to maximize the length of muscle available for the flap. It is critical to obtain meticulous hemostasis at the cut muscle edge, as there is little or no tissue at that level to tamponade bleeding and a small ooze can continue for hours postoperatively. To mobilize the muscle for the transposition flap without tension, a few lateral feeding vessels generally need to be tied off, and the lateral fascia is incised well down the length of the muscle. The muscle is transposed over the femoral vessels and secured in place to the external abdominal oblique aponeurosis/inguinal ligament with three or four interrupted, horizontal mattress 2-0 non-absorbable, braided polyester sutures oriented so that the knots are pushed down onto the sartorius muscle. The sutures are placed in a staggered fashion to avoid being placed at the same level in the ligament, which would otherwise weaken the fascia (**FIG 6**).

Placement of Drain and Closure

- If a concomitant pelvic dissection (i.e., superficial and deep lymphadenectomy) is planned, see the following text and closure is deferred until completion of that portion of the procedure.
- A flat or round closed-suction drain is routinely placed in the bed of dissection and brought out through a separate stab incision relatively close to the wound but away from the thinnest parts of the skin flaps. The incision is closed with interrupted 3-0 absorbable, polygalactin sutures for the subcutaneous tissue and a running suture of 4-0 absorbable, monofilament suture for the subcuticular skin layer. Cyanoacrylate adhesive (or equivalent) is used over the subcuticular closure for extra protection. The leg is wrapped with an Ace wrap from the level of the metatarsals to mid-thigh, and a thigh-length SCD is placed over the Ace and on the contralateral extremity. The urinary catheter, if used, is left in place at the end of the case.



A B

FIG 5 ● **A.** The appearance of the completed left inguinofemoral lymphadenectomy dissection with a view of the specimen attached only by the saphenofemoral junction *(arrow)* with the superficial femoral artery immediately lateral. **B.** The appearance of the ligated saphenofemoral junction *(arrow)* after removal of the specimen without any narrowing of the superficial femoral vein, and a view of the superficial femoral artery lateral to the vein as well as the sartorius muscle that forms the lateral boundary of the dissection.

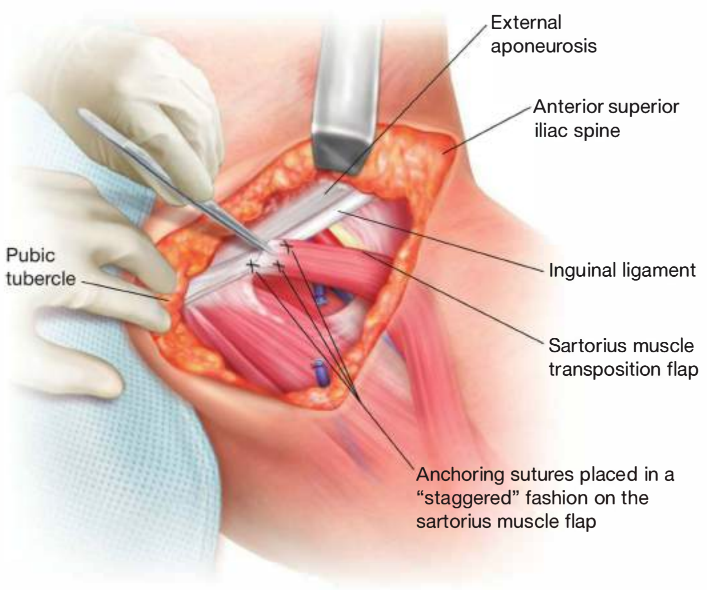


FIG 6 ● Sutures that anchor the sartorius muscle transposition flap are placed in a staggered fashion instead of being placed on a single plane in order to avoid weakening the fascia.

ILIOINGUINAL LYMPHADENECTOMY

Division of the Abdominal Wall and Retroperitoneal Exposure of the Pelvis

- When conducted as a portion of a combined ilioinguinal lymphadenectomy, the pelvic portion of the lymphadenectomy occurs through the same incision. The incision may need to be lengthened sufficiently above the inguinal crease to ensure adequate visualization (**FIG 2D**).
- The pelvic portion of the ilioinguinal lymphadenectomy involves the removal of the obturator and iliac nodes up to the bifurcation of the iliac vessels through a retroperitoneal approach. In some individuals, the common iliac nodes can be removed if grossly involved by extending the fascial incision cephalad, but para-aortic nodes are considered beyond the scope of the dissection and are rarely accessible through the retroperitoneal approach.
- Through the same skin incision used for the inguinofemoral dissection, the external and internal abdominal oblique aponeuroses are incised parallel to the direction of the fibers of the respective muscles (**FIG 7A**). The peritoneum is retracted superiorly and medially, which typically mobilizes the ureter out of the field. Retraction of the peritoneal contents superiorly and medially exposes the external iliac artery and vein with associated node-bearing tissue (**FIG 7B**).

Retrieval of Iliac Nodal Tissue

- The external iliac vessels are skeletonized over their anterior aspect. All fibrofatty and lymphatic tissue overlying the iliac vessels is retrieved from the bifurcation proximally to the posterior aspect of the inguinal ligament distally.

Retrieval of Obturator Nodal Tissue

- The external iliac vein is retracted laterally to expose the obturator space medially. Fibrofatty and lymphatic tissue is removed down to the level of the obturator nerve (**FIG 8**). Caution should be taken when dissecting medially as the obturator vessels and tributaries are difficult to visualize and can be difficult to control if injured.
- The obturator foramen and the pubic rami should be carefully inspected and palpated to ensure that nodes are not left behind in those locations.

Placement of Drain and Closure

- While not absolutely required, a second closed-suction drain can be deployed into the bed of the dissection and brought through the divided abdominal muscle fibers distally, exiting the skin through a separate stab incision. The internal and external abdominal oblique fasciae are closed with absorbable monofilament sutures. Closure then proceeds as described earlier in the inguinofemoral dissection.

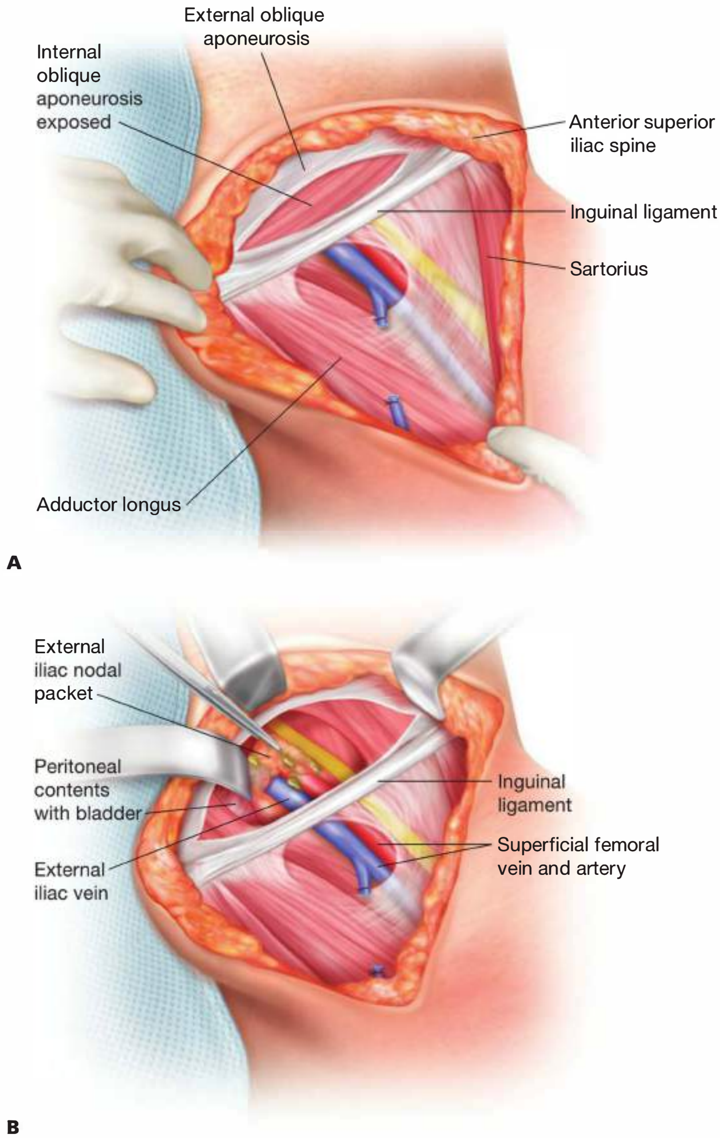


FIG 7 ● **A.** The external oblique aponeurosis has been incised in a direction parallel to its fibers, exposing the underlying internal oblique aponeurosis. **B.** Anterior view of the external iliac artery and vein with delivery of the external iliac nodal packet.

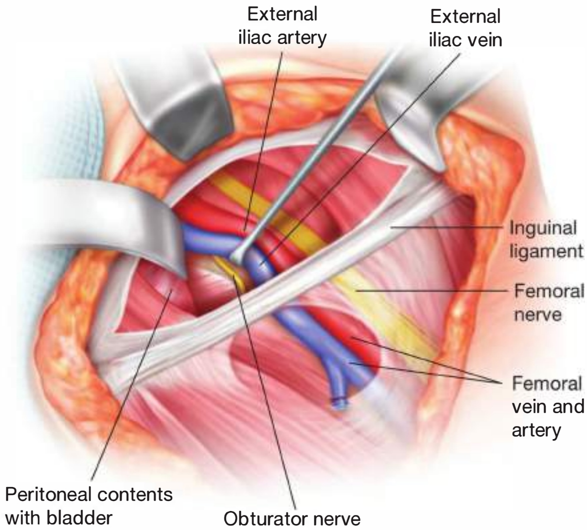


FIG 8 ● Appearance of the completed ilioinguinal dissected field with the obturator nerve exposed deep and medial to the external iliac vessels.

PEARLS AND PITFALLS

Indications	■ The diagnosis of inguinal metastasis should be made using the least invasive method possible. ■ Palpable disease should be evaluated by percutaneous fine needle aspiration or core needle biopsy rather than open biopsy whenever possible. ■ Sentinel node biopsy incisions should be fashioned while being mindful of the possibility that inguinal lymphadenectomy may be required in the future. ■ Sentinel node biopsy incisions directly in the inguinal crease are not advised due to the difficulty with the subsequent lymphadenectomy incision if necessary. ■ In cases where there is nodal disease without a known primary, a careful physical examination to identify a primary cancer is warranted, including examination of the skin of the lower body, digital rectal examination, and examination of the penis/vulva.
Placement of incision	■ Incisions should be fashioned to avoid crossing the inguinal crease where feasible.

Extent of resection	■ Saphenous vein preservation may be considered for cases being performed for micrometastatic disease and when the vein is not involved with scar or the seroma/biopsy cavity.
	■ Indications for inclusion of pelvic lymphadenectomy in the absence of clear-cut pelvic involvement have not been definitively established; but typically, scenarios for which ilioinguinal lymphadenectomy is potentially considered are the following:
	  ■ Macroscopic inguinofemoral disease
	  ■ Four or more positive nodes identified at sentinel lymphadenectomy
	  ■ Pelvic drainage observed at the time of lymphoscintigraphy with a positive inguinofemoral sentinel node

Key postoperative care	■ Patients are typically placed on bedrest overnight. ■ DVT prophylaxis is typically instituted on the evening of the procedure and continued while the patient is in the hospital unless there is clinical concern for hemorrhage. ■ Lymphedema precautions include compression with Ace wraps or fitted compression garments with aggressive institution of lymphedema therapy at the first clinical sign of lymphedema.

POSTOPERATIVE CARE

- The patient is typically kept on bedrest overnight with the urinary catheter, if used, in place, and affected extremity raised to above the level of the heart. The affected extremity is kept wrapped with an Ace from the metatarsals to mid thigh, with thigh-length SCDs in place on the contralateral extremity and over the Ace on the ipsilateral extremity.
- If the patient's physical examination and the drain output are not concerning for postoperative bleeding, prophylactic subcutaneous low-molecular-weight heparin is administered on the evening of the procedure and continued daily while the patient is hospitalized.
- On the first postoperative day, the urinary catheter, if present, is removed and the patient is encouraged to ambulate.

- After an inguinofemoral lymphadenectomy, patients are discharged after 1 or 2 nights when pain is controlled with oral analgesics.
- After ilioinguinal lymphadenectomy, patients are kept nil per os for the first night. If there is no sign of ileus, the diet can be advanced on postoperative day 1. Patients typically remain in the hospital for at least 2 nights and are discharged when pain is controlled with oral analgesics and are tolerating a diet.
- On discharge, patients are encouraged to ambulate to minimize risk of DVT, wear Ace or fitted gradient compression stockings during the day, and to elevate the operated leg above the level of the heart at night.
- At the first clinical sign of lymphedema, lymphedema therapy is ordered and verification of compliance with the fitted compression stockings is done.

OUTCOMES

- Five-year overall survival rates for melanoma metastatic to regional lymph nodes are listed below[6]:
  - Stage IIIA melanoma—1 to 3 nodes involved with microscopic disease and nonulcerated primary tumor—78%
  - Stage IIIB melanoma—1 to 3 nodes involved with microscopic disease and an ulcerated primary tumor or 1 to 3 nodes involved with macroscopic disease and a nonulcerated primary tumor—59%
  - Stage IIIC melanoma—4+ nodes involved, 1 to 3 nodes involved with macroscopic disease and an ulcerated primary tumor, matted lymphadenopathy, or disease that includes in-transit and nodal metastasis—40%

COMPLICATIONS AND RELEVANT MANAGEMENT

- Seroma—if symptomatic can be percutaneously drained; open drainage should be avoided
- Lymphedema—managed with early compression and lymphedema therapy
- Wound dehiscence—risk is minimized by confining area of the flap to the boundaries of the femoral triangle and can be managed with a wound vac device as needed
- Infection—typically managed with oral antibiotics
- DVT/pulmonary embolism—risk is minimized by the routine use of low-molecular-weight heparin prophylaxis and high index of suspicion should be maintained for early diagnosis and treatment
- Sensory deficit is common but typically does not require management unless there is a persistent neuralgia
- Recurrence

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Chapter 30 Minimally Invasive Inguinal Lymph Node Dissection for Melanoma

James W. Jakub

DEFINITION

- Minimally invasive inguinal lymph node dissection (MILND) is defined as an inguinal lymph node dissection performed through trocar ports. Many names have been coined for this videoscopic approach, and unfortunately, minimally invasive has also been used by some to describe an open technique using smaller incisions.
- The terminology surrounding the inguinal node dissection can be confusing. Urologic groin dissections separate the superficial inguinal basin as anterior to the cribriform fascia and the "deep" inguinal nodes as those nodes along the femoral vessels deep to this fascial layer. Melanoma surgeons have historically referred to both of these basins as a "superficial inguinal lymph node dissection" or "inguinalofemoral" and the pelvic or external iliac/obturator lymph nodes are referred to as a "deep inguinal lymph node dissection" or "ilioinguinal." In this chapter, when we describe an inguinal lymph node dissection, it will refer to all the nodes in the groin distal to the inguinal ligament and superficial to the external oblique aponeurosis, superficial and deep to the cribriform fascia. The deep or ilioinguinal dissection is discussed in Part 5, Chapter 29.

ANATOMY

- The anatomy critical to the MILND is identical to that for the conventional open operative approach and is depicted in **FIGS 1A,B** and **2**. The superficial and deep inguinal lymph nodes are separated by the cribriform fascia, which is violated at the fossa ovalis. There are approximately 10 lymph nodes in the superficial basin and five in the deep.
- The borders of the femoral triangle are graphically depicted in **FIG 2**.

NATURAL HISTORY

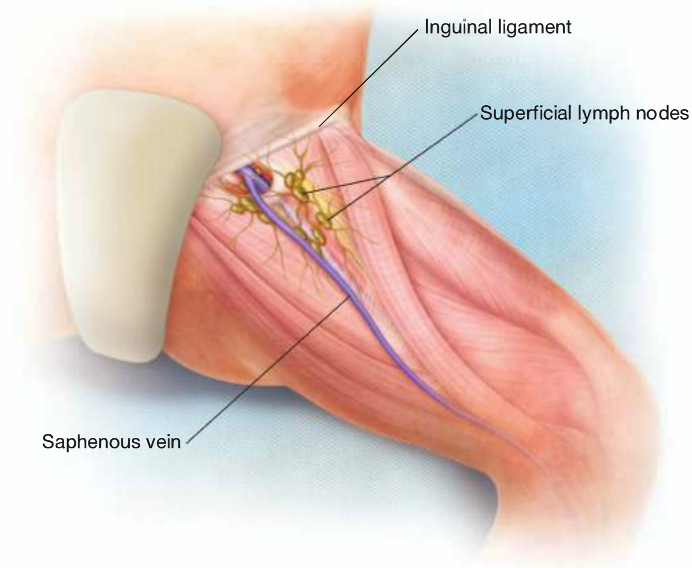
- Complete inguinal lymph node dissection is advised for any patient with melanoma metastatic to the inguinal lymph nodes in the absence of distant metastases. Microscopic and macroscopic subclassifications of stage III disease are distinguished as clinical and not pathologic entities.[1] If disease is detected by physical exam, this is considered macroscopic, whereas a positive sentinel lymph node (SLN) represents microscopic disease regardless of the tumor burden identified pathologically. Stage III melanoma patients represent a very heterogeneous cohort and prognosis varies greatly based on the number of positive lymph nodes, nodal burden in the lymph nodes, and presence or absence of synchronous in-transit metastasis. Five-year overall survival for this group of patients is approximately 50%, but based on the specific subcategory varies widely from 25% to 75%.

PATIENT HISTORY AND PHYSICAL FINDINGS

- An MILND is indicated in most cases that would be considered for traditional inguinal nodal dissection including melanoma; cutaneous squamous cell carcinoma (SCC); and some urologic (penile), gynecologic (vulvar), anal, or low-lying rectal cancers.
- Physical examination should not only evaluate the inguinal nodal basin but also identify in-transit disease between the primary and inguinal nodal basin, particularly in the case of melanoma. Radiographic or gross nodal disease can be found cephalad to the inguinal ligament and superficial to the external oblique aponeurosis, especially in cases of a truncal primary.
- For lower extremity disease, the popliteal nodal basin should be evaluated; and for disease of the trunk, consideration for contralateral inguinal or axillary drainage needs to be considered based on location of the primary.
- Physical examination should also evaluate for prior scars in the field (sentinel lymph node biopsy [SLNB] or saphenous vein harvest from prior coronary artery bypass graft [CABG]) and skin changes suggestive of cutaneous involvement. This can be direct extension with overlying cutaneous hyperemia and fixation of disease or nodularity/ulceration that is often seen in SCC. For penile primaries, the genitals and base of penis should be inspected for cutaneous involvement.
- Most frequently, an MILND will be performed for microscopic disease following a positive SLNB. In this setting, waiting a minimum of 6 weeks from the SLNB to the MILND allows time for the acute operative inflammatory changes to resolve. An MILND may be considered in selected cases of macroscopic disease. Caution and sound clinical judgment should be used to avoid violating the specimen, assuring an en bloc resection and for radiographic disease, that the identified disease to be resected will indeed be contained inside the contents of dissection.
- MILND is contraindicated in the setting of cutaneous involvement or a prior lymphadenectomy in the same field. MILND may be considered in a prior radiated field, but again, caution should be stressed.

IMAGING AND OTHER DIAGNOSTIC STUDIES

- Positive SLNB for microscopic disease
  - In general, this is a delayed diagnosis and MILND is offered as a staged procedure, as typically, frozen section is not performed on SLNs for melanoma. Even in institutions where frozen section is performed on SLNs (such as



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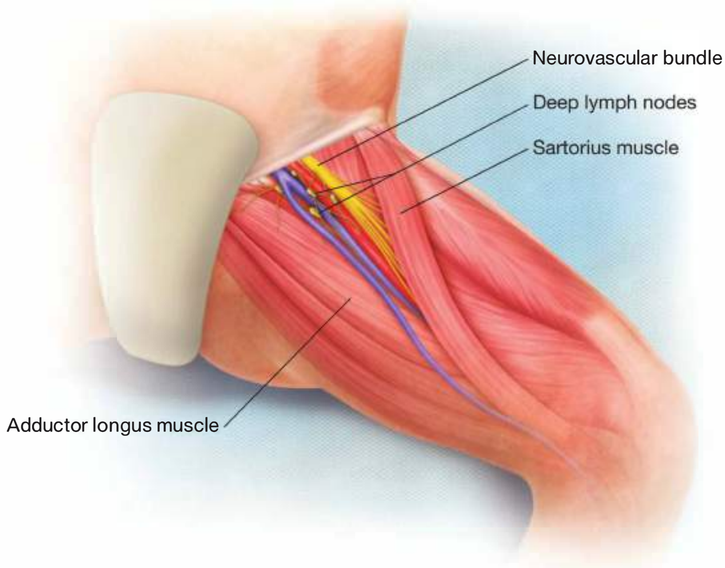

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FIG 1 ● **A,B.** Anatomy of the superficial and deep inguinal basin.

our own), there is no need to freeze the SLNs of the groin if MILND may be offered at a later date.
- The yield of systemic imaging to find clinically occult stage IV disease after a positive SLN is less than 5% and typically not warranted prior to MILND.[2–4]
- Deep pelvic (external iliac/obturator) node dissection is typically not required.

- Clinical inguinal regional nodal disease
  - In the setting of a palpable inguinal lymph node, a fine needle aspiration (FNA) to confirm the clinical diagnosis is frequently appropriate prior to embarking on an inguinal node dissection.
  - A search for systemic disease with whole-body imaging (computed tomography [CT] scan or positron emission tomography [PET]/CT) is reasonable prior to MILND as the true positive rate is above 10%.[5,6]
  - The decision to embrace a routine, selective or nihilistic, and hence, almost never approach to the pelvic basin will not be covered in this section. In general, for clinically apparent disease, I strongly consider a combined deep pelvic node dissection at the same setting.
  - There is limited data on minimally invasive approach to the pelvic lymph nodes for melanoma. Technically, it can be performed as clearly shown in clinical practice with gynecologic and urologic procedures. However, the role in melanoma is not defined. Basic questions such as, "Should an extraperitoneal versus an intraperitoneal approach be used?" and "Is converting an extraperitoneal

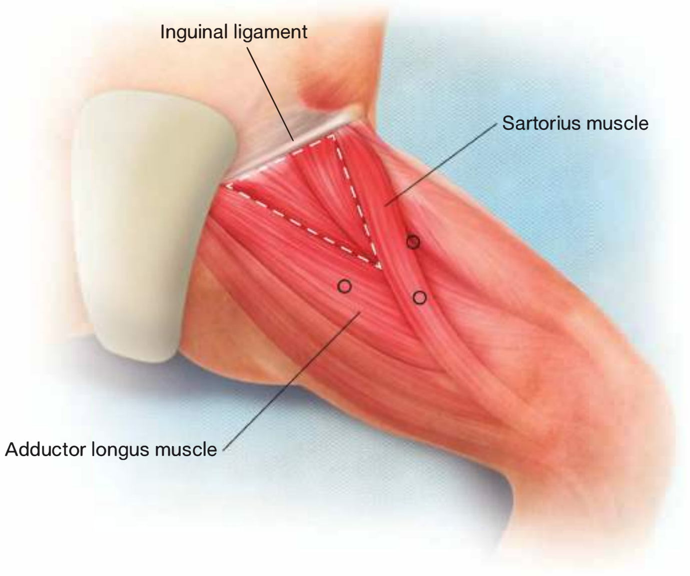


FIG 2 • Borders of the femoral triangle as well as trocar placement for MILND.

disease to an intraperitoneal operation sound?" have not been established. At the time of this writing, when performing a combined inguinal and a pelvic node dissection, I personally perform this as an open approach.

NONOPERATIVE MANAGEMENT

- The current standard, off protocol, is for a regional node dissection for all cases of a positive SLN, including immunohistochemical disease only.
- At the time of this publication, the Multicenter Selective Lymphadenectomy Trial II (MSLT II) randomizing patients with a positive SLNB to observation of the basin or standard lymph node dissection, just closed to accrual.

SURGICAL MANAGEMENT

- A word of caution: Data on short- and long-term morbidity are limited at the time of this publication.[7,8] Seromas are common and can be prolonged; wound complications requiring more than outpatient oral antibiotics are rare. Randomized single institution (Delman, personal communication, February 2013) and single-arm multi-institutional surgical trials (NCT01500304) are actively ongoing to define the short-term morbidity and surgical learning curve for this procedure. One measure of oncologic adequacy of the procedure is lymph node yield and this appears to be similar.[7,9] There is no data to date regarding oncologic outcomes and patients need to be clearly made aware, that as of the time of this publication, it is unknown if the regional control and cure rates with this approach are worse, better, or equivalent to a standard open approach. This candid discussion is necessary as part of the informed consent process (at the time of this printing one manuscript has been published).[9]

Preoperative Planning

- Preoperative baseline bilateral limb volumes should be considered.
- Brief with anesthesia and the operating room (OR) team prior to the start of the procedure:
  - Hypercarbia is to be expected. Unlike laparoscopy performed in an intraperitoneal location, this entire dissection is performed in the subcutaneous plane and much higher levels of carbon dioxide (CO_2) will be systemically absorbed. Anesthesia team needs to be aware and appropriate ventilatory modifications made to avoid the need for conversion.
  - Ensure you have towers in correct position, patient position is rehearsed, and desired equipment, including dissector and laparoscopic supplies, are in the room.
- Prophylactic antibiotics are provided.
- Mechanical venous thromboembolism (VTE) prophylaxis in the form of sequential compression devices are placed on the contralateral leg. Chemical VTE prophylaxis in the form of subcutaneous heparin is provided prior to incision and ideally prior to induction of general anesthesia.
- A Foley catheter is placed sterilely on the prepped field and sealed out of the dissection field with the genitalia by a sterile towel and Ioban.

Positioning

- In the typical setup, the patient is positioned supine with the legs split either on a split-leg table (my preference) or in the synchronous position with Yellofin gel stirrups. The operative leg is abducted and slightly flexed at the knee (**FIG 3**). If the leg is left straight, the surgeon will almost inevitably perform the dissection too lateral. The surgeon and the assistant stand so one is between the legs and the other stands lateral to the operative leg. The surgeon and the assistant may change positions during certain portions of the procedure if desired. The surgical technician stands on the opposite side of the patient's body.
- Video towers are placed at the head of the table, one above each shoulder (**FIG 3**). Minimal operative instrumentation is needed on the Mayo stand. If there is a need to emergently convert, appropriate instruments should be immediately available.

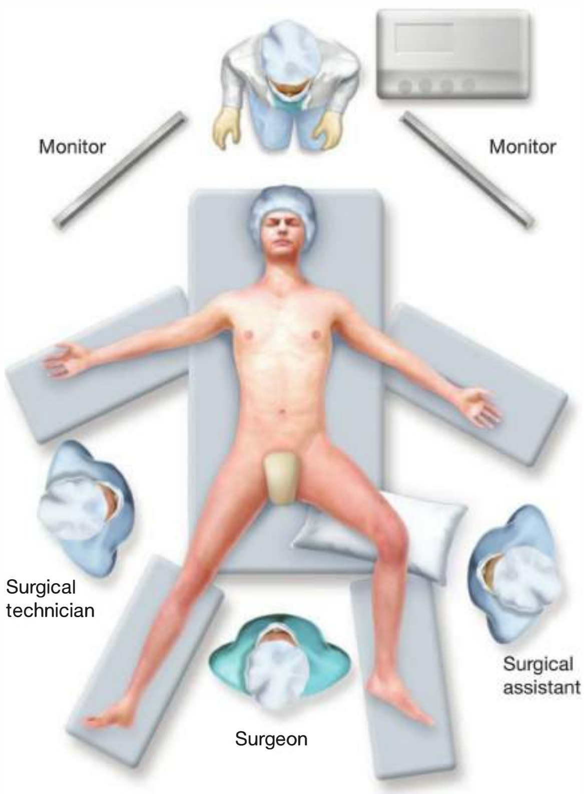


FIG 3 ● Operating theater setup and patient position.

Approach

- The current approach involves en bloc resection of the muscular fascia and saphenous vein with the lymphadenectomy specimen. The plane of dissection off the sartorius muscle and adductor may not be as apparent with a minimally invasive approach as during an open procedure, and to be clear that the dissection is in the correct plane, we have scored the fascia and visualized the underlying muscle.
- Resecting the muscular fascia is the approach initially described by Delman et al.[10] and the approach we have followed. Whenever embarking on a new procedure, it is critical that caution is exercised and the procedure is approached with this mindset, assuring that the extent of the oncologic resection is at least as complete as the traditional standard for which it is meant to replace. It is also true that the minimally invasive approach should, as much as possible, exactly mirror the technique of the open approach. As with any novel technique, this procedure will likely evolve with time, and with experience, it may be shown that a muscular fascia and saphenous vein preserving approach is as safe and oncologically sound.
- We do not excise the SLNB scar if present. We also do not make an open incision to confirm the adequacy of dissection because the videoscopic view should make this obvious. If there is any question of inadequate resection, a small proximal incision can be made and the extent of the oncologic operation should not be jeopardized because of a perceived feeling of inadequacy or failure by "converting."

MINIMALLY INVASIVE INGUINAL LYMPH NODE DISSECTION

Operating Room Setup

- In the typical setup, the patient is positioned supine with the legs split either on a split-leg table (my strong personal preference) or in the synchronous position with Yellofin gel stirrups. The operative leg is abducted and slightly flexed at the knee (**FIG 3**). The surgeon and the assistant stand so one is between the legs and the other stands lateral to the operative leg. The surgeon and the assistant may change positions during certain portions of the procedure if desired. The surgical technician stands on the opposite side of the patient's body.
- Video towers are placed at the head of the table, one above each shoulder (**FIG 3**). Minimal operative instrumentation is needed on the Mayo stand. If there is a need to emergently convert, appropriate instruments should be immediately available.
- The anatomy critical to the MILND is identical to that for the conventional open operative approach and is depicted in **FIGS 1** and **2**. The superficial and deep inguinal lymph nodes are separated by the cribriform fascia, which is violated at the fossa ovalis. There are approximately 10 lymph nodes in the superficial basin and five in the deep.
- The borders of the femoral triangle are graphically depicted in **FIG 2**.
- External landmarks are identified. Palpation is performed to identify the medial border of dissection, which is the adductor longus muscle. This is marked with a marking pen. Next, similar palpation is performed to identify the sartorius muscle and identify its medial border, which will mark the lateral boundary of the dissection. The convergents of these lines occur at the distal border of dissection, which is the apex of the femoral triangle. Proximal dissection extends 3 to 5 cm cephalad to the inguinal ligament and it includes the soft tissues superficial to the external oblique in this location.
- Next, the three trocar sites are marked. The distal most incision is marked 3 cm from the apex of the femoral triangle. The other two trocars are placed proximal to this, each 5 cm apart, one medial and one lateral (see **FIG 5A,B**). Through one of the trocar sites, blunt dissection is performed with the index finger separating along the natural avascular plain between the subcutaneous fat and underlying soft tissue. Three 10/12 mm trocars are next introduced. As a

FIG 4 ● Photo depicting trocar placement and initial CO_2 insufflation at beginning of case (image © Mayo Clinic, 2014).

result of the thin subcutaneous tissue, a leak around the trocar may be encountered. As a result, the incision should be kept to a minimum and only one trocar site should be used for the initial blunt dissection. Short trocars are ideal, and bariatric instruments should be available in order to reach the proximal most dissection. Using trocars with balloons to minimize the leak are ideal.

- CO_2 insufflation is performed. Initially, 25 mmHg for 10 minutes and then decreased to 15 mmHg for the remainder of the procedure (FIG 4).

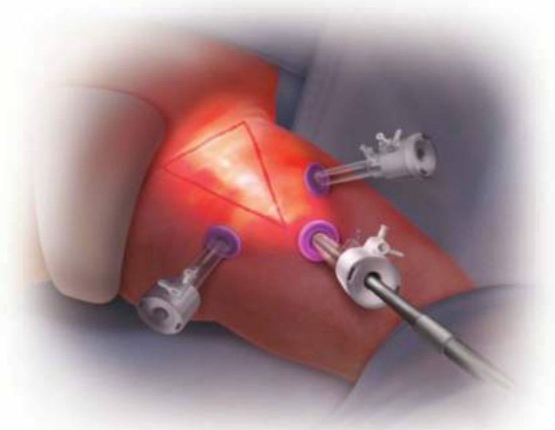
Superficial Dissection

- I perform the entire dissection with an ultrasonic dissector (personal preference) or LigaSure® device, except when freeing the tissue from the external oblique aponeurosis where I use a hook cautery.
- Camper's fascia is preserved. Dissection is performed superficial to Scarpa's fascia.
- Initial dissection starts in a space created by the digital dissection and CO_2 insufflation. The dissection is begun distally and continued proximally. The initial dissection is performed in order to create a working space between the subcutaneous tissue and underlying regional contents.
- Dissection is performed fairly superficially, superficial to Scarpa's fascia. This can be appreciated with an external view showing the transillumination of the light source through the skin (FIGS 5A,B). Dissection can be assisted by external palpation over the previously marked boundaries of the triangle. Running a finger up and down the previously drawn landmarks while viewing internally assists one in defining the borders and extent of the superficial dissection. As dissection is completed more proximally, the loose areolar tissue overlying the external oblique aponeurosis can be appreciated. The entire anterior dissection within the externally marked triangle should be completed.

Sartorius Exposure

- The next portion of the procedure is the lateral dissection to identify the sartorius muscle. Dissection is performed through the fatty tissue until the sartorius fascia is identified.

A



B

FIG 5 ● A,B. Photo and image demonstrating trocar placement, flap thickness, and drain placement. Dissection is quite superficial and this is demonstrated in these images showing how well the light transilluminates through the skin flaps (Fig. 5a © Mayo Clinic, 2014).

The fascia is divided, identifying the underlying muscular fibers of the sartorius. This is initiated distally, and once identified, you simply march proximally up this layer. The fascia is continually scored from distal to proximal as shown in FIG 6. This is continued up toward the inguinal ligament.

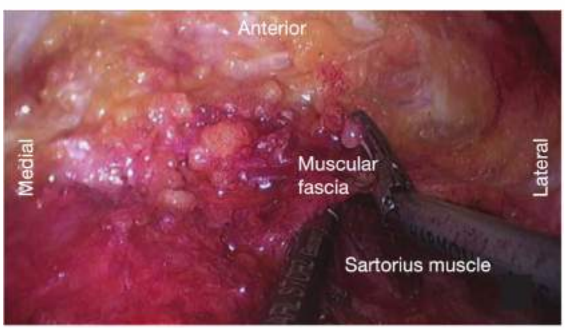


FIG 6 ● The lateral border of the deep dissection is shown here. The muscular fascia is scored from distal to proximal exposing the sartorius muscle (image © Mayo Clinic, 2014).

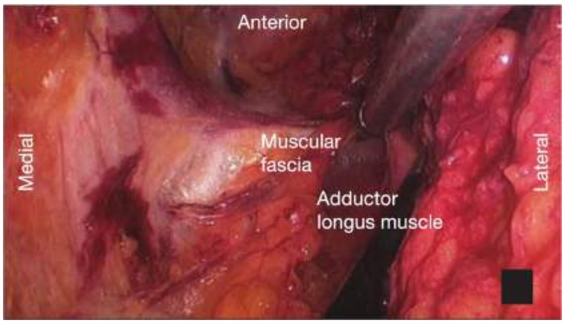


FIG 7 ● The medial border of the deep dissection is shown here. The muscular fascia is scored from distal to proximal exposing the adductor longus muscle (image © Mayo Clinic, 2014).

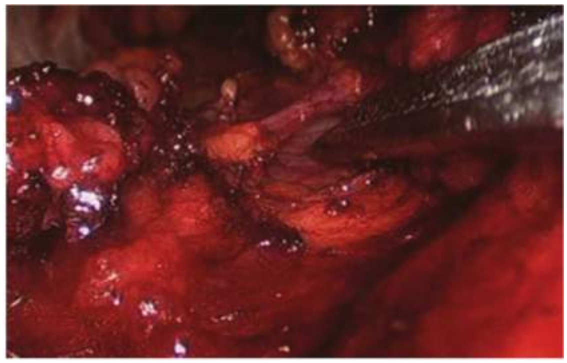


FIG 9 ● The distal saphenous vein is being divided as it crosses the adductor longus muscle (image © Mayo Clinic, 2014).

Adductor Longus Exposure

- A similar approach is taken medially to identify the adductor longus muscle (FIG 7). Because of the crossing saphenous vein, the medial dissection is started more proximal in this location. This dissection is also continued proximally to the inguinal ligament.
- The specimen is rolled laterally off the adductor. As we progress medially, the deep border of dissection becomes the pectineus muscle (FIG 8).
- It is fairly common for the knee to be "in the way" during portions of the dissection as a result of the knee bumped and the leg position. I find that I am not infrequently operating with the handle of the dissection device turned upside down to accommodate this reality.

Exposure and Division of Distal Saphenous Vein

- The next step is to identify and divide the saphenous vein distally. At this point, the dissection is begun more proximally on the adductor longus.
- The saphenous vein is identified and circumferentially dissected out. It is located two-thirds of the distance from the inguinal ligament to the apex of the triangle as the vein crosses the adductor muscle.
- The vein can be divided with an endovascular stapler, LigaSure® or ultrasonic dissector per surgeon preference and vessel caliber (FIG 9).

Apex Dissection

- Next, the apex dissection is completed. This is the remaining soft tissue between the sartorius and the adductor at the distal most aspect of the dissection.
- The contents are grasped and elevated under tension with traction in both the superficial and cephalad direction (FIG 10). This tissue is controlled with the nondominant hand, as the dissection of the remaining tissue over the apex is completed.

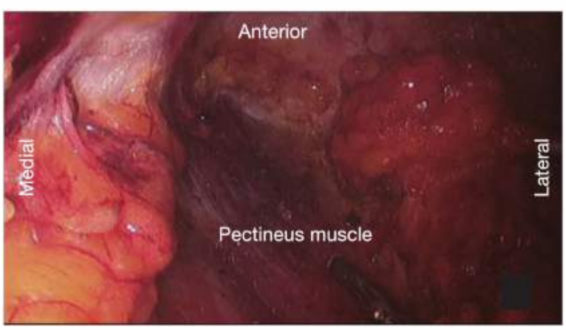


FIG 8 ● The pectineus muscle is exposed as the proximal portion of the specimen is rolled from medial to lateral off the adductor (image © Mayo Clinic, 2014).

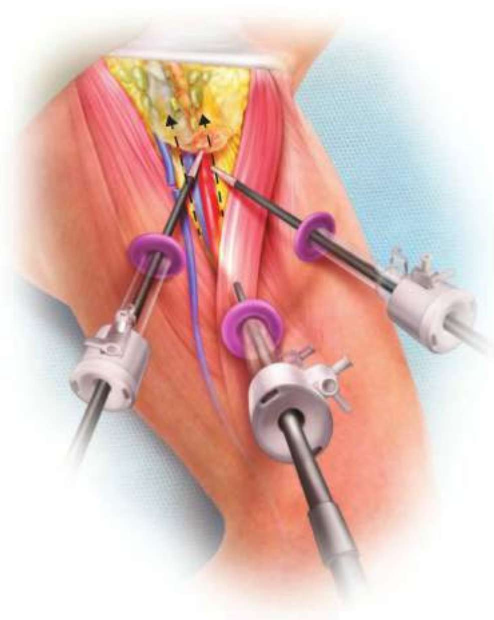


FIG 10 ● At the apex of the femoral triangle, the contents are grasped and retracted under tension by pushing the specimen anterior and cephalad.

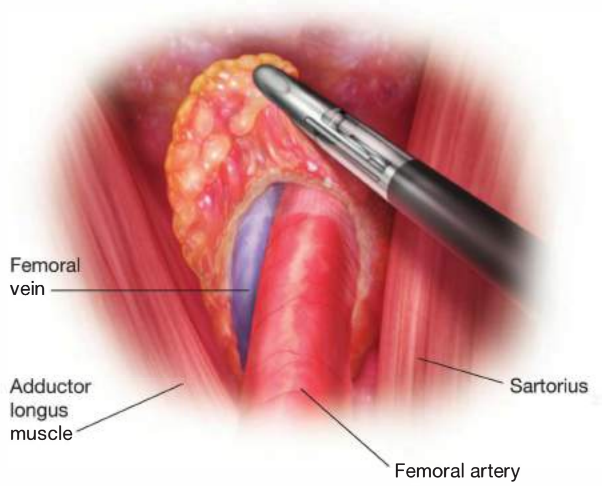


FIG 11 ● As the dissection at the apex continues deep from distal to proximal, the femoral vessels will come into view with the artery the first to be encountered.

- At this point, the dissection is performed by walking up the medial aspect of the sartorius from distal to proximal and rotating the contents medially. Because the femoral nerve lies in this location, a thin rim of fat is left on top of the nerve.
- As this process is repeated and continued, beginning at the apex and dissecting proximally, the femoral vasculature will be identified at this location (**FIG 11**).
- Because of the position of the lower extremity in abduction and flexion, the femoral artery lays directly anterior to the femoral vein. The femoral vein is deep and medial, and as we dissect proximally, the vessels will spiral and the two vessels will ultimately become parallel with each other lying in the same plain. Dissection should stay directly on the adventitia of the femoral vessels. Some prefer to use a laparoscopic Kittner for this dissection. I mainly use the dissection shears. The anterior half of the vessels are completely exposed.
- **FIG 12A,B** show the relative position change of vessels in relation to each other as we proceed from distal to proximal; this is accentuated by the leg being in a position of abduction.
- The deep inguinal lymph nodes are resected en bloc with this procedure. Our deep dissection plain is deep to the cribriform fascia. The cribriform fascia is an extension of the fascial lata. It separates the superficial inguinal lymph nodes from the deep inguinal lymph nodes. The cribriform fascia is penetrated by the saphenous vein at the fossa ovalis. The plane of dissection is depicted in **FIG 12A,B**.
- The femoral vein is appreciated deep and medial to the artery, just proximal to the apex. This is dissected out in a similar fashion. The anterior as well as the medial and lateral aspect of the vessels are skeletonized. There is no need to circumferentially dissect out these structures (**FIG 13A,B**).

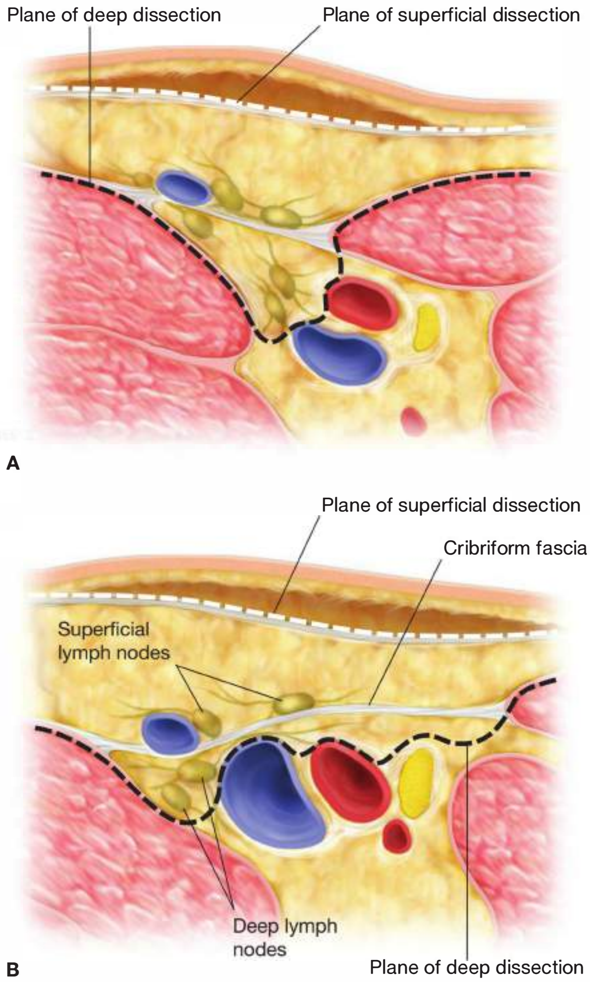


FIG 12 ● **A,B.** The superficial and deep dissection planes are graphically depicted here. These figures also demonstrate the relative position change of vessels in relation to each other as we proceed from distal to proximal, respectively.

- The femoral vein will be somewhat collapsed because of the CO_2 insufflation in this closed space. Its caliber will also be seen to fluctuate with ventilation.
- The medial dissection is completed off the adductor as we progress more proximally. As we continue our dissection, we simply walk up the adductor from distal to proximal. Continued anterior traction is applied to the specimen as we expose the vessels heading toward the inguinal ligament.

Proximal Dissection of Saphenous Vein at the Fossa Ovalis

- The medial and anterior surface of the femoral vein is skeletonized and we continue along medial aspect of this vessel under the inguinal ligament. Based on how far proximal you prefer to dissect here, Cloquet's lymph node can be removed en bloc with the specimen. If desired, a suture can be placed to mark Cloquet's node.

FIG 13 ● **A,B.** Intraoperative photos of the relationship of the vessels to each other and relative position change from distal to proximal, respectively (images © Mayo Clinic, 2014).

- The pectineus muscle can be seen here as the deep boundary of dissection. At this point, dissection is deep and proximal to the shelving edge of the inguinal ligament (**FIG 14**).
- The tissue is freed from medial to lateral off the previously exposed inguinal ligament.
- At this point, the saphenofemoral junction is identified, coming directly anterior off the femoral vein, approximately 3 cm distal to the inguinal ligament as the saphenous vein penetrates the cribriform fascia at the fossa ovalis. This will be identified as you dissect from distal to proximal along the medial surface of the femoral vein (**FIG 15**).

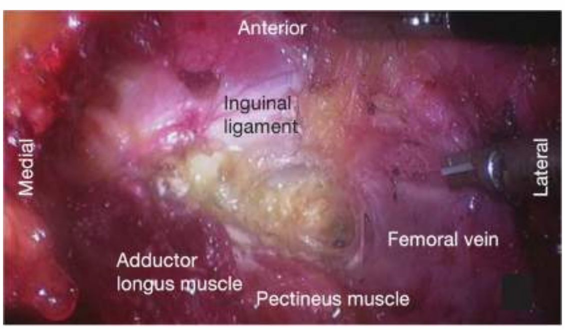


FIG 14 ● This image shows the empty space created deep to the inguinal ligament at the proximal/medial aspect of the dissection. The medial aspect of the femoral vein is skeletonized. One can choose to extend proximal to include Cloquet's lymph node with the specimen (image © Mayo Clinic, 2014).

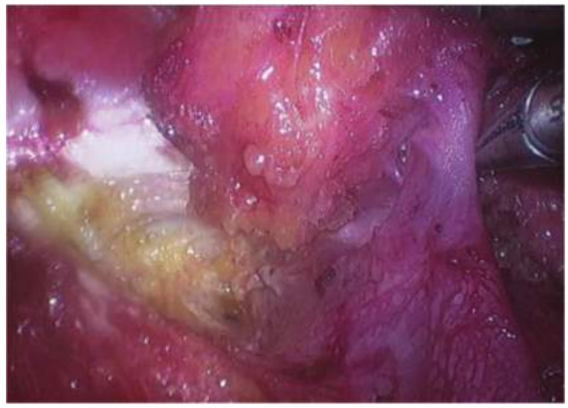


FIG 15 ● The saphenofemoral junction is identified as the dissection off the medial and anterior surface of the femoral vein is continued proximally (image © Mayo Clinic, 2014).

- The saphenofemoral junction is cleared and divided with a linear endovascular stapler (**FIG 16**). The proximal/medial tissue must first be freed off the femoral vein before this can be accomplished. It is better to complete this dissection proximal and medial to the saphenofemoral junction and make this window wider than you expect before attempting to introduce the stapler.
- The remaining proximal dissection of the femoral vessels (mostly cephalad and lateral) is then completed, removing the inguinal contents off of the remaining attachments with the femoral vessels. Short trocars and long instruments have been necessary in my experience in order to reach this proximal most dissection.
- If not already done so, any remaining soft tissue cephalad to the inguinal ligament is to be included (3 to 5 cm). This is easily peeled down off the external oblique aponeurosis, using hook cautery if desired, and included en bloc with the specimen. The remaining attachments with the inguinal ligament and external oblique aponeurosis are completed.

FIG 16 ● The intraoperative photo shows the proximal saphenous vein being divided with an endovascular stapler (image © Mayo Clinic, 2014).

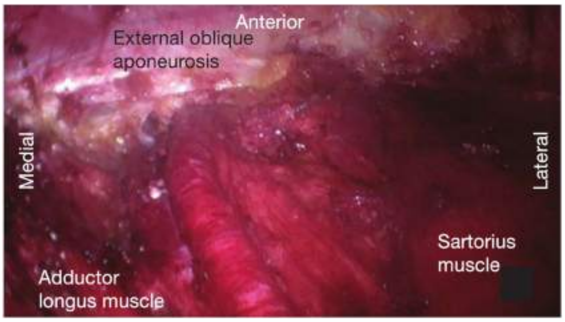


FIG 17 ● Intraoperative photo at the completion of the operation showing the musculature of the femoral triangle exposed, including the fascia overlying the external oblique aponeurosis, proximal to the inguinal ligament, and skeletonization of the anterior half of the femoral vessels (image © Mayo Clinic, 2014).

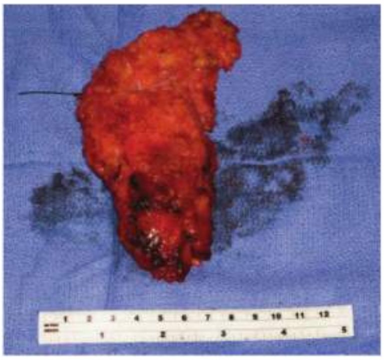


FIG 18 ● Photo of the inguinal contents after en bloc resection using the minimally invasive approach (image © Mayo Clinic, 2014).

- In a similar fashion, any remaining lateral attachments are freed off the sartorius followed by the final attachments off the inguinal ligament.

Specimen Removal

- Once the specimen is free, the contents are placed in an endobag.
- The anatomic boundaries are clearly delineated and you can visualize the soft tissue removed cephalad overlying the external oblique aponeurosis (**FIG 17**).
- Once completed, the drain is passed through the lateral trocar sites.
- The extracted specimen is depicted in **FIG 18**.
- A photo taken 1 week postoperatively is shown (**FIG 19**). It should be noted that the proximal longitudinal scar is from the original SLNB and not part of the MILND.
- At the end of the case, the genitals will be edematous from the CO_2 dissection. This is not a concern; the Foley can be removed at the end of the case and this should resolve by morning rounds. Crepitance up to the chest has been reported in some cases but has never been of clinical significance in my experience and to my knowledge. A chest strap during the operation can serve avoid this.

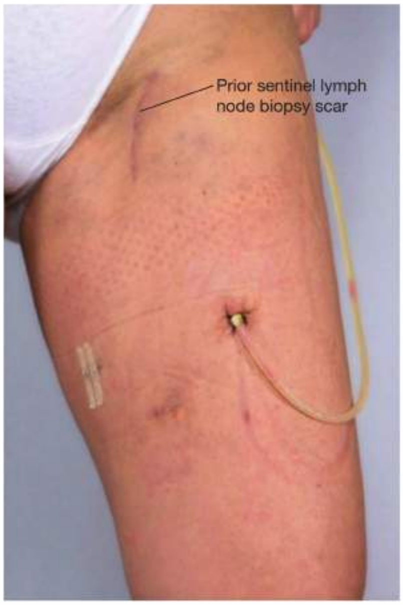


FIG 19 ● Photo of operative leg at the first postoperative visit.

PEARLS AND PITFALLS

High conversion rate	■ Embarking on this procedure without adequate training ■ Frustration and lack of patience ■ As with any new minimally invasive procedure, this should be scheduled at a date and time when there are limited other external pressures.
Unable to reach proximal dissection	■ Placing trocars too distal or instruments too short
Dissection too lateral	■ Typically, this is a result of not placing the leg in adequate abduction and external rotation prior to the start of the procedure.

Inadequate lymphadenectomy	■ Not staying within defined anatomic boundaries ■ Not dissecting anterior to Scarpa's fascia ■ Not dissecting the deep inguinal lymph nodes by staying on the adventitia of the femoral vessels (not dissecting deep to the cribriform fascia) ■ Not dissecting the tissue cephalad to the inguinal ligament
Conversion secondary to hypercarbia	■ Not briefing with anesthesia team and making appropriate minute ventilation adjustments
Constant leak during case	■ Finger dissection of more than one port site at start of case and making incisions too large
Drain not holding suction	■ Not sealing incision closed tightly around drain at end of case. There is no subcutaneous fat between trocar site and cavity, unlike an abdominal procedure or open nodal dissections in which the drain is passed through a subcutaneous tunnel, so this remains very unforgiving.
Seroma/prolonged drain days	■ See section regarding Postoperative Care

POSTOPERATIVE CARE

- Patient is admitted as an outpatient overnight and discharged within 23 hours. Drain care is reviewed in detail. Same-day discharge could be considered as pain has not been an issue.
- Regarding seromas, activity, and drain days, my practice continues to evolve. I went from limited activity to one of minimal activity and near bed rest at home until the drain comes out, and my current approach at the time of publication is back to limited activity. As a result of the malignancy, the immediate perioperative period, restricted activity to almost one of bedrest, patients were discharged home on daily low-molecular-weight heparin (LMWH), prophylactic VTE dosing. This minimal activity and compression of the surgical site did not appear to result in decreased drain days, so I have since stopped and allow limited activity. If considering home chemical VTE prophylaxis with LMWH, there is no need for a home health or visiting nurse; patients can be taught while in the hospital to self-administer this medication.
- The patients are seen prior to discharge by the physical medicine and rehabilitation lymphedema therapist. Compressive leg wrapping is applied as well as compression to the operative field (compressive biker shorts with a foam insert or sock placed directly over the basin). I have no data this decreases seroma or lymphedema or allows for earlier drain removal. Patients and family are educated on dressing changes and follow-up is arranged for the 1-week postoperative visit.
- Ensure the drain is holding suction prior to discharge.
- Redness and minor bruising of the flap is typical and noted on postoperative day 1 and on the first postoperative visit. These findings do not represent cellulitis and antibiotics are generally not indicated.
- There are two approaches to the drain removal. This is a balance between an increased risk of infection as the drain days increase versus accepting a higher seroma rate. The verdict is not out on the best approach here:
  - Remove drain at 2 to 3 weeks regardless of output and accept a seroma. Observation of the seroma is reasonable, if asymptomatic. Patients need to be educated preoperatively that a fluid collection will develop in their groin and not to be concerned.
  - Leave drain until output is less than 30 to 40 mL a day for 2 consecutive days. This often means keeping the drain up to 7 weeks.
  - As a result of the expected prolonged number of drain days (NOT flushing up the drain, just rinsing the bulb and emptying), our drain care regimen consists of rinsing the bulb with dilute Dakin's solution three times a day and placing a chlorhexidine Biopatch around the drain exit site and sealing it with a Tegaderm. The chlorhexidine disc is changed every third day and the drain site is cleaned with an alcohol wipe with each dressing change. This practice is based on Dr. Degnim's work in breast surgery and I only use for groin dissection because of the prolonged drain days.[11]

OUTCOMES

- The outcome data is limited[7,8] and frank discussion with the patient must be held explaining that this operation is being performed for malignancy, but it remains unknown if this is as oncologically sound as an open approach. The extent of resection should never be jeopardized to accomplish the procedure with the smallest incision possible. Seromas and prolonged drain days appear to be the Achilles heel thus far; we are exploring ways to combat this. Based on the limited experience worldwide, wound complications including breakdown and infections appear to be much less of an issue compared to the open approach (no big incision, no big wound problem). If lymphedema rates will be decreased is unknown at present. Major neurovascular structures are in the field and at risk. Flap necrosis can occur, but despite very thin flaps, I have not personally seen this.

COMPLICATIONS

- Seroma
- Hematoma
- Wound dehiscence
- Flap necrosis
- Major vascular injury
- Femoral nerve injury
- Drain not holding suction
- Recurrence
- Lymphedema
- Infection
- Anesthesia risks
- Hypercarbia
- Inadequate lymphadenectomy

ACKNOWLEDGMENTS

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Chapter 31 Selective Neck Dissection for Melanoma

Vasu Divi

DEFINITION

- The goal of a selective neck dissection for melanoma is the complete removal of the lymph nodes and lymphatics that drain a specific region of skin in the head and neck.
- This procedure is performed for patients presenting with clinically evident regional metastasis as well as for patients with a positive sentinel lymph node.

PATIENT HISTORY AND PHYSICAL FINDINGS

- All patients with melanoma of the head and neck should undergo palpation of the regional lymphatics, including the parotid glands and cervical levels 1 to 5.
- Melanomas at the junction of the neck and the chest, back, or shoulder should also include palpation of the axillary lymph nodes.
- All patients with melanoma, particularly those with proven regional metastases, should have a focused review of symptoms, looking for symptoms concerning for metastatic disease.
- All patients with melanoma should also have a complete skin exam, looking for second primary cutaneous malignancies.

IMAGING AND OTHER DIAGNOSTIC STUDIES

- Preoperative imaging of the neck is not necessary in patients without clinically evident neck disease.
- In patients with palpable adenopathy
  - Imaging by contrast-enhanced computed tomography (CT) scan is generally recommended to evaluate the extent of disease.
  - Fine needle aspiration is used to obtain pathologic diagnosis of the enlarged lymph node.
- In cases of distant metastatic disease, the need for selective neck dissection is balanced against the life expectancy of the patient. In many cases, achievement of regional control in the neck is preferred, given the complications of untreated disease in the head and neck.

SURGICAL MANAGEMENT

Preoperative Planning

- Determination of the type of neck dissection to be performed is based on the location of the primary tumor and location of neck disease.
- The relevant lymphatic basins of the head and neck include the parotid lymph nodes, levels 1 to 5, and the postauricular lymph nodes (**FIG 1**).
- This serves as a rough guide to when different lymphatic basins should be addressed; ultimately, the clinician should dissect all lymphatic basins that could potentially be harboring clinical disease based on an understanding of lymphatic drainage patterns.
  - The removal of the superficial lobe of the parotid gland is performed for any primary cutaneous tumor anterior to the external auditory canal and above the angle of the mandible.

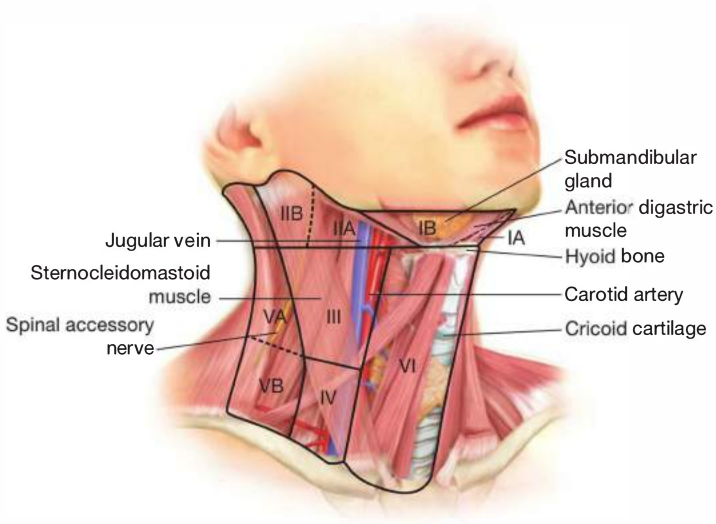

FIG 1 ● Levels of the neck. Level 1 includes all nodes between the contralateral anterior belly of the digastric, ipsilateral posterior belly of the digastric, and the inferior edge of the mandible. Level 2 includes the nodes below the skull base between the posterior belly of the digastric, posterior edge of the SCM, and above the level of the hyoid. Level 3 includes all nodes between the hyoid bone and cricoid cartilage arch, between the lateral and the internal carotid artery, and the posterior edge of the SCM. Level 4 includes all nodes between the cricoid cartilage arch and clavicle, between the lateral and the internal carotid artery, and the posterior edge of the SCM. Level 5 includes all nodes from the skull base down to the posterior border of the sternocleidomastoid muscle to the clavicle, anterior to the trapezius muscle.

- Levels 1 to 4 are dissected with any lesion involving the scalp anterior to the plane of the external auditory canal, facial skin, or anterior neck skin.
- Levels 2 to 5 are dissected with any lesion involving the scalp posterior to the plane of the external auditory canal or posterior neck skin.
- If the primary lesion is in the scalp and located very close to the plane of the external auditory canal, dissection should include levels 1 to 5.

Positioning

- Patients are placed supine with the top of the head at the edge of the surgical bed.
- A bump is placed underneath the shoulder blades to allow for extension of the neck, being careful to maintain support of the head on the operating room (OR) table.

SELECTIVE NECK DISSECTION LEVELS 1 TO 4

- A curvilinear incision is made midway between the angle of the mandible and the clavicle; the incision travels within a neck crease, extending a few centimeters from the mastoid tip toward the approximate midpoint of the thyroid cartilage (**FIG 2**).
- Skin is incised down through the subcutaneous tissue and platysma.
- Subplatysmal skin flaps are elevated to expose the deeper contents overlying levels 1 to 4 of the neck; this will extend to the mentum, along the strap musculature in the midline, to the posterior border of the sternocleidomastoid muscle (SCM), and down to the level of the clavicle (**FIG 3**).
- The marginal mandibular nerve is identified in the superficial layer of the cervical fascia near the angle of the mandible and is identified using nerve stimulation. The nerve is dissected free and elevated over the plane of the mandible (**FIG 4**).

FIG 2 ● The neck incision is marked out between the mandible and clavicle.

- The facial artery and vein are identified and ligated as they cross over the plane of the mandible.
- The tissue over the mandible is then incised from the mentum to the angle of the mandible, taking care not to injure the previously dissected marginal mandibular nerve. This tissue is pulled inferiorly, taking care to remove the perifacial lymph nodes located near the facial vessels. During this

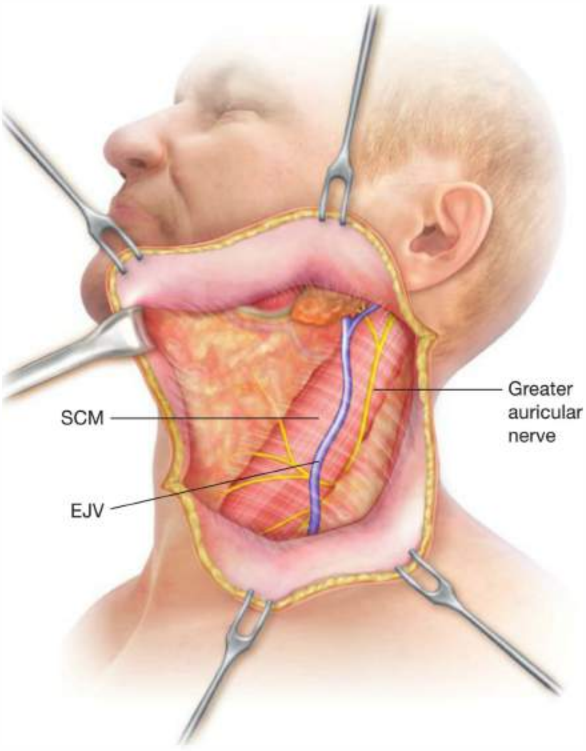

FIG 3 ● The neck incision is completed with subplatysmal flaps elevated superiorly and inferiorly.

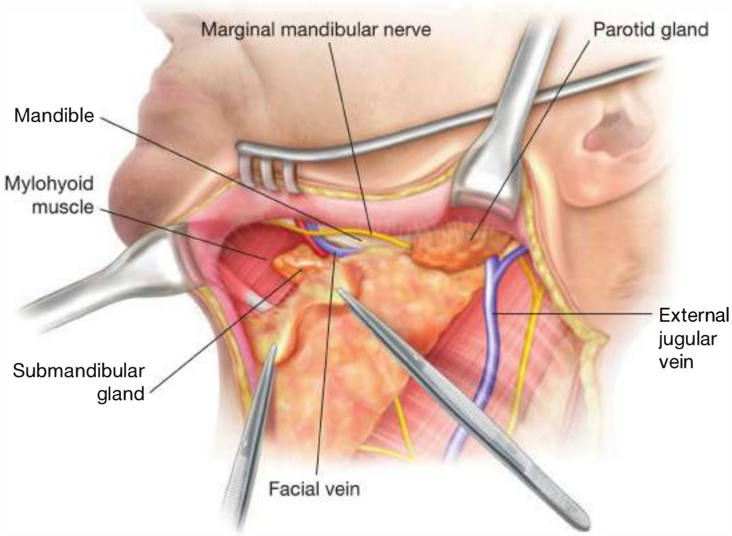

FIG 4 ● The marginal mandibular nerve is elevated over the mandible and the contents of level 1A are dissected posteriorly. Division of the facial artery and vein would occur at this point or earlier in the dissection.

dissection, the retromandibular vein may be identified and ligated as it travels through the tail of the parotid gland.

- Incise soft tissue over contralateral anterior belly of the digastric muscle from mentum down to hyoid bone.
- Begin elevating contents of level 1A by pulling tissue laterally off the mylohyoid muscle toward the ipsilateral anterior belly of the digastric muscle; this will require division of tissue along the hyoid bone inferiorly.
- Bring packet of tissue over ipsilateral digastric and back onto mylohyoid until the edge of the mylohyoid is reached see **FIG 4**.
- Retract the mylohyoid muscle medially to allow for exposure of the contents deep to the submandibular gland. This may require some blunt dissection in this area. Identify the hypoglossal nerve, lingual nerve, and submandibular duct (**FIG 5**).
- Divide the submandibular duct, taking care not to cause excessive bleeding from the nearby veins (**FIG 6**).
- Divide the submandibular ganglion and allow the lingual nerve to retract superiorly.
- Pull the submandibular gland and packet of tissue laterally, carefully dividing the tissue over the posterior belly of the digastric (**FIG 7**).
- Approximately halfway up the posterior belly, the facial artery is again seen travelling under the digastric and into the submandibular gland; divide the artery a second time.
- Trace the posterior belly superiorly, dividing the overlying tissue until the SCM is reached. If it has not already

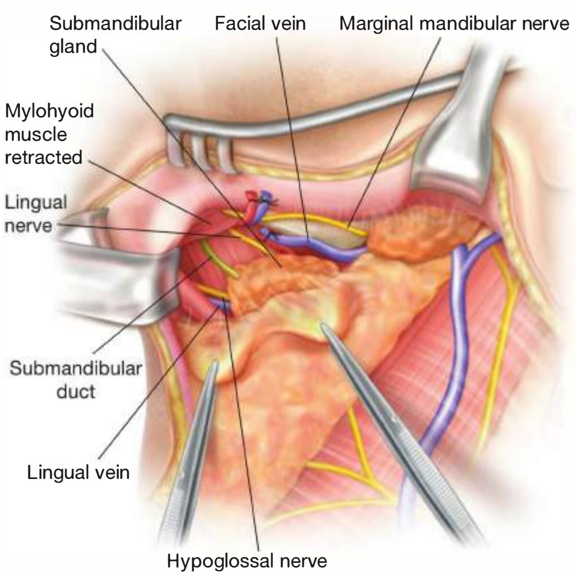

FIG 5 ● The mylohyoid muscle is retracted anteriorly exposing the lingual nerve, submandibular duct, and hypoglossal nerve. The hypoglossal nerve is in a deeper plane than the lingual nerve and is only exposed after dividing the overlying fascia.

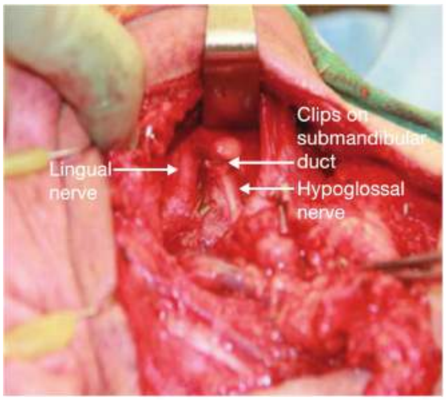

FIG 6 ● View of the right neck level 1B with the submandibular gland removed and the mylohyoid muscle retracted anteriorly. Clips are seen on the submandibular duct remnant.

been divided, the retromandibular vein is usually encountered as it exits the parotid gland near the angle of the mandible—carefully divide the vein.

- The SCM is then "unwrapped." At the posterior edge of the SCM, incise the fascia over the muscle. This will require division of the cutaneous nerves that course over the muscle; the great auricular branch to the ear as well as the external jugular can sometimes be traced out and saved.
- Pull the fascia medially to unwrap the SCM; be careful to take all tissue over the muscle because lymph nodes associated with the external jugular vein must be removed.

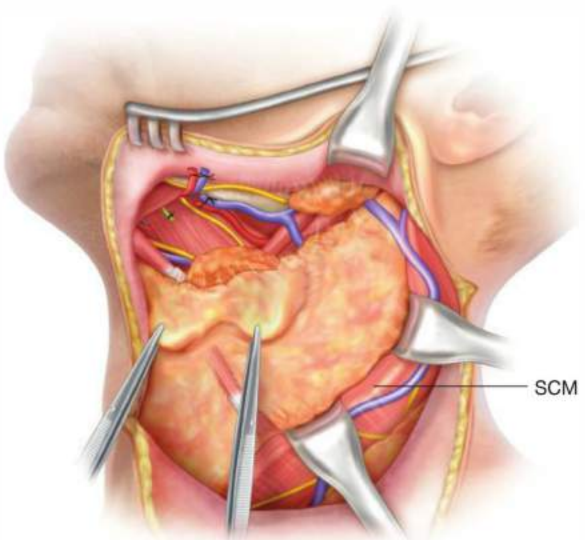

FIG 7 ● The contents of level 1B are pulled over the posterior belly of digastric. The facial artery could be dissected free from the gland (as shown) or divided a second time as it crosses under the digastric.

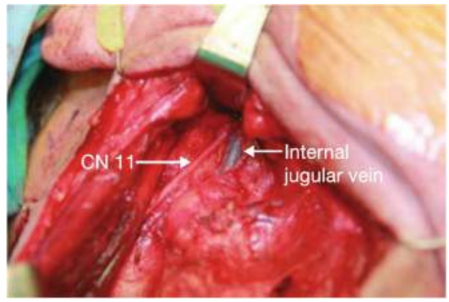

FIG 8 ● The contents of the right-sided level 2 are exposed with CN 11 in clear view as it courses over the internal jugular. The posterior belly of digastric is retracted superiorly.

- After the anterior surface of the SCM is wrapped, carefully roll the muscle outward to start unwrapping the deep surface; at the junction of the upper one-third and lower two-thirds, the cranial nerve (CN) XI (the spinal accessory nerve) will be encountered as it enters the muscle.
- Continue to unwrap and elevate the muscle of the floor of the neck until the posterior edge is reached, taking care to not stretch or injure CN XI.
- At this point, the posterior belly of the digastric should be traced underneath the SCM and then mobilized so it can be pulled superiorly.
- At the hyoid bone, the omohyoid muscle is identified and traced low into the neck to the posterior edge of the SCM. It is mobilized as well so it can be pulled inferiorly.
- Next, the posterior belly of the digastric is pulled superiorly while CN XI is traced underneath the muscle by dividing the overlying tissue until it courses over the internal jugular (IJ) vein; the nerve usually passes superficial to the vein (80%) but can also pass deep to it (20%) (**FIG 8**).
- The spinal accessory nerve is elevated off the deep neck and is circumferentially dissected up to the IJ; the wall of the IJ vein is then skeletonized (**FIG 9**).
- The transverse process of C1 is palpated on the floor of the neck. This will serve as the superior limit of dissection.
- Lymphatic tissue of level 2B is mobilized by dividing the tissue between the IJ and the posterior edge of the SCM down to the level of the floor of the neck (levator scapulae muscle). Superiorly, the contents of level 2B will need to be pulled underneath the CN XI (**FIG 9**).
- The posterior edge of dissection parallels the posterior border of the SCM. This tissue is incised down to the floor of the neck as well, taking care to not divide the cervical rootlets (**FIG 10**).
- The inferior margin of dissection is approximately at the clavicle. The omohyoid muscle can be retracted inferiorly or divided to access this area.
- Start by identifying the IJ low in neck and skeletonizing the wall. Next, divide the tissue adjacent to the IJ down to the floor of the neck. This tissue needs to be carefully ligated with sutures or clips due to the presence of the thoracic duct. The tissue is divided between the IJ and the posterior edge of the SCM.

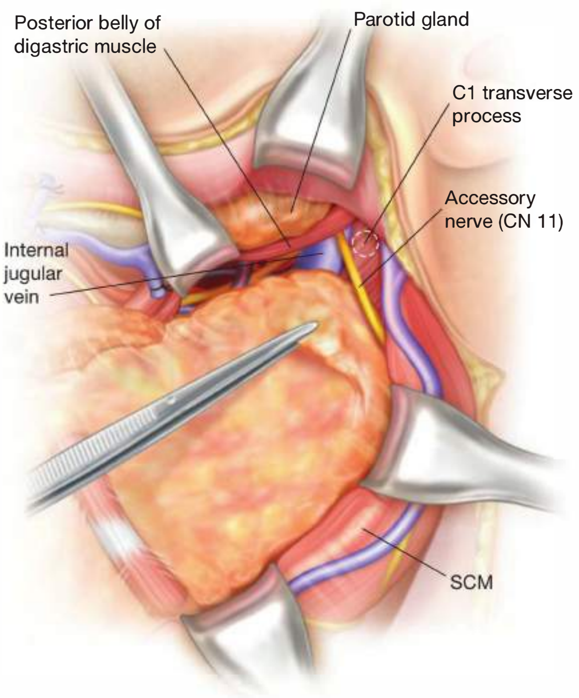

FIG 9 ● The contents of level 2B are dissected and passed underneath CN 11. The transverse process of C1 is palpable beneath the muscle.

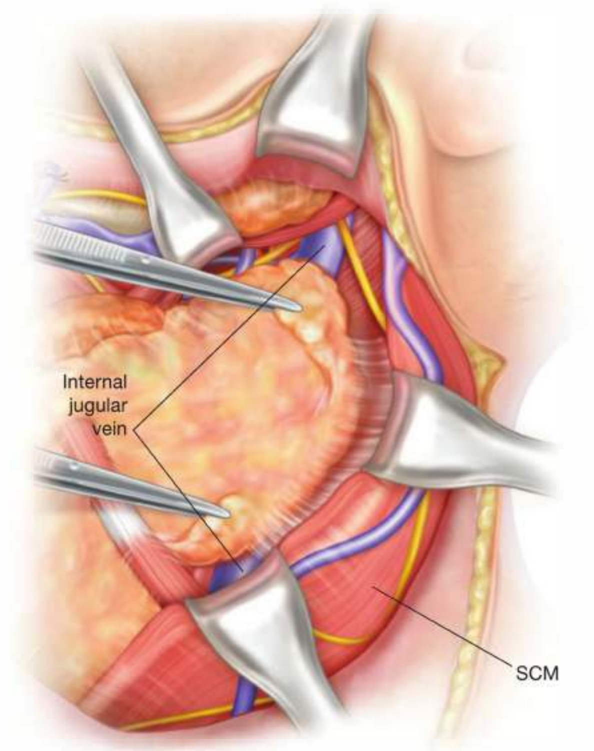

FIG 11 ● The inferior dissection at the level of the clavicle is complete, allowing the lymphatic tissue of levels 2, 3, and 4 to be elevated off the floor of the neck.

- The tissue is then brought forward off the floor of the neck onto the IJ vein (**FIG 11**). Follow the fascia of the floor without violating the fascia covering the deep neck muscles.
- The package of tissue is then brought over the IJ by entering the fascia of the carotid sheath; as the tissue is dissected off the IJ, the branches of the IJ are ligated (**FIG 12**). Once the IJ is nearly circumferentially dissected, the carotid artery is in view (**FIG 13**).

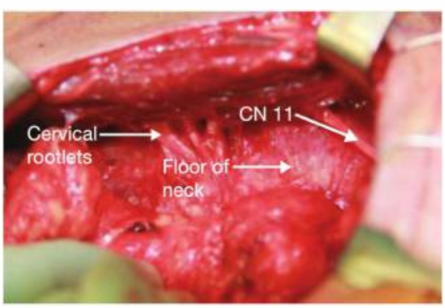

FIG 10 ● With the SCM retracted in the right neck, the contents are elevated off the floor of the neck. CN 11 is seen on the right side of the picture, and in the middle of the picture, the cervical rootlets are seen piecing the floor of the neck and wrapped around the posterior SCM.

- The hypoglossal nerve is identified underneath the digastric. This is traced posteriorly, dividing the overlying tissue and veins until the nerve travels between the carotid and IJ (**FIG 14**).
- The package is brought over the carotid until the superior thyroid artery is seen; at this point, transition is made to the fascia of the visceral space (**FIG 15**).
- The package of tissue is then truncated at the lateral border of the strap musculature.

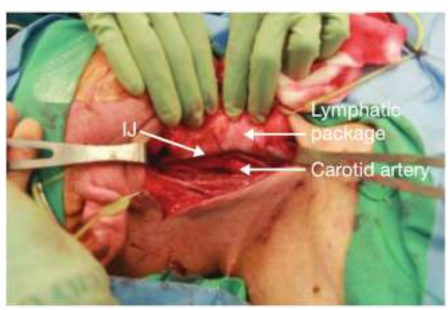

FIG 12 ● The lymphatic package is pulled medially in the right neck, still attached to the internal jugular. The package will be taken off of the IJ and onto the visceral space.

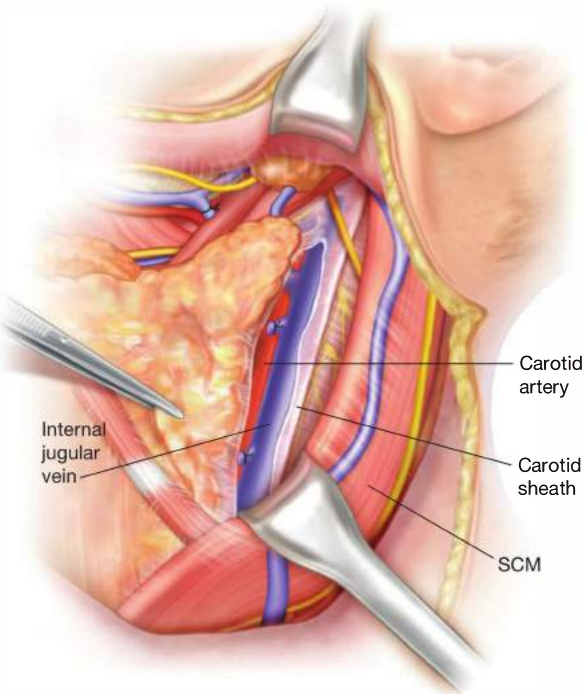

FIG 13 ● The carotid sheath is entered and the branches of the IJ are divided allowing the packet to be transitioned onto the carotid artery.

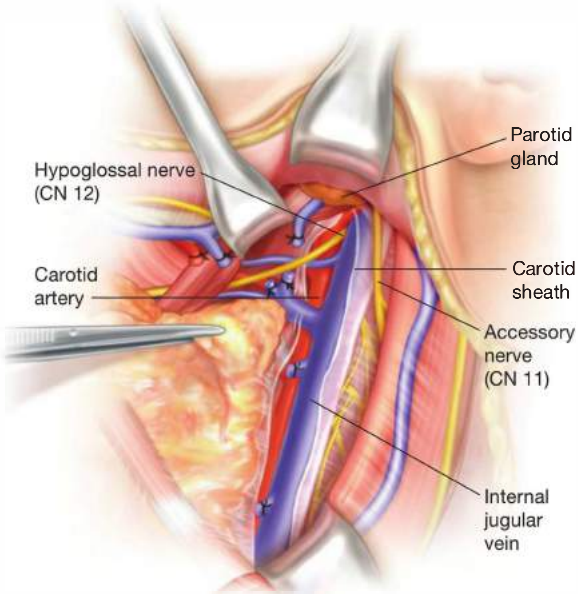

FIG 14 ● The hypoglossal nerve is traced out from where it crosses the digastric until it courses between the carotid and the IJ. The overlying veins are delicate and must be divided carefully to avoid significant bleeding which could obstruct the view of the vein.

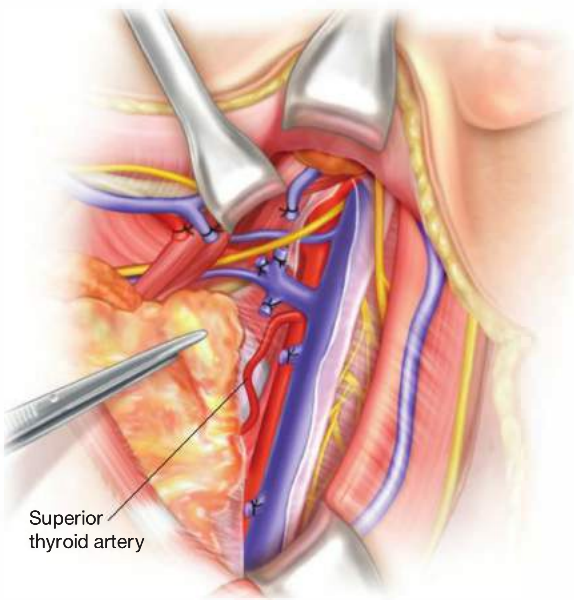

FIG 15 ● The packet is transitioned off the carotid space and onto the visceral space carefully preserving the superior thyroid artery.

TECHNIQUES

SELECTIVE NECK DISSECTION LEVELS 2 TO 5 (POSTERIOR-LATERAL NECK DISSECTION)

- The skin incision is modified from the prior procedure being located more posteriorly and travelling lower in the neck.
- Alternatively, a "limb" can be dropped down from the incision to give access to the area over the supraclavicular fossa.
- Posteriorly, the platysma is absent; therefore, the approximate plane of the superficial layer of the cervical fascia is followed.
- The skin flap is raised to the edge of the trapezius muscle posteriorly and inferiorly; the muscle edge is often not seen and therefore must be estimated.
- CN XI is located within the level 5 area. The nerve usually exits the posterior border of the SCM approximately 2 cm above where the great auricular nerve wraps around the muscle. The position is confirmed with nerve stimulation.
- Once the nerve is identified, it is traced from the posterior edge of the SCM until it travels underneath the trapezius muscle; as the nerve approaches the trapezius, it often splits into more than one branch, each of which should be preserved.
- The nerve is then mobilized and elevated from the level 5 contents.
- Next, the posterior superior edge of the SCM is skeletonized.
- This dissection is carried out to the level of the mastoid tip, where the dissection turns posteriorly until the edge of the trapezius is identified.
- In this area, the tissues are cut down to the floor of the neck until the levator scapulae muscle is identified.
- The posterior edge of the SCM and the edge of the trapezius muscle are dissected in their entirety down to the floor of the neck; care is taken to not injure CN XI as it exits and enters these muscles.
- Inferiorly, the tissue at the level of the clavicle is divided heading toward the floor of the neck; careful not to violate the fascia of the floor of the neck to avoid injury to the transverse cervical vessels or the brachial plexus.
- This dissection will connect to both the anterior SCM dissection and the posterior trapezius dissection.
- The omohyoid muscle can be divided near its insertion into the scapula.
- The contents of level 5A and 5B are now brought forward by elevating them off the floor of the neck; during this process, the sensory cervical rootlets can be dissected free and preserved or divided.
- Once the contents are brought to the posterior edge of the SCM, the contents can either be truncated at this point or tucked underneath the SCM.
- The remainder of the levels 2 to 4 neck dissection proceeds as described above; begin by identifying the posterior belly of the digastric muscle and tracing it up to the SCM.

UNIQUE SCENARIOS

- Skin involvement
  - Involvement of the skin can happen from metastatic disease in the neck or from a primary lesion in the neck.
  - Extent of involvement should be determined based on CT scan and palpation with careful attention to the platysma and dermis.
  - Mark at least 1 cm around areas of subcutaneous or dermal involvement; closure is assisted by using elliptical-shaped excisions and paying close attention to resulting skin flaps for rotation or advancement.
  - At the time of skin incision, these areas should incised down through the level of the platysma.
  - Subplatysmal skin flaps are elevated around the area of involvement, leaving the skin overlying the tumor pedicled on the tumor.
- Involvement of structures
  - Necessity for resection of the SCM, CN XI, IJ, or additional structures is based on involvement seen on imaging studies or at the time of surgery.
  - Tumor should never be violated to preserve any of these structures.

PEARLS AND PITFALLS

Communication with anesthesia	■ It is essential that the patient is not paralyzed for the operation to allow for monitoring of the marginal mandibular nerve, CN XI, and CN XII. Short-acting paralytics used for induction generally wear off by the time the incision is made.
Placement of incision	■ The incision should be about two fingerbreadths below the edge of the mandible to avoid injuring the marginal mandibular nerve during skin flap incision and elevation.
Identification of structures	■ The fascial planes provide excellent boundaries for dissection and should almost always be followed during the neck dissection.
Excision	■ If grossly positive lymph nodes are encountered, take a cuff of normal tissue to surround the node. This can involve removing a portion of the SCM or sacrificing the IJ.

Division of specimen	■ The specimen is typically divided into the corresponding levels of the neck dissection to allow pathology to separately report which levels contained positive lymph nodes.
Prior to closure	■ The level 4 area of the neck is checked for a chyle leak with a sustained Valsalva maneuver. Any evidence of clear or milky fluid should be treated by sewing over or clipping the area.

POSTOPERATIVE CARE

- Following surgery, patients are admitted to the general inpatient unit.
- Postoperative antibiotics are continued for 24 hours.
- Postoperative subcutaneous heparin is used immediately following surgery.
- Closed suction drains are used until output is less than 30 mL per day.
- Patients with extensive CN XI dissection are seen by physical therapy for arm mobilization and strengthening exercises.

OUTCOMES

- The rate of regional recurrence after selective neck dissection for melanoma depends on the extent of cervical disease at the time of resection. It is as low as 15% for micrometastatic disease and as high as 50% for macroscopic disease with extracapsular extension.
- Postoperative radiation therapy is considered for patients with extracapsular extension, a single node greater than 4 cm, three or more positive nodes, or for neck dissections following a regional recurrence.
- Recurrent neck disease after neck dissection must be carefully evaluated to determine resectability.

COMPLICATIONS

- Hematoma
- Chyle leak
- CN XI injury
- Hypoglossal injury
- Marginal mandibular weakness
- Stroke

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Chapter **32**

Popliteal Dissection

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DEFINITION

- Popliteal dissection, or popliteal lymphadenectomy, is the removal of all lymph node–bearing tissue from the popliteal fossa. This procedure is most commonly performed for melanoma but may rarely be performed for other cutaneous cancers or for the limited number of sarcomas that have a propensity to metastasize to lymph nodes.
- Popliteal dissection is indicated in patients with no evidence of distant metastatic disease who are found to have the following:
  - Positive popliteal sentinel lymph node biopsy (microscopic nodal disease)
  - Clinically positive popliteal lymph nodes (macroscopic nodal disease)
- Boundaries of the popliteal fossa (**FIG 1**)
  - Superomedial: semitendinosus and semimembranosus muscles
  - Superolateral: biceps femoris muscle
  - Inferomedial: medial head of the gastrocnemius muscle
  - Inferolateral: lateral head of the gastrocnemius muscle and plantaris muscle
  - Roof: skin, superficial fascia, deep (popliteal) fascia
  - Floor: popliteal surface of femur, capsule of knee joint, oblique popliteal ligament, fascia overlying popliteus muscle

PATIENT HISTORY AND PHYSICAL FINDINGS

- A thorough history should be elicited prior to treatment, including a detailed past medical and surgical history, present medications and allergies, and a personal and family history of cancer. A complete head-to-toe skin examination should be performed. All lymph node basins (cervical, supraclavicular, axillary, epitrochlear, inguinal, popliteal) should be evaluated for clinically positive lymph nodes.
- Clinically positive lymph nodes typically present as a palpable mass. However, enlarged lymph nodes in the popliteal fossa may not be easily palpable because of the thick overlying fascia. Therefore, a careful examination of the popliteal fossa is essential.
- Most patients undergo popliteal dissection because of a positive sentinel lymph node biopsy. Sentinel lymph node biopsy has now become the standard of care for evaluating regional lymph node basins in patients with cutaneous melanoma greater than 1 mm in Breslow thickness who have no evidence of distant metastatic disease (see Part 5, Chapter 27). Current standard of care for patients with positive sentinel lymph nodes includes completion lymphadenectomy of the involved lymph node basin; observation alone should be performed in the context of a clinical trial. Approximately 50% of patients with a positive popliteal sentinel lymph node biopsy will also have documented inguinal disease; therefore, popliteal and inguinal dissections are often performed concomitantly.[1,2]

IMAGING AND OTHER DIAGNOSTIC STUDIES

- A clinically positive lymph node should be evaluated using fine needle aspiration biopsy. Popliteal dissection is performed for a positive biopsy.
- For patients with clinically negative lymph nodes, preoperative lymphoscintigraphy should be performed at the time of the initial sentinel lymph node biopsy even if the primary melanoma is located on an extremity. Lymphoscintigraphy will demonstrate drainage to popliteal lymph nodes in 1% to 9% of patients with distal lower extremity melanoma (i.e., below the knee; **FIG 2**).[1–5] By far, the most common locations for primary melanomas that drain to the popliteal fossa are the posterolateral foot and posterior lower leg; however, primary melanomas of the anterior lower leg or

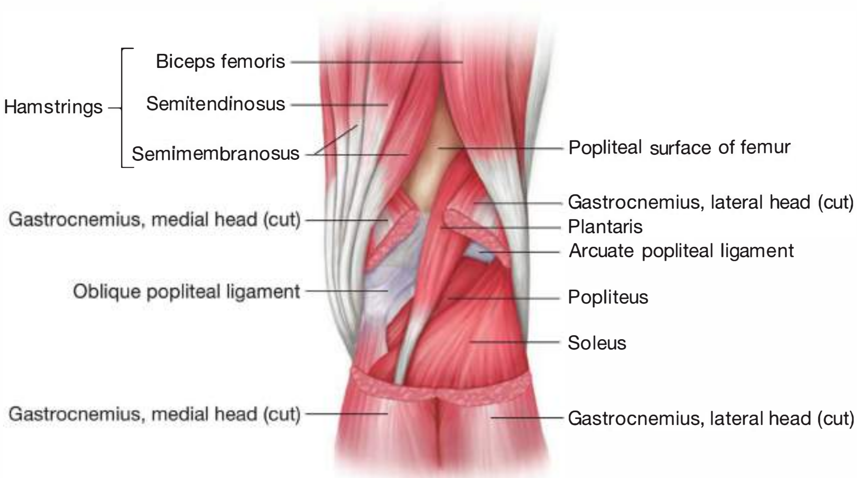

FIG 1 ● Boundaries of the popliteal fossa (right leg).

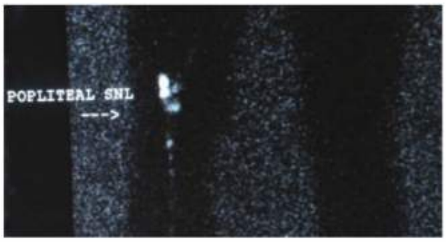

FIG 2 ● Lymphoscintigraphy demonstrating lymphatic drainage to the popliteal fossa from a primary melanoma of the distal right foot.

anteromedial aspect of the foot will also occasionally drain to the popliteal fossa.[1–4] The overall incidence of a positive popliteal lymph node is 0.3% to 2.8%.[1–3,5]

SURGICAL MANAGEMENT

Preoperative Planning

- In the preoperative area, a focused history and physical examination should be repeated, and the patient's prior pathology and imaging studies should be reviewed.
- The patient should be marked to confirm laterality.
- Although there are no data that specifically address the wound infection rate in popliteal dissection, we favor the administration of a dose of preoperative antibiotics, particularly if concomitant inguinal dissection is planned.

Positioning

- The patient is placed prone, with pressure points padded, and the operative knee slightly flexed (FIG 3). The operative leg should be prepped circumferentially from above the midthigh to below the midcalf.
- If a concomitant inguinal dissection is planned, the popliteal dissection is usually performed first.

FIG 3 ● Patient position for popliteal dissection. Note that the operative leg (right) is slightly flexed.

PLACEMENT OF INCISION

- There are two options for the incision for popliteal dissection (FIG 4). The incision should be planned such that a prior incision for sentinel lymph node biopsy can be excised.
- The S-shaped incision was described by Karakousis[6] in his initial report of the technique of popliteal dissection. This incision typically extends from approximately 10 cm proximal to the joint crease along the lateral thigh overlying the biceps femoris

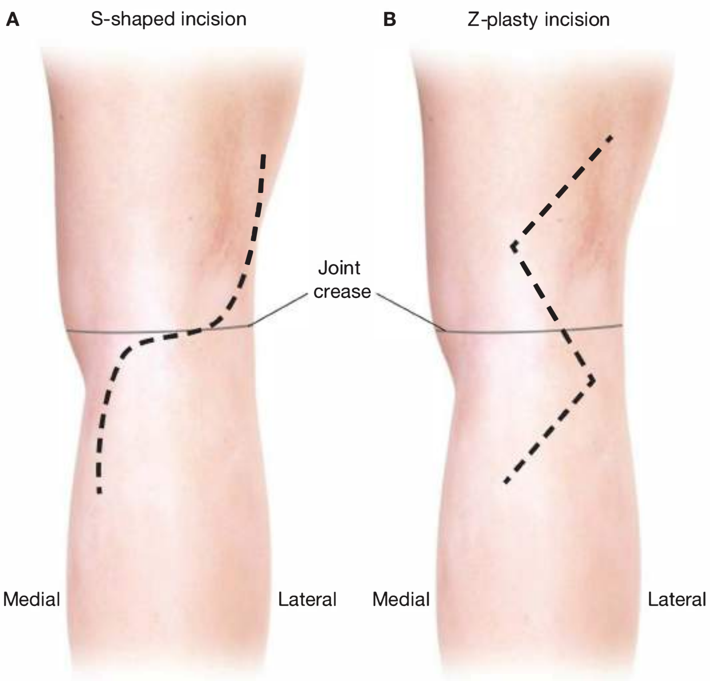

FIG 4 ● Incisions for popliteal dissection (right leg). **A.** S-shaped incision. **B.** Z-plasty incision.

muscle, crosses the joint transversely, and extends approximately 10 cm distal to the joint crease along the medial calf overlying the medial aspect of the gastrocnemius muscle (**FIG 4A**). A mirror image of this incision, extending from the medial thigh to the lateral calf, is also acceptable and may be preferable depending on the orientation of the incision used to perform the sentinel lymph node biopsy.

- We prefer a Z-plasty incision that allows for optimal exposure and heals without joint contracture.[7] Again, the orientation is typically superolateral to inferomedial. The width and length of the Z is relative to the size of the lower thigh, usually with an interior angle ranging from 100 to 120 degrees (**FIG 4B**).

SKIN INCISION AND RAISING OF FLAPS

- The incision is created and dissection is carried down through the subcutaneous tissue. Medial and lateral flaps are raised while traction is maintained with skin hooks. The flaps should expose all of the boundaries of the popliteal fossa, remaining above the deep fascia.
- The lesser saphenous vein is exposed inferiorly; it should be ligated and divided (**FIG 5**).

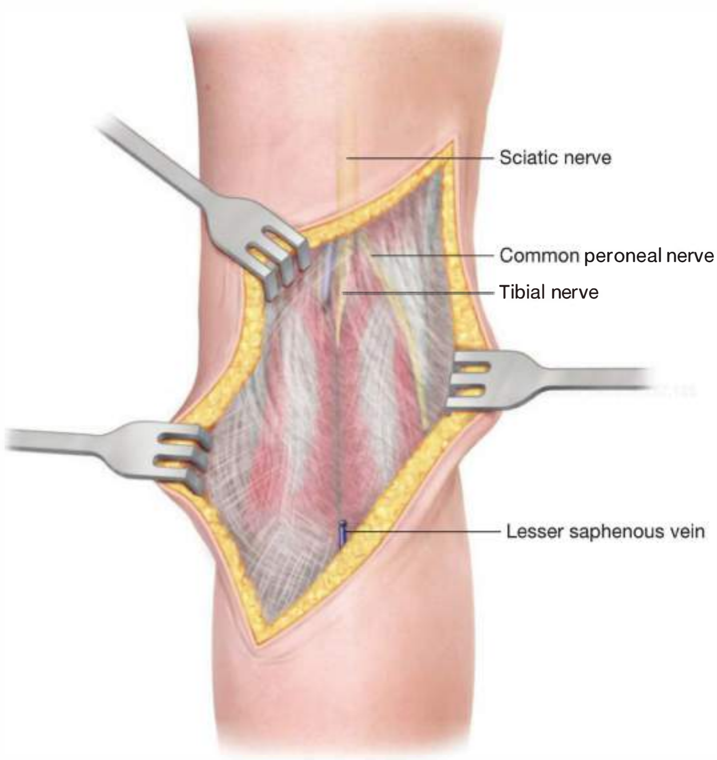

FIG 5 ● Medial and lateral skin flaps are raised, and the lesser saphenous vein is divided (right leg).

INCISION OF THE DEEP FASCIA AND IDENTIFICATION OF STRUCTURES TO BE PRESERVED

- The deep fascia is incised vertically with great care not to injure underlying structures; the nerves are very superficial (**FIG 6**).
- The common peroneal nerve runs laterally in the field, just medial to the biceps femoris muscle. The lateral sural nerve branches medially from it and eventually connects inferiorly with the medial sural nerve to form the sural nerve. The lateral sural nerve may be sacrificed if necessary; no significant deficit is appreciated as long as the medial sural nerve remains intact.
- The tibial nerve is the most superficial midline structure. It lies lateral to the popliteal vessels at the superior aspect of the popliteal fossa then courses anterior to the vessels and lies medial to them at the inferior aspect of the popliteal fossa. The medial sural nerve branches off of the tibial nerve and descends in the groove between the heads of the gastrocnemius muscle to where it connects inferiorly with the lateral sural nerve. The medial sural nerve should be preserved if possible; however, it can be divided if greater access to deeper structures is needed. The patient will experience sensory loss along the lateral aspect of the ankle and foot.
- The popliteal vessels are ensheathed; upon opening the sheath, the popliteal artery will be located slightly medial and deep to the popliteal vein (**FIG 7**). The popliteal vein has several small tributaries below the level of the lesser saphenous vein branch, which can cause bothersome bleeding.

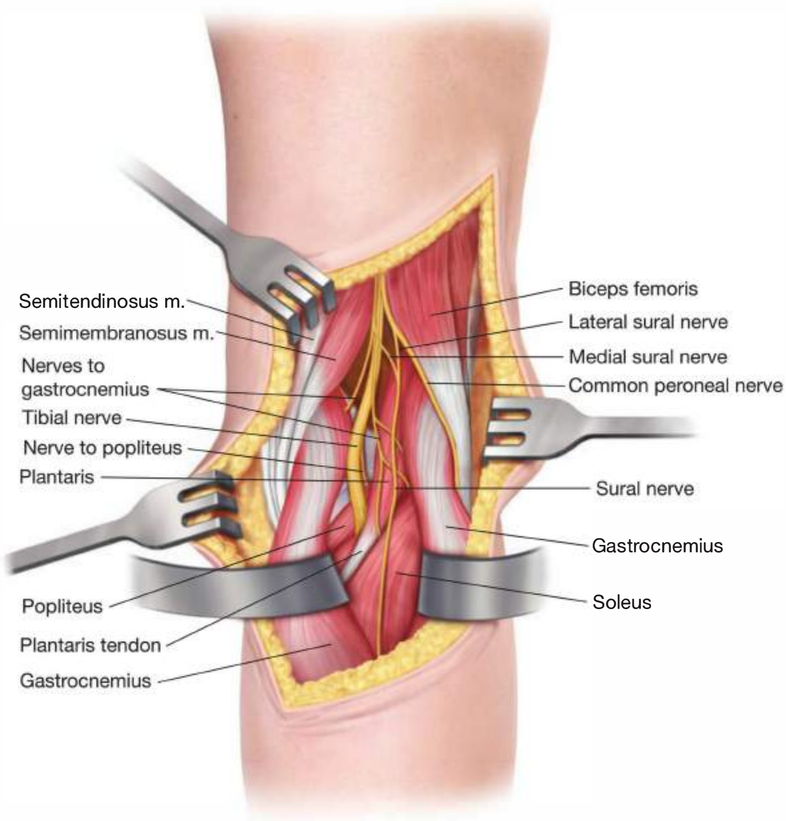

FIG 6 ● Upon opening the deep fascia and entering the popliteal fossa, the nerves are exposed (right leg).

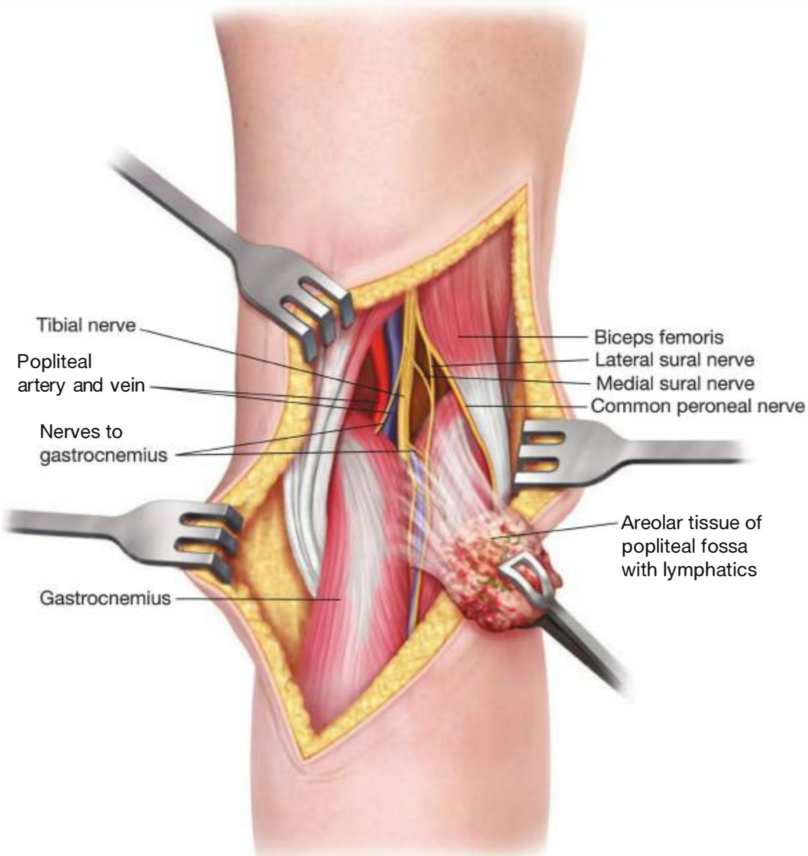

FIG 7 ● The nodal specimen is swept away from the nerves and vessels (right leg). Careful attention must be made to the space between the popliteal vessels and the knee joint (anterior/deep to the vessels) as one to two lymph nodes are commonly located here and are easily overlooked.

DISSECTION OF FIBROFATTY NODE–BEARING TISSUE AWAY FROM NERVES AND VESSELS

- The fibrofatty node–bearing tissue is dissected sharply away from the nerves and vessels and is removed in continuity, with care to preserve all important structures (**FIGS 7** and **8**).
- It is important to recognize that one or two lymph nodes are frequently located in the space between the popliteal artery and the knee joint (i.e., anterior to the popliteal artery from the anatomic perspective or deep to the popliteal artery from the perspective of the operating surgeon). These lymph nodes are often overlooked; this space should be carefully dissected so as to not leave lymphatic tissue behind.
- After removal of the specimen, the popliteal fossa should be evaluated thoroughly by inspection and palpation to ensure that all lymphatic tissue has been resected.
- The specimen is sent to pathology for permanent section.

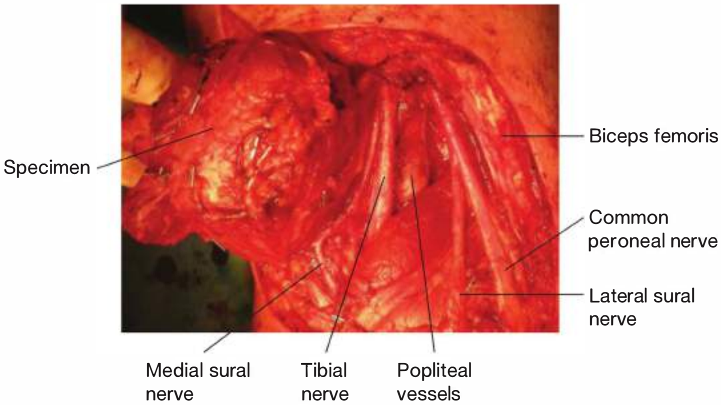

FIG 8 ● Photograph depicting resection of bulky disease in the popliteal fossa (right leg). Skin and subcutaneous tissue were resected en bloc with the specimen, and plastic surgical reconstruction was required for closure.

CLOSURE

- Hemostasis is achieved. The wound is irrigated copiously with saline.
- A 15-Fr round fluted, closed suction drain is placed into the wound and brought out through a separate stab incision (usually inferiorly; **FIG 9**).
- The incision is closed using absorbable suture for the deep dermis and a subcuticular stitch for the skin. A sterile dressing is applied.

FIG 9 ● The drain is brought out through a separate stab wound inferiorly (right leg).

PEARLS AND PITFALLS

Indications	■ Clinically palpable lymph nodes may be difficult to appreciate in the popliteal fossa because of thick overlying fascia. ■ Most patients undergo popliteal dissection because of a positive sentinel lymph node biopsy.
Incision	■ Options are S-shaped and Z-plasty to preserve joint function. ■ Orient incision so that prior sentinel lymph node biopsy scar is excised (usually superolateral to inferomedial).

Raising of medial and lateral flaps	■ Extend flaps to boundaries of popliteal fossa. ■ Ligate and divide lesser saphenous vein inferiorly.
Incision of the deep fascia and identification of structures to be preserved	■ Take care as fascia is incised; important structures lie directly beneath it. ■ Identify common peroneal nerve, tibial nerve, medial sural nerve, lateral sural nerve, popliteal artery, and popliteal vein. ■ Division of lateral sural nerve alone results in no significant deficit. ■ Division of medial sural nerve results in sensory loss.
Dissection of fibrofatty node–bearing tissue away from nerves and vessels	■ Remember to dissect the space between the popliteal artery and the knee joint (i.e., anterior or deep to the artery), as one or two lymph nodes are frequently identified in this location and are easily overlooked.
Closure	■ Place a drain.

POSTOPERATIVE CARE

- The patient remains hospitalized at least overnight, but perhaps for several days, depending on the extent of other lymphadenectomies that may have been performed during the same operation. A posterior knee splint (knee immobilizer) is used for the first few postoperative days to allow for wound healing prior to returning to full mobility. Ambulation is often initially difficult; physical therapy is useful. The drain may be removed when output falls below 30 mL per day; typically, this is a relatively short interval compared with drain times for axillary or inguinal dissections.

OUTCOMES

- Lymphedema is rare after popliteal dissection, and the functional outcome of the knee is usually excellent.
- The popliteal fossa is historically reported to contain 6 to 7 lymph nodes.[6] However, contemporary experience suggests that finding far fewer nodes is more common.[7] In a recent study of 15 patients who underwent popliteal sentinel lymph node biopsy, the mean number of popliteal lymph nodes harvested was 1.4 (range was 1 to 3); however, in 6 patients who subsequently underwent completion popliteal dissection, the mean number of lymph nodes in the popliteal dissection specimen was 0.3, with 4 of the 6 patients' specimens yielding no additional (nonsentinel) lymph nodes.[2]
- Overall, the 5-year survival for patients with stage III melanoma (lymph node–positive disease) ranges widely (14% to 85%), with the 5-year survival of a patient with a single microscopically positive lymph node approximating 70%.[8–10] It is difficult to determine whether the presence of a positive popliteal lymph node carries a different prognosis when compared with the presence of a positive lymph node in one of the more commonly involved regional lymph node basins (i.e., axillary, inguinal, cervical). Because popliteal disease is overall quite rare, the literature contains only case reports and small case series, most of which include both patients with micrometastatic disease and patients with clinically palpable disease.[1,3] A relatively large contemporary study in the literature reports on 15 patients who underwent popliteal sentinel lymph node biopsy; 8 patients had a positive sentinel lymph node. At an average follow-up of 64 months, 3 (37.5%) patients had died of melanoma, 1 (12.5%) was alive with disease, and 4 (50%) had no evidence of disease.[2] Given the very small numbers, these statistics are likely similar to overall 5-year survival rates for patients with positive nodes in the more commonly involved regional lymph node basins.

COMPLICATIONS

- Common complications of popliteal dissection include wound infection (cellulitis or abscess), seroma, and hematoma.
- Injury to the common peroneal nerve results in postoperative foot drop and sensory loss or paresthesias over the dorsum of the foot (including the space between the great and second toes) and lateral shin.
- Injury to the tibial nerve results in postoperative loss of plantar flexion of the foot, loss of flexion of the toes, weakened inversion of the foot, and sensory loss or paresthesias over the posterior aspect of the leg and the sole of the foot.

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Chapter 33 Isolated Limb Infusion

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DEFINITION

- *Isolated limb infusion* is the term that is commonly used to indicate a minimally invasive, low flow rate, nonoxygenated perfusion of an extremity with chemotherapy to effect control of a cancer within that extremity[1] (**FIG 1**). It is a more recent modification of a more traditional technique commonly referred to as *isolated limb perfusion* (see Part 5, Chapter 34), which uses higher flow rates and an oxygenated circuit to perfuse the chemotherapy through the extremity where vascular control is obtained during an open procedure and is often combined with a formal node dissection. Comparatively, isolated limb infusion is a shorter, better tolerated, less complex procedure, not requiring a perfusionist, an oxygenator, nor blood products to prime the extracorporeal circuit.[2,3] Proponents of limb perfusion claim a higher response rate, particularly in bulky disease; however, the techniques have not been compared in a randomized fashion.

PATIENT HISTORY AND PHYSICAL FINDINGS

- The most common indication for this procedure is a patient with in-transit melanoma restricted to an extremity whose lesions are too numerous or recurrent to be amenable to simple excision. It should be thought of as a limb salvage technique to treat regionally advanced disease and has no proven systemic benefit. Therefore, it is not commonly used in the face of distant metastasis unless regional control/palliation is the central goal.
- Common malignancies treated in this manner include melanoma and Merkel cell carcinoma. Other histologies treated less commonly include squamous cell carcinoma and sarcoma.
- A through history and physical should be performed with attention to documenting location and extent of extremity disease, limb function, edema, vascular exam, and evaluation of draining nodal basins.
- Limb volume is estimated by water displacement.
  - Sequential circumferential measurements or computed tomography (CT) volumetric measurements have been described as alternatives.
  - The contralateral limb should be measured if the involved limb is edematous.
  - The limb is submerged in a water tank up to level anticipated to be at bottom of tourniquet. The water level is marked and then after removal of the limb, the tank is filled with a measured amount of water to reach the marked level.
- Patients should have nonoccluded arterial and venous systems to allow catheter placement and chemotherapy infusion.

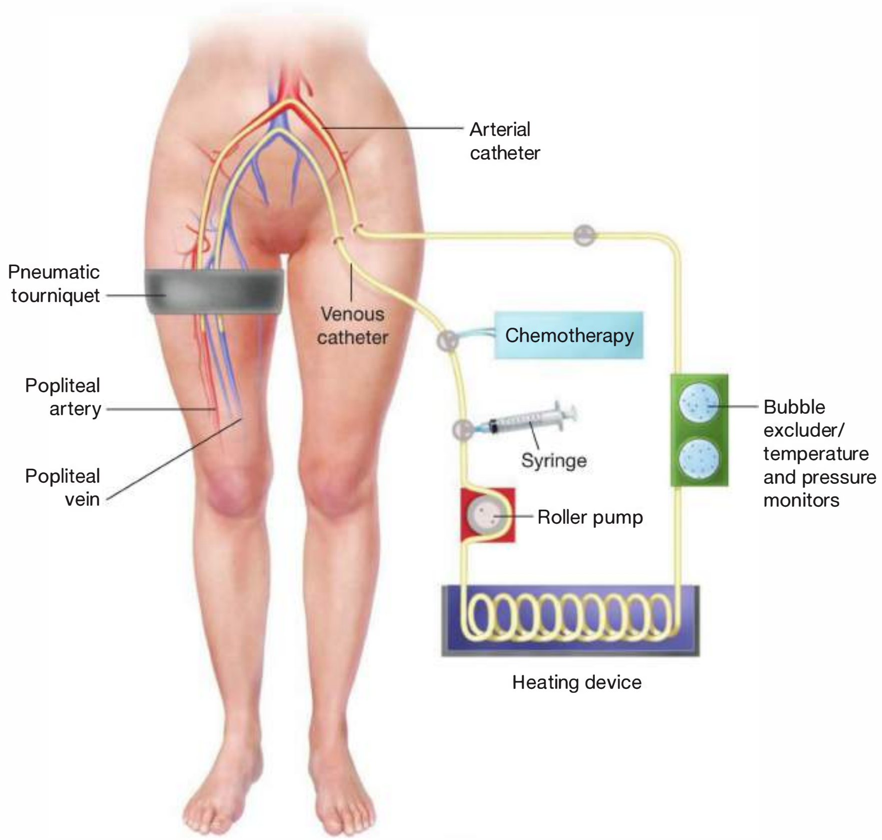

FIG 1 • Schematic of circuit used for isolated limb infusion. Roller pump is optional.

- The extent of disease needs to be distal enough in the extremity to be able to place a tourniquet proximally.
  - In selected cases, this may require resection of limited more proximal disease combined with infusion of greater distal disease burden distally.
  - Isolated limb infusion can be combined with a lymph node dissection with direct placement of the catheters in the exposed vessels.

IMAGING AND OTHER DIAGNOSTIC STUDIES

- Arterial and venous duplex ultrasound to establish arterial and venous patency. With adequate collaterals, limb infusion has been described even when superficial vessels are occluded.
- Imaging to evaluate limb disease burden if lesions are deep seated and difficult to quantitate on exam
- Imaging to evaluate for distant disease including brain magnetic resonance imaging (MRI); whole body positron emission tomography (PET)/CT; and/or chest, abdomen, pelvis contrast-enhanced CT scans

SURGICAL MANAGEMENT

- Patients should be discussed in multidisciplinary fashion to consider alternatives to isolated infusion including isolated limb perfusion; intralesional therapy; simple excision; radical excision, including circumferential excision and grafting or amputation; radiation; or systemic cytotoxic, immunotherapeutic, and other biologic therapies as well as clinical trial eligibility.

Preoperative Planning

- Who and where vascular access is to be obtained should be determined preoperatively and may be institution specific. Possible methods include the following:
  - Interventional radiology. Vascular access can be performed in the interventional radiology suite, with the patient then transported to the operating room (OR) with the arterial and venous catheters in place.
  - Vascular surgery. Some vascular surgeons have the training, experience, and interest to perform the vascular access as an alternative to the interventional radiologist. Access can be obtained in the OR directly if appropriately equipped with fluoroscopic capabilities. Although additional OR time is required if done in the OR, the catheters can more easily be manipulated later, as needed. Moreover, access can be obtained under general anesthesia and risk of dislodgement during transport/bed transfer is eliminated.
  - Chemotherapy. Melphalan and dactinomycin are prepared just prior to the procedure. The calculated drug dosage is often reduced if the patient's actual body weight exceeds ideal body weight by multiplying the calculated drug dose by the ratio of ideal to actual body weight.
  - Melphalan dose is 7.5 mg/L volume for lower extremity infusions (maximum dose of 100 mg) or 10 mg/L volume for the upper extremity (maximum dose 50 mg).
  - Dactinomycin dose is 1% of the melphalan dose (maximum 0.5 mg).
  - The drugs are mixed together in 400-mL normal saline lower extremity (200 mL upper extremity) and delivered to OR for administration.

FIG 2 ● Exposed affected limb with tourniquet proximally.

Positioning

- The patient is positioned supine on a fluoroscopy-capable OR bed for vascular access or in case catheter manipulation is needed.
- The room should be prewarmed.
- A heated circulating water blanket is placed around the affected extremity or an external radiant heater utilized (**FIGS 2** and **3**).

FIG 3 ● Affected limb wrapped in water blanket.

- Heated air blankets are placed on the patient's trunk and head or an external radiant heater is used.
- A pneumatic tourniquet is placed on the proximal aspect of the extremity with the lower edge marked with a radiopaque hemostat. For distal-only infusions, the tourniquet can be placed lower.
- Needle temperature probes are inserted into deep and superficial locations within the proximal and distal limb locations.
- Baseline activated clotting time (ACT) is obtained.

VASCULAR ACCESS

- Venous and arterial access is obtained in the uninvolved lower limb using the Seldinger technique with ultrasound and fluoroscopic guidance.
- After placing a vascular access sheath, a 5- or 6-Fr 100-cm catheter is introduced into the external iliac artery retrograde and manipulated across the iliac bifurcation and down the index limb arterial system to a point beyond the lower edge of the tourniquet. Similarly, a 7- to 8-Fr catheter is placed thru the venous system and positioned below the tourniquet (**FIG 4**).
- The patient is heparinized at 200 to 300 units/kg to obtain an ACT of 400.

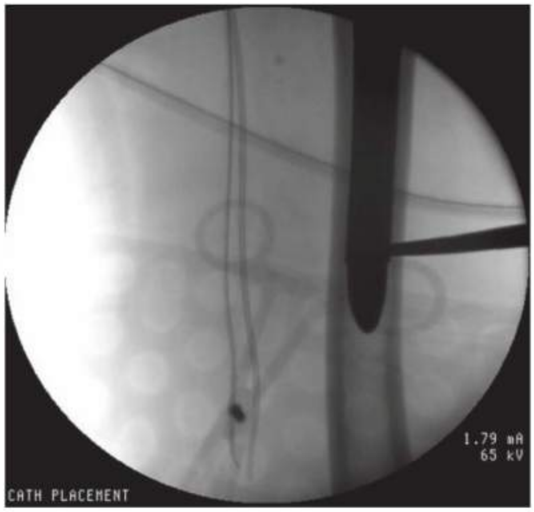

FIG 4 ● Radiograph of extremity with catheters in place below lower edge of pneumatic tourniquet. Note, wire in arterial catheter will be removed prior to infusion.

INFUSION CIRCUIT

- The catheters are connected to sterile ¼″ pump tubing with high-flow stopcock connectors and a 20-mL syringe as a hand pump or thru a single roller pump (**FIGS 5** and **6**).
- The circuit then passes through a heat exchange unit or heated water bath set to heat the fluid to 41°C followed by a bubble excluder before connecting to the arterial catheter. The circuit is primed with saline.
- Inflate the tourniquet to 250 to 300 mmHg.
- Adequate flow is obtained by hand pumping the syringe and using the three-way stopcock to pull from the venous catheter and infuse toward the arterial catheter. Alternatively, a roller pump can be used at rate approximately 100 mL per minute.

FIG 5 ● Photograph of roller pump workstation with temperature monitors, heat exchanger (water bath not depicted), ACT monitor, pressure gauge, and patient in background.

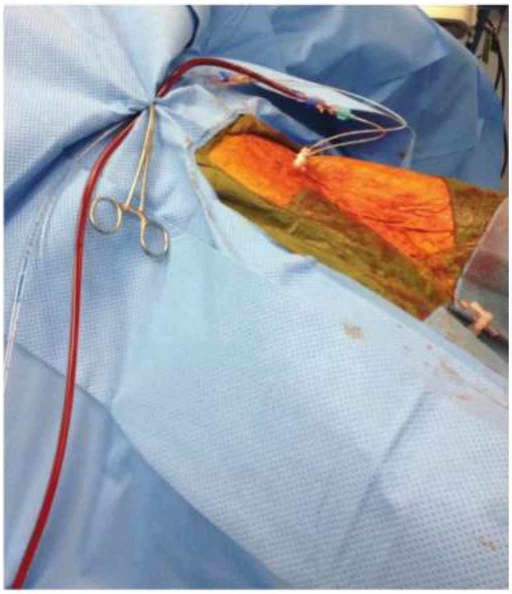

FIG 6 ● Contralateral groin with catheters in place connected to infusion circuit.

CHEMOTHERAPY INFUSION

- If the hand or foot is not to be perfused, an Esmarch bandage is tightly wrapped around the hand or foot to exclude the chemotherapy.
- Papaverine (60 mg for the lower extremity, 30 mg for the upper extremity) is infused into the circuit.
- The chemotherapy drug and dosage is double checked and then infused into circuit.
- Chemotherapy and blood are circulated for 30 minutes by hand pump syringe or roller pump method.
- Temperature, flow rate, pressure, and extremity are monitored. Blood gas and ACT are checked at 10- to 15-minute intervals.

CHEMOTHERAPY WASHOUT

- The venous tubing is disconnected from circuit and allowed to gravity drain blood into a waste container.
- One liter of lactated Ringer's solution (500 mL upper extremity) is infused into the arterial circuit.

CONCLUSION

- The tourniquet is released after notification to anesthesiologist of possible electrolyte and volume changes.
- The catheters are removed while leaving sheaths in place. Esmarch bandage, if used, is removed.
- Vascular exam of infused extremity is assessed and, if baseline, protamine is given to reverse the heparin.
- Once ACT is corrected, the sheaths are removed with pressure applied for hemostasis at the vascular puncture sites.

PEARLS AND PITFALLS

Drug dosing	■ If no ideal body weight correction, overall response rate may be increased; however, toxicity is also increased without clear improvement in complete response rate.
Poor venous return	■ Catheter may be up against valve, vein sidewall, or pulled back under tourniquet. ■ With heating, limb may vasodilate leading to relative intravascular volume loss. Infusing an extra 500-mL saline into limb through arterial circuit may help.
Proximal disease	■ An Esmarch bandage can be used as a tourniquet high on the limb to allow for greater volume of leg infused.

Limb temperature	■ Pumping heated blood through circuit prior to chemotherapy administration can heat up limb internally to greater than 37°C in 5 to 15 minutes.
Antiemetics	■ Steroids should not be used as antiemetics during or after anesthesia as they have an unknown effect on response rate.
Residual melanin pigmentation	■ Response may continue over several months. In-transit lesions may flatten but retain pigment. Biopsy may indicate melanin-laden macrophages without viable tumor.

POSTOPERATIVE CARE

- The patient is routinely extubated and admitted to an appropriate care unit capable of frequent neurovascular extremity monitoring for first 24 hours. Baseline serum creatinine phosphokinase (CPK), complete blood count (CBC), and chemistry panel are obtained.
- The extremity should be elevated when in bed, but the patient is allowed to get out of bed after 24 hours if extremity toxicity is not evident.
- Twice-daily physician examination should be performed, checking for vascular access complications, vascular and neurologic exam, and for compartment syndrome. Daily CPK is obtained, as muscle injury will routinely occur to some extent.
- CPK levels are expected to rise, peaking on postoperative days 4 and 5. Once levels begin to decrease and the extremity is stable, then the patient may be discharged. If the patient is reliable and has immediate health care access, it may be possible to discharge patient sooner with careful outpatient follow-up and instructions as the inpatient care after the first day is for toxicity monitoring.
- If the CPK levels rapidly rise sooner than day 4 and/or exceed 1,000 IU/L, then the patient is in danger of developing a compartment syndrome and potential limb loss. Steroids can ameliorate associated inflammation and decrease risk of requiring operative intervention. Dexamethasone can be given at 4 mg every 6 hours with rapid taper when the CPK drops below 1,000 IU/L.

FIG 7 ● **A.** Photograph of limb with in-transit disease. **B.** Photograph of same limb 4 weeks following isolated limb infusion.

OUTCOMES

- A complete clinical response is seen in 30% to 40% of patients after a single isolated limb infusion with another 30% to 50% of patients experiencing a partial response.[4–7] Complete responses are often durable, whereas partial responses are usually not (**FIGS 7A,B**). Response may take 2 to 6 weeks to be seen clinically. Limb salvage is obtained in the vast majority of patients, whereas 5-year overall survival is approximately 30% due to distant disease progression. Nearly all patients will develop some side effects from the procedure including skin erythema and lymphedema. Approximately half of patients will report return to baseline limb function by 3 months and the remainder by a year.
- Isolated limb infusion is better tolerated with less toxicity as compared to isolated limb perfusion, is technically easier to perform, and appears to have similar response rates.

COMPLICATIONS

- Potential complications related to vascular access include hematoma, pseudoaneurysm, dissection, and embolization. Stroke can be a complication of upper extremity arterial access.
- Toxicity from the isolated limb infusion of chemotherapy into the extremity skin and soft tissue are classified by the Wieberdink grading scale (Table 1).[8] Grade V or limb loss occurs in less than 1% of cases.
- Systemic toxicity from the chemotherapy should be rare but might include nausea and bone marrow suppression.

Table 1: Wieberdink Extremity Toxicity Scale

Grade I	No reaction
Grade II	Slight erythema and/or edema
Grade III	Considerate erythema and/or edema with some blistering; slightly disturbed motility permissible
Grade IV	Extensive epidermolysis and/or obvious damage to the deep tissues, causing definite functional disturbances; threatening or manifest compartmental syndromes
Grade V	Reaction that may necessitate amputation

From Wieberdink J, Benckhuysen C, Braat RP, et al. Dosimetry in isolated perfusion of the limbs by assessment of perfused tissue volume and grading of toxic tissue reactions. Eur J Cancer Clin Oncol. *1982;18(10):905–910.*

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Chapter 34 Isolated Limb Perfusion

Omgo E. Nieweg   Oscar E. Imhof   Bin B.R. Kroon

DEFINITION

- Compared to other cancer types, melanoma has a particular biology in various respects. In-transit dissemination is typical of this disease and occurs in a few percentage of patients. In-transit metastases grow from tumor cells that are stuck in a lymph vessel in the skin or in the subcutaneous tissue. Such metastases are preferably excised but they tend to recur in larger numbers (**FIG 1**). Isolated perfusion can be considered when they are situated on a limb and their number is too great or they recur too frequently.
- Isolated limb perfusion (ILP) enables treatment of an arm or leg with a high dose of chemotherapy without exposing the remainder of the body to the drug(s). This is accomplished by isolating the limb from the body's circulation and creating a separate oxygenated blood circuit. This is in contrast to isolated limb infusion (ILI), a low-flow, nonoxygenated perfusion that is described in Part 5, Chapter 33. ILP and ILI are therapeutic options for patients with locally or regionally advanced melanoma that would otherwise require a more debilitating operation, for example, amputation.

PATIENT HISTORY AND PHYSICAL FINDINGS

- After treatment of their primary melanoma, patients are instructed to regularly examine the scar of the excision for local recurrence and to check the skin and subcutaneous tissue around this area up to the regional lymph node basin for visible or palpable satellite and in-transit metastases. The physician who follows the patient inquires about new regional lesions. Patients themselves detect about half of the recurrences, but at an early stage, they can look quite innocuous. The detection of the more subtle ones requires the expertise and suspicious mind of an experienced surgeon.
- A detailed history should be obtained to assess the general condition of the patient and to be informed about other relevant ailments, allergies, and medication.
- Physical examination of melanoma patients is aimed at detecting a local recurrence, satellite metastases, in-transit metastases, regional lymph node involvement, and a subsequent primary melanoma. A detailed examination of the skin, the regional subcutaneous tissue, and the regional node field is warranted.
- The vascular situation of the limb is assessed. The presence of peripheral arterial pulsations needs to be sufficient to allow for ILP.

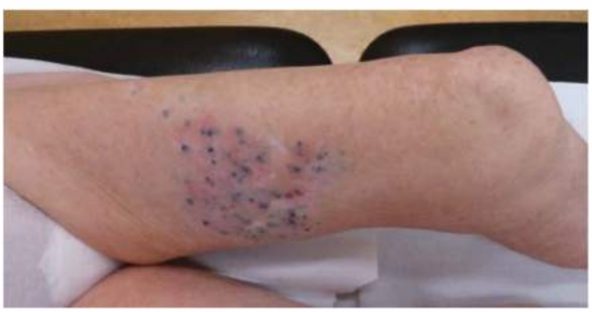

FIG 1 ● Extensive in-transit metastases on the left thigh.

IMAGING AND OTHER DIAGNOSTIC STUDIES

- The presence of advanced melanoma in the extremity should be confirmed by biopsy.
- In addition to the routine preoperative tests, screening for metastases elsewhere is appropriate as their presence may change the treatment plan. Whole body positron emission tomography (PET) or computed tomography (CT) and magnetic resonance imaging (MRI) of the brain are frequently recommended for this purpose.
- Arteriography is indicated if the arterial blood supply is questionable. A complete obstruction in the target artery or a major impediment downstream renders perfusion impossible. Extensive arterial calcification per se is not a contraindication.
- An elevated tumor marker such as the TA90 glycoprotein antigen or the S100 protein provides an opportunity to monitor the course of the disease.

SURGICAL MANAGEMENT

Rationale and Contraindications

- Extensive involvement limited to a certain region is typical for melanoma.
- The rationale for ILP is that melanoma is sensitive to cytotoxic drugs but effective treatment requires a higher dosage compared to various other cancer types. In contrast to the vital organs, the normal tissues in the extremities tolerate such a high dose. ILP with cytotoxic medication may improve regional tumor control while limiting the systemic side effects.
- The procedure makes it possible to vary physiologic conditions such as blood flow, temperature, and oxygenation.
- Prophylactic ILP is not indicated in patients with excised high-risk primary melanoma without evidence of regional metastases.[1]
- The contraindications are listed in Table 1. A major vascular obstruction may prevent access to the artery and precludes the operation.
- Diabetes mellitus with severe peripheral vascular disease is a contraindication.
- ILP should not be performed in children as it may damage the epiphyseal plates.
- Previous radiotherapy is a relative contraindication as perfusion may cause necrosis of prior irradiated skin.
- A large superficial tumor with major tendon involvement is a relative contraindication.

Table 1: Absolute and Relative Contraindications to Isolated Limb Perfusion

Absolute contraindications
Obstruction of major artery
Diabetes with serious peripheral vascular disease
Child with open epiphyseal plates
Relative contraindications
Previous radiotherapy
Large superficial tumor with major tendon involvement
Brain metastases
Infected wound or ulcer

- Brain metastases tend to bleed and their presence is a relative contraindication.
- An infected wound or ulcer is another relative contraindication.
- ILP can be carried out safely at an advanced age.[2] The presence of regional node involvement is not a contraindication, as this procedure can be combined with a regional node dissection. In the presence of distant metastases, systemic therapy is a reasonable first option, but perfusion can provide good regional palliation in the presence of refractory bloodborne metastases.

Anatomy

- For advanced disease of the leg, ILP can be performed at the femoral or iliac level. The arm can be treated at the brachial level or through the axilla.

Preoperative Planning

- ILP requires cooperation of the surgeon, the perfusionist, and the nuclear medicine worker in addition to the customary operating room team.
- Melphalan is the standard drug used in current practice. The dosage of the drug is adjusted to the need of the individual patient. The volume of the extremity is an often used parameter to calculate the required melphalan dose. The volume can be determined using a water reservoir (FIG 2). Adjustments to the dosage can be made based on risk factors for regional toxicity like female gender and obesity.

FIG 2 ● Water reservoir for measuring the volume of a limb. On the right is the elevator to bring the patient up to the required height. The elevator handle is on the left.

- ILP requires sophisticated technology. The surgeon should verify the availability of the required drug(s) and make sure that the necessary equipment and materials are present and in good working order.
- General anesthesia is required. Epidural anesthesia is to be avoided as it induces vasodilation and predisposes to leakage of blood from the systemic circulation to the perfusion circuit.
- Preoperative antibiotics are not necessary.

TECHNIQUES

ISOLATED FEMORAL PERFUSION

Positioning

- The patient is placed on the operating table in a supine position. The leg may be slightly exorotated.
- The leg is prepped and draped in a sterile fashion in its entirety.
- A pneumatic tourniquet is positioned around the upper thigh, but it is not inflated yet.
- A heating blanket is wrapped around the knee and the lower leg.
- A cotton doughnut is positioned underneath the heel to prevent decubitus.
- The operating table is tilted toward the surgeon.

Incision

- A longitudinal incision of approximately 10 cm is made starting just below the pneumatic tourniquet (FIG 3). The incision runs over the sartorius muscle. The skin and the subcutaneous tissue are divided and, subsequently, the fascia. Adson retractors are placed (FIG 4).

Access to the Superficial Femoral Vessels and Cannulation

- The external femoral vessels run behind the sartorius muscle. The vessels are reached either medially or laterally from the muscle. The thin fascia covering the vessels (FIG 5) is incised, exposing the superficial femoral artery. The artery is mobilized over the exposed length (FIG 6). Small arteries branching from the superficial femoral artery are ligated and divided. A vessel loop facilitates the dissection. The accompanying vein is identified when the artery is pulled aside (FIG 7). The vein is mobilized over the exposed length. Attributing branches are ligated at the confluence and divided.
  - Heparin is administered in a quantity of 150 units/kg body weight.

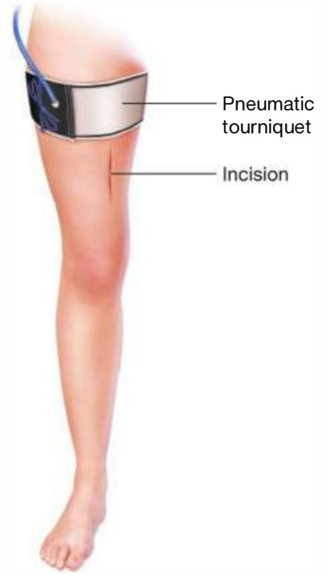

FIG 3 ● The incision is made over the inner thigh just below the pneumatic tourniquet.

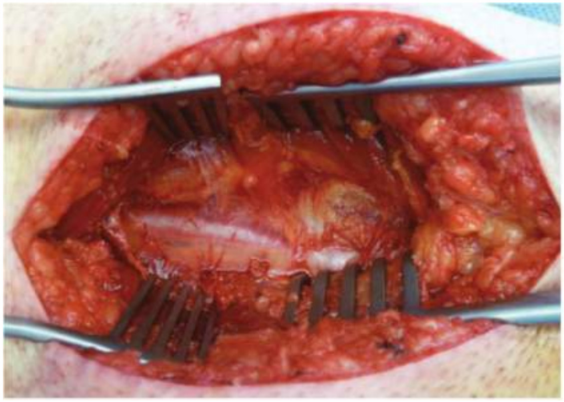

FIG 5 ● The superficial femoral artery can be seen through the thin fascia that covers the vessels.

- Open access to the saphenous vein at the level of the ankle is gained to measure the venous pressure. The venous pressure is monitored throughout the procedure and should not deviate more than 10 mm H_2O from the initial assessment. An increase is associated with postoperative morbidity.
- The appropriate diameter of arterial and venous cannulae for the perfusion is determined. The cannulae are tunneled subcutaneously underneath the tourniquet to the open wound to prevent kinking.
- The vein is clamped cranially and caudally. A transverse venotomy of a few millimeters is performed.

FIG 6 ● The superficial femoral artery is mobilized.

FIG 4 ● The long adductor muscle **(above)** and the sartorius muscle **(below)** are exposed. The superficial femoral vessels lie behind the sartorius muscle.

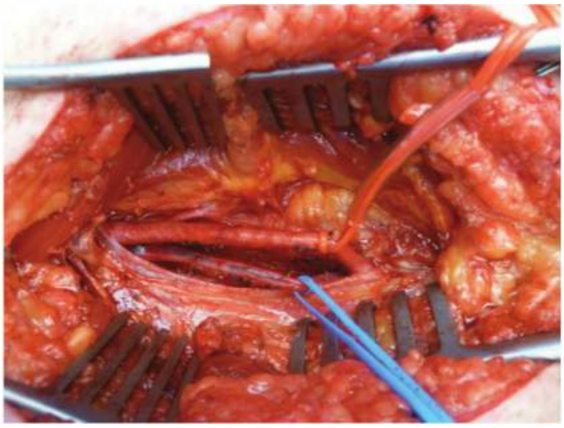

FIG 7 ● The superficial femoral artery is pulled aside (red vessel loop) and the accompanying vein is identified and dissected (blue vessel loop).

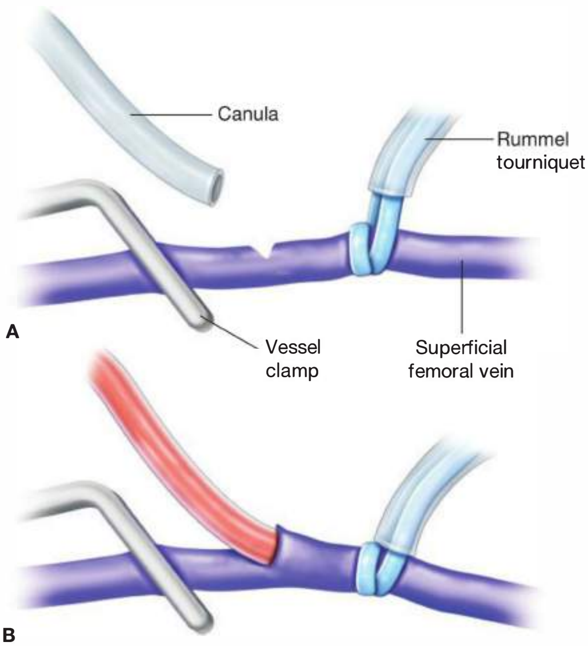

FIG 8 ● **A,B.** Insertion of cannula in superficial femoral vein.

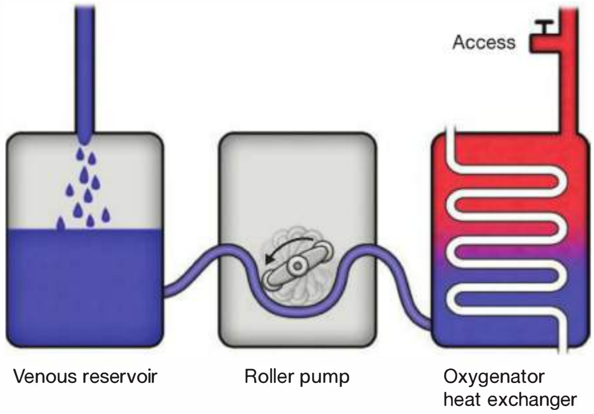

FIG 10 ● The perfusion device contains a venous inflow reservoir, a roller pump, an oxygenator annex heat exchanger, and access to the circuit for tapping blood and administration of drugs.

The cannula is inserted caudally and secured with the vessel loop (**FIG 8A,B**). The cannula is hooked up to the extracorporeal circuit and 300 mL of blood is tapped for the perfusion circuit. Subsequently, the arteriotomy is performed in a similar fashion and the arterial cannula is introduced and secured, and the circuit is completed (**FIG 9**).

Establishing the Perfusion

- The perfusion device consists of a reservoir to collect the venous blood, an oxygenator, a heat exchanger and a roller pump (**FIG 10**). In addition to the patient's own blood, the perfusion fluid consists of 100 mL of a crystalloid solution (lactated Ringer's solution), 200 mL 6% hydroxyethyl starch solution (HES) and 2,500 units of heparin. The hematocrit is approximately 30%. The flow should be generous, but it should not increase the venous pressure in the limb. The flow is typically 30 to 60 mL/L lower extremity volume/min. The venous blood is recollected by gravity.
- Thermistor probes are inserted in the subcutaneous tissue and a muscle compartment of the lower leg and the thigh. At this point, the leg is found to be around 34°C.
- The heating blanket is another tool to attain the desired temperature of 37°C.
- The tourniquet is inflated to a pressure of 350 mmHg, if necessary higher. This occludes the collateral vessels to and from the systemic circulation in the skin, the subcutaneous tissue and muscles. **FIG 11** shows the setup at this point.
- Escape of the drug(s) from the limb to the main circulation is to be avoided. Leakage can be monitored continuously by administering a small dose of a radiopharmaceutical such as technetium 99m-labeled serum human albumin to the perfusion circuit.[3] An even smaller background dose is administered intravenously into the systemic circulation. A gamma-ray detector is placed over the heart (**FIG 12**). The percentage of leakage can be calculated when the number of counts increases after correction for the physical half-life of the radionuclide (**FIG 13**).
- Substantial leakage either way can also be detected by assessing the fluid level in the venous return reservoir.
- The drug is administered when the flow and venous pressure are stable, when the tissue temperatures are around 37°C, and there is no leakage. Melphalan has always been the drug of choice. The dosage is 10 mg/L of perfused volume with adjustments based on risk factors for morbidity. The dose should not exceed 150 mg.
- The limb is exposed to the melphalan for 1 hour.
- The temperature in the various tissues is kept between 37°C and 38°C.

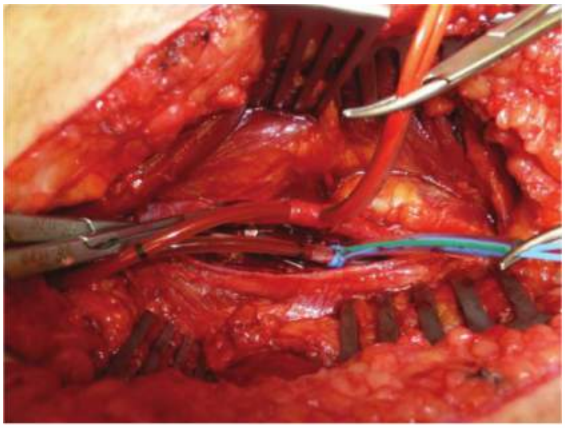

FIG 9 ● The cannulae in the superficial femoral artery and vein are secured with vessel loops tightened through Rummel tourniquets.

FIG 11 ● From top to bottom, note the cotton doughnut under the heel to prevent decubitus, the thermistors with the white cords to monitor the tissue temperatures, the blue warming blanket that is folded open for the picture, the open wound that would normally be covered with a wet gauze to prevent the vessels from drying out, the pneumatic tourniquet around the root of the thigh, and the arterial **(left)** and venous cannulae tunneled subcutaneously underneath the tourniquet.

- Tumor necrosis factor-α induces apoptosis of tumor endothelial cells and is beneficial in patients with bulky tumor nodules.[4] It causes thrombosis and increased melphalan penetration. A dose of 3 mg is given 30 minutes preceding the melphalan administration. When tumor necrosis factor is used, the temperature of the leg is increased from 37°C to 39°C to 40°C in the last half hour. At this time, most of the melphalan has been accumulated in the tissues, which limits potential heat-induced toxicity.
- Parameters to monitor are flow, venous and arterial blood gas values, venous and arterial pressure in the perfusion circuit, leakage to or from the systemic circulation, and venous pressure and tissue temperature in the limb.
- There is considerable variation in the perfusion technique between institutions. Some surgeons use body weight (0.5 to 1.5 mg/kg) or another parameter to calculate the melphalan dose instead of the volume of the leg. Some surgeons use other drugs than the ones described here, such as dactinomycin or cisplatin. Tumor necrosis factor is not registered throughout the world. If available, the dosage used ranges between 0.5 and 4 mg. Despite its obvious advantages, few surgeons use autologous blood for the perfusion circuit. Temperatures up to 43°C have been used for the leg, but these higher temperatures tend to severely increase the postoperative morbidity. The venous pressure is not always measured to guide the flow. The duration of the perfusion in different institutions ranges from 45 to 90 minutes. Judging by the published response rates, one technique is not necessarily better than another.

FIG 12 ● Mobile gamma-ray detector with screen to assess leakage.

Terminating the Perfusion

- After the leg has been exposed to the drug for the intended duration, the perfusate is washed from the leg using a colloid or a similar fluid followed by a lactated Ringer's solution. Massaging the leg helps to clear the less well-perfused tissues. The leg will be seen to turn pale.
- Meanwhile, the temperature probes and the venous pressure cannula are removed. The saphenous vein is ligated.

FIG 13 ● The *green* curve reflects the leakage. Note steep increase when background radiopharmaceutical is administered to the systemic circulation and subsequent two bumps up when the main dose initially passes through the perfusion circuit. The curve is flat thereafter, indicating adequate isolation during the perfusion.

- The flushing is terminated when the fluid that comes back from the leg is clear. The tourniquet is deflated and taken off. The cannulae are removed from the superficial femoral artery and vein and the distal vessel clamps are reapplied.
- The vein is closed with a running Prolene 6-0 suture (**FIG 14**) and the clamps are removed. The artery is closed with horizontal mattress sutures using double-armed Prolene 6-0 (**FIG 15**).

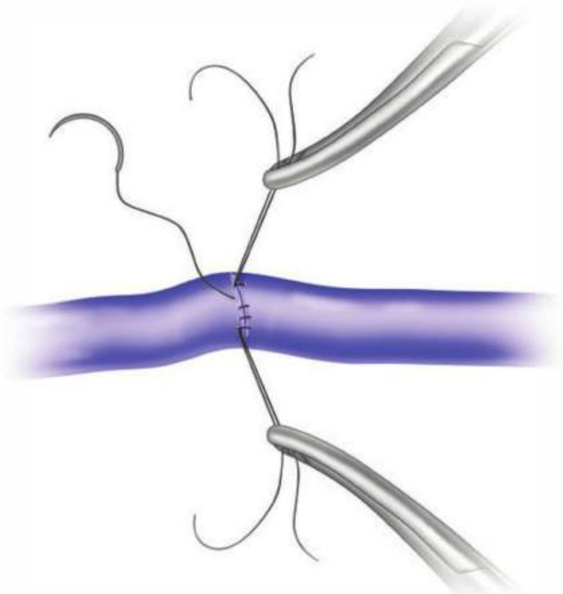

FIG 14 ● The vein is closed with a running Prolene 6-0 suture.

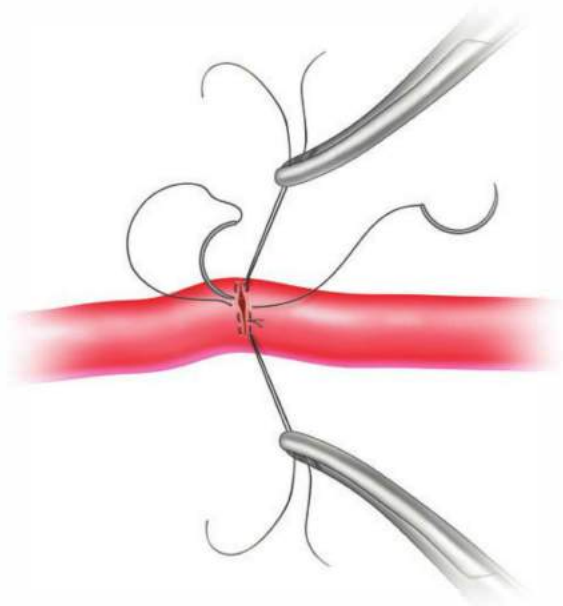

FIG 15 ● The artery is closed with double-armed Prolene 6-0. Horizontal mattress sutures evert the edges of the arterial wound in order to appose the endothelium layers.

- The clamps from the artery are removed and the leg assumes a pinkish hue. The nuclear medicine worker will now see an upward turn in his curve and the leakage, which typically is 0% during the perfusion, ends up being 2% or 3%.
- A vacuum drain is inserted and the wound is closed in layers.
- Protamine administration to counter the heparin is optional.

ISOLATED ILIAC PERFUSION

Aspects Specific to Isolated Iliac Perfusion

- Isolated perfusion at the external iliac level is performed if the disease involves the upper thigh. Specific points inherent to this procedure that are different from femoral perfusion are described here.
- The approach to the external iliac vessels is extraperitoneal. The Bookwalter retractor provides an excellent exposure. An external iliac and obturator lymph node dissection is carried out first (see Part 5, Chapter 29, Inguinal Lymph Node Dissection). These nodes may contain metastasis, but even if this is not the case, their dissection is worthwhile because they can become involved later on and a retroperitoneal approach is challenging after perfusion. Also, an iliac and obturator node dissection results in little morbidity.
- Arterial branches and venous tributaries of the external iliac vessels are ligated and divided. The obturator artery and vein are ligated and also other vessels that connect to the thigh. The internal iliac vessels may be clamped temporarily.
- The tips of the cannulae are positioned in the common femoral vessels.
- Because the diameter of the iliac vein is generous, a longitudinal venotomy can be performed without fear of stenosis after suturing.
- Occlusion of collateral vessels is obtained by wrapping an Esmarch rubber bandage around the thigh through the groin, anchored by a Steinmann pin in the iliac crest. The Steinmann pin is inserted before the heparin is administered.
- Prolene 5-0 is used for closing the vessels.

ISOLATED BRACHIAL PERFUSION

Aspects Specific to Isolated Brachial Perfusion

- Isolated perfusion at the brachial level is performed if the disease is limited to the forearm. Some specific points inherent to this procedure are described here.
- The patient is placed on the operating table in a supine position. The arm is placed in 90% abduction.
- A pneumatic tourniquet is wrapped around the proximal upper arm.
- An 8-cm longitudinal incision is made over the medial aspect of the upper arm, caudally from the tourniquet.
- Microvascular instruments are used.
- The cannulae are led through a subcutaneous tunnel underneath the tourniquet to avoid kinking.
- Both veins may be cannulated if the venous return from a single one is insufficient.
- The quantity of autologous blood needed to prime the extracorporeal circuit is 200 mL.
- Venous pressure measurement is performed using the cephalic vein at the wrist (FIG 16).
- The tourniquet is inflated to a pressure of 250 mmHg.
- The dosage of melphalan is 13 mg/L of perfused volume if the volume of the arm exceeds 3.5 L, with adjustments based on risk factors for morbidity. Otherwise, 10 mg/L of perfused volume is given. The dosage of tumor necrosis factor is 2 mg.
- Prolene 6-0 sutures are used for closing the vessels. Alternatively, the vein(s) may be ligated because there is sufficient collateral circulation.

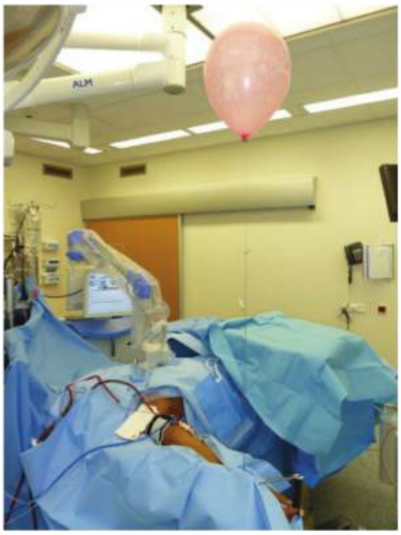

FIG 16 ● Helium-filled balloon keeping up the venous pressure line in a brachial perfusion.

ISOLATED AXILLARY PERFUSION

Aspects Specific to Isolated Axillary Perfusion

- Isolated perfusion at the level of the axilla is performed if the disease involves the upper arm. Some specific points inherent to this procedure and differing from the brachial perfusion are described here.
- The axilla is approached via an incision along the lateral margin of the major pectoral muscle. Axillary lymph node dissection is optional (see Part 5, Chapter 28, Axillary Lymph Node Dissection for Melanoma).
- The axillary vein is exposed and dissected. The axillary artery lies amidst the brachial plexus and is mobilized. Branches are ligated and divided.
- Occlusion of collateral vessels is obtained by wrapping an Esmarch rubber bandage around the upper arm through the axilla anchored by a Steinmann pin in the humeral head. A cotton pad underneath the bandage protects the brachial plexus from undue pressure.[5]

PEARLS AND PITFALLS

Volume measurement	■ If the limb is edematous, the volume of the contralateral limb—if normal—should be measured to guide the melphalan dosage.
Drug dosage	■ A sufficient dose for the desired effect is warranted but an excessive dose can be associated with limb-threatening morbidity. The surgeon threads a thin line and this implies a careful calculation of the drug dose and attention to the details of the procedure.
Prevention of systemic side effects	■ Extremely high doses of cytotoxic drugs are used and the toxicity in case of leakage of the drugs to the systemic circulation can be life threatening. Therefore, painstaking occlusion of collateral vessels and meticulous measuring of leakage are of the essence.
Insertion of the cannula in the femoral vein	■ Valves in the femoral vein may prevent accurate positioning of the venous cannula. A high arterial inflow and temporary clamping of the vein create a generous outflow, which opens the valves and facilitates advancing the cannula. Alternatives are abduction of the leg or cannula insertion over a Fogarty catheter.

Perfusion	■ The hand and foot are particularly sensitive to the side effects of melphalan. Their exposure to the drug can be limited by temporarily excluding them from the perfusion circuit. This can be accomplished by wrapping the hand or foot in a tight Esmarch rubber bandage for the first 30 minutes of the melphalan perfusion.
Major tendon involvement is a contraindication	■ A large superficial tumor mass with substantial tendon involvement intuitively appears as an appropriate indication for perfusion. However, a complete response will lead to necrotic tendons that may necessitate amputation.
Autologous blood	■ Most surgeons use allogeneic blood, but autologous blood obtained at the beginning of the procedure is cheaper and safer.
Elderly patients	■ In contrast to what is often suggested in the literature, advanced age is not a contraindication, as ILP is effective and quite safe in elderly patients.[2]
Palliation	■ In the presence of refractory blood-borne metastases, ILP can provide valuable palliation for patients with otherwise unmanageable limb disease that is bothersome because of pain, recurrent bleeding, or fungating infection.

POSTOPERATIVE CARE

- Overnight monitoring of the distal arterial pulsations is obligatory as arterial occlusion at the level of the sutured arteriotomy is a complication that is threatening in the first few hours.
- Postoperatively, the leg is kept elevated on a Braun frame to limit development of edema. The vacuum drain is removed the next day. Patients experience surprisingly little pain. Muscle-setting exercises are performed, but bed rest is maintained until the inflammatory signs subside.
- Creatine phosphokinase is checked daily. An increase in the first few days is normal but an excessive level may indicate muscle necrosis due to a compartment syndrome.
- An anticoagulant is given for the duration of 3 months.
- Responding dermal in-transit metastases may be seen to wrinkle, shrink, and develop a crust. Subcutaneous metastases typically soften and show fluctuation on physical examination.
- The patient is mobilized when the inflammatory signs subside. The patient is discharged when fully mobilized, usually after 7 to 10 days.

OUTCOMES

- There appears to be no relationship between limb toxicity and tumor response to the treatment.[6]
- A response may become evident as early as on the operating table but may also take up to 9 months. Remaining lesions can be excised later in case of a partial response. ILP results in a complete response in 54% of the patients.[7] The complete response is durable in half of them. In an additional 30% of patients, a partial response is obtained. The complete response rate when tumor necrosis factor is used is around 70%,[8] but the end result is not better than with melphalan alone. Ten-year survival in patients with a complete response is 49%.[9]
- Long-term survivors have a better quality of life than comparable control individuals.[10]
- The Wieberdink classification is used to quantify the limb morbidity (Table 2).[11]
- Acute regional toxicity determines long-term morbidity. One year after treatment, 44% of the patients show some degree of morbidity: recurrent infections, 3%; neuropathy, 4%; pain, 8%; muscle atrophy or fibrosis, 11%; limb malfunction, 15%; or lymphedema, 28%.[12] The lymphedema can be attributed to concomitant lymph node dissection.
- Postoperative toxicity necessitates amputation in 0.9% of the patients.[13] Amputation for intractable recurrence is required in 2.4% of the patients.[14]

COMPLICATIONS

- Perioperative mortality is less than 1%.[13,15]
- If tumor necrosis factor is used, some of the drug inevitably remains in the body and may cause a slight fever immediately after the operation.
- Serious postoperative complications associated with ILP are rare but they demand urgent intervention. Arterial thrombosis looms in the first few hours and requires thrombectomy. A venous patch is often necessary to ensure a sufficient flow.
- Excessive swelling of the muscles in the limb compresses the vessels, which may decrease the blood supply and lead to a compartmental syndrome. Excruciating pain suggests this diagnosis and it can be confirmed by measuring the intracompartmental pressure. Timely fasciotomy of the involved muscle compartments prevents permanent damage.
- In the first few days, an inflammatory response typically develops and the leg becomes red, warm, and slightly edematous.
- Over a period of 2 to 3 weeks, the edema and redness subside and give way to a tan discoloration that gradually disappears over the course of several months.

Table 2: Wieberdink Classification of Postoperative Limb Morbidity

1	No skin reaction
2	Redness, edema
3	Blisters
4	Superficial necrosis, damage to deep tissues causing functional disturbance, threatening or manifest compartmental syndrome
5	Necrosis requiring amputation

Wieberdink J, Benckhuysen C, Braat RP, et al. Dosimetry in isolation perfusion of the limbs by assessment of perfused tissue volume and grading of toxic tissue reactions. Eur J Cancer Clin Oncol. *1982;18:905–910.*

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Chapter 35

Thyroid Lobectomy

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DEFINITION

- Total thyroid lobectomy is defined as the surgical removal of an entire thyroid lobe and isthmus. It can be used as a diagnostic or a therapeutic procedure.
- Thyroid disease requiring a lobectomy is most often due to the presence of a thyroid nodule. Palpable thyroid nodules are common and occur in 4% to 7% of the general population with an increased incidence with advanced age.[1]
- The most common indications for a thyroid lobectomy are the following:
  - A thyroid nodule with diagnostic uncertainty
  - A symptomatic thyroid nodule (e.g., compressive unilateral goiter or autonomous toxic nodule)

DIFFERENTIAL DIAGNOSIS

- Benign thyroid nodule
- Toxic adenoma
- Thyroid cancer
- Intrathyroidal parathyroid adenoma
- Lymph node

PATIENT HISTORY AND PHYSICAL FINDINGS

- Although thyroid nodules are common, the vast majority of them are benign. A thorough patient history can assist the clinician in determining which thyroid nodules may require surgical management. Previous radiation to the neck, a rapidly growing mass, hoarseness, associated lymphadenopathy, or a family history of cancer may raise the suspicion of malignancy. Dysphagia, choking, or intolerance to things around the neck may suggest local compressive symptoms from a large thyroid nodule.
- The physical exam should focus on characteristics of the thyroid such as size, firmness, and the presence of nodules. The neck should be palpated for associated lymphadenopathy.

IMAGING AND OTHER DIAGNOSTIC STUDIES

- **Thyroid function studies.** A thyroid-stimulating hormone (TSH) can assess the biochemical status of the patient's thyroid. A TSH should be obtained prior to any fine needle aspiration to ensure the patient is not hyperthyroid.
- **Ultrasonography.** Neck ultrasound is a user dependent but highly sensitive adjunct in the evaluation of the thyroid and cervical lymphadenopathy. It can also assist in fine needle aspiration of thyroid nodules. A high-frequency probe of 7.5 MHz to 10 MHz is required.
- **Biopsy.** Fine needle aspiration can help determine benign from potentially malignant nodules. It is often done using ultrasound guidance. The cytopathology results can be categorized according to the Bethesda system.[2] These categories are associated with varying risks of malignancy allowing for different proposals for clinical management (Table 1).[3]
- **Computed tomography (CT).** A preoperative neck or chest CT is usually not necessary except in specific situations:
  - Malignancy—A neck CT may suggest local invasion of the thyroid into surrounding structures such as the carotid artery, internal jugular vein, or trachea which could potentially modify the operative approach. A CT scan of the neck can also provide a detailed map of cervical lymphadenopathy. A chest CT can evaluate for metastatic disease.
  - Large goiters—A neck and chest CT scan can help determine the degree of tracheal obstruction or substernal extension of large goiters. Patients with clinical evidence of airway obstruction should have a CT to provide anatomic information to help manage a potentially difficult airway.
- **Laryngoscopy.** Flexible laryngoscopy should be performed on all patients with hoarseness or a previous history of neck surgery. This provides a current assessment and baseline evaluation of bilateral vocal cords prior to surgery.

SURGICAL MANAGEMENT

- Thyroid lobectomy is therapeutic for patients with a unilateral goiter or a solitary toxic nodule which is symptomatic.
- Thyroid lobectomy is diagnostic and can potentially be therapeutic for patients with indeterminate thyroid nodules such as those categorized as "follicular lesions of undetermined significance," "follicular neoplasms," or "suspicious for malignancy."
- Although thyroid malignancy often warrants surgical intervention, thyroid lobectomy is typically not the standard of care. Total thyroidectomy is recommended for most thyroid malignancies greater than a centimeter in size. A thyroid lobectomy may sometimes be appropriate for very small (less than a centimeter) well-differentiated thyroid cancers in select patients.
- In any thyroid lobectomy, the patient and surgeon should be prepared for the conversion to a total thyroidectomy if intraoperative findings dictate this need. If the patient was

Table 1: Thyroid Fine Needle Aspiration Classification Scheme and Clinical Management

Category	Risk of Malignancy	Suggested Management
Nondiagnostic		Repeat FNA under ultrasound
Benign	<1%	Monitor
Follicular lesion of undetermined significance (e.g., atypia)	5%–10%	Repeat FNA or thyroid lobectomy
Follicular neoplasm	20%–30%	Thyroid lobectomy
Suspicion for malignancy	50%–75%	Thyroid lobectomy or total thyroidectomy
Malignant	100%	Total thyroidectomy

FNA, fine needle aspiration.
From Cibas ES, Ali SZ. The Bethesda system for reporting thyroid cytopathology. Thyroid. *2009;19(11):1159–1165; Baloch ZW, Cibas ES, Clark DP, et al. The National Cancer Institute thyroid fine needle aspiration state of the science conference: a summation.* Cytojournal. *2008;5:6.*

not counseled of this possibility, the surgeon should complete the lobectomy and defer definitive management until appropriate consent from the patient.

Preoperative Planning

- Thyroid lobectomy is performed under a general anesthesia, but locoregional anesthetic with sedation may be adequate for lobectomy in select patients.
- Routine use of preoperative antibiotics is not common as wound infections after thyroid lobectomy are rare.[4]

Positioning

- The patient is placed in the supine position with the arms padded and tucked at the side (**FIG 1**). A roll can be placed under the shoulders to help extend the neck; however, extreme extension should be avoided as this can cause postoperative discomfort.

FIG 1 ● Patient positioning. The arms should be padded and can be tucked to the side with a sheet using a towel clip.

SKIN INCISION AND FLAP CREATION

- A low collar incision is placed symmetrically across the neck despite only removing a lobe. The incision is ideally located about two fingerbreadths above the sternal notch or 1 cm below the cricoid cartilage (**FIG 2**). This location provides good exposure to the entire thyroid gland and particularly the superior pole.
- Placing the incision in a skin crease can provide excellent cosmetic results. If no skin crease is appropriate, Langer's lines provide an adequate guide.

FIG 2 ● Incision anatomy. The sternal notch and cricoid cartilage are palpated to help determine the incision site.

GLAND EXPOSURE

- The incision is carried through the subcutaneous tissue and platysma. Subplatysmal flaps are created to enhance mobility from the incision (**FIG 3**). These flaps should extend to the thyroid cartilage superiorly and the suprasternal notch inferiorly. The assistant should retract the skin to help create the plane of dissection. The anterior jugular veins will remain down on the strap muscles if the correct plane is dissected.
- The midline raphe between the strap muscles is opened and dissection extends down to the level of the isthmus (**FIG 4**).
- The sternohyoid and, subsequently, the sternothyroid muscles are dissected off the thyroid and reflected laterally.
- The thyroid lobe is then retracted medially with a finger or hemostatic clamp. The space between the thyroid and the carotid sheath is opened bluntly until the prevertebral fascia is encountered (**FIG 5**). During this portion of

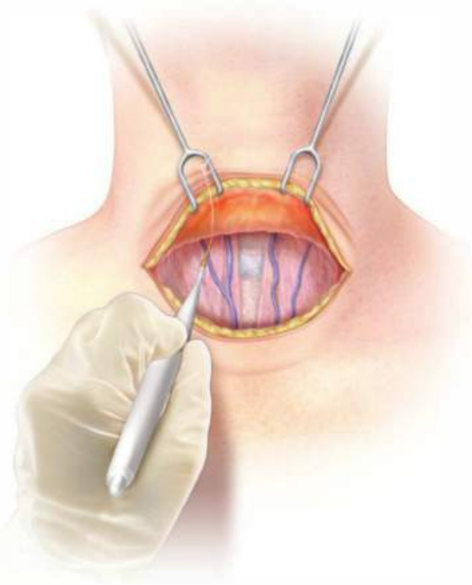

FIG 3 ● Creation of subplatysmal flaps. Adequate retraction helps creation of the subplatysmal flaps and prevents buttonholing the skin.

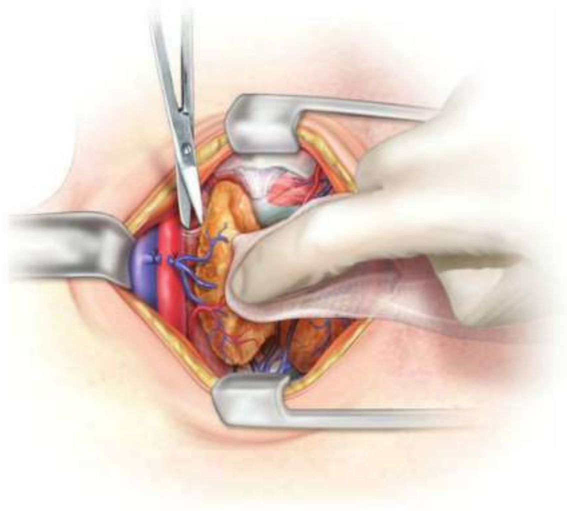

FIG 5 ● Exposure of the posterior thyroid. The thyroid is retracted toward the midline and the middle thyroid vein is divided. The areolar tissue behind the thyroid can be bluntly dissected with scissors.

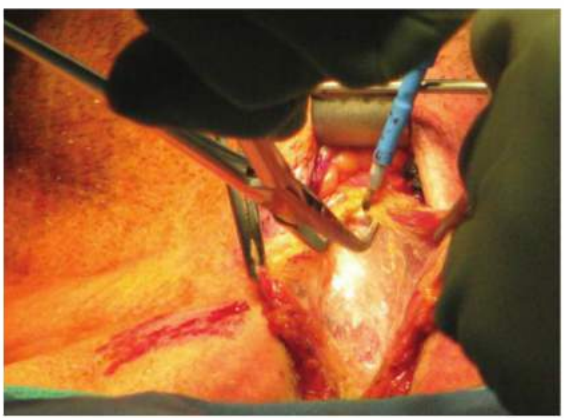

FIG 4 ● Exposure of the thyroid. The midline raphe between the strap muscles is avascular and provides access to the thyroid when opened.

the dissection, the middle thyroid vein should be controlled and ligated.

- Dissection of the isthmus can help mobilize the thyroid gland. The superior suspensory ligament and associated vessels at the superior border of the isthmus should be divided. A pyramidal lobe can be dissected and divided if present.
- The inferior vessels and attachments to the trachea along the inferior border of the isthmus should also be divided.
- The contralateral thyroid lobe can be palpated to ensure no abnormalities; however, formal dissection on the contralateral side should be avoided to prevent scar formation.

SUPERIOR POLE DISSECTION

- The cricothyroid space is an avascular space between the cricothyroid muscle and thyroid gland. This space can be bluntly opened all the way to the prevertebral fascia. Retraction of the superior pole of the thyroid in the inferior and lateral directions can facilitate this dissection (**FIG 6**).
- The external branch of the superior laryngeal nerve may be identified during this dissection and should be preserved. The nerve is vulnerable to injury as it crosses the vessels close to the superior pole of the thyroid prior to its insertion into the muscle. The anatomic variations of the nerve in relation to the superior thyroid vessels are best described by Cernea et al.[5] (**FIG 7**).
- The superior pole vessels are divided at the level of the thyroid capsule to prevent injury of the nerve (**FIG 6**). This dissection should proceed from medial to lateral.
- A superior parathyroid gland may be identified in this area and should be dissected off the gland.

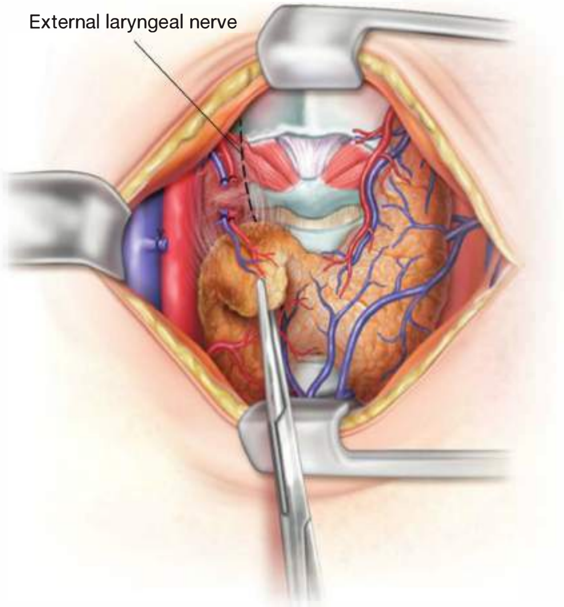

FIG 6 ● Exposure of the superior pole. The cricothyroid space is opened up bluntly. Retraction of the superior pole in a lateral and inferior direction helps to minimize the risk of injury to the external branch of the superior laryngeal nerve *(dotted line)*.

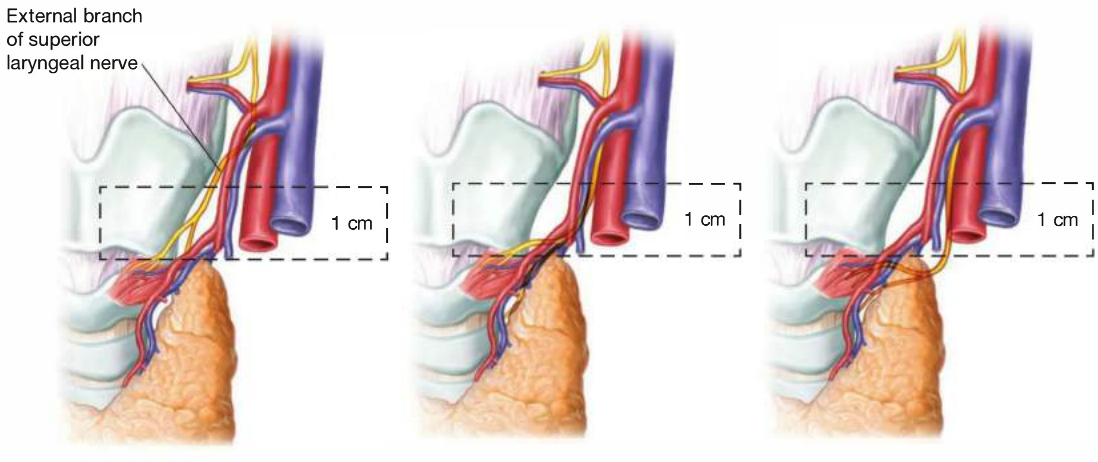

FIG 7 ● Anatomic variations of the external branch of the superior laryngeal nerve. The nerve crosses the vessels greater than a centimeter from the superior pole in type 1 anatomy. Type 2 anatomy places the nerve at higher risk of injury during dissection because it crossed less than a centimeter from the superior pole (type 2a) or even below it (type 2b). (From Cernea CR, Ferraz AR, Nishio S, et al. Surgical anatomy of the external branch of the superior laryngeal nerve. *Head Neck*. 1992;14:380–383.)

LATERAL LOBE DISSECTION

- Once the superior pole is mobilized, the lateral and inferior aspect of the thyroid can be dissected. The thyroid lobe should be retracted medially or elevated out of the wound. An assistant should retract the carotid sheath laterally to open up the lateral space.
- The identification and preservation of the recurrent laryngeal nerve is critical to the dissection. The nerve should be identified early and can often be found where it passes inferior to the inferior thyroid artery. Once the nerve is found, the dissection proceeds along the course of the nerve up to its cricothyroid insertion. The nerve is most vulnerable in this area.

- The tertiary vessels of the inferior thyroid artery are divided at the level of the thyroid capsule (**FIG 8**). This capsular dissection helps decrease the risk of nerve injury and devascularization of the parathyroid glands.
- The attachments of the thyroid to the trachea are freed by dividing the ligament of Berry.

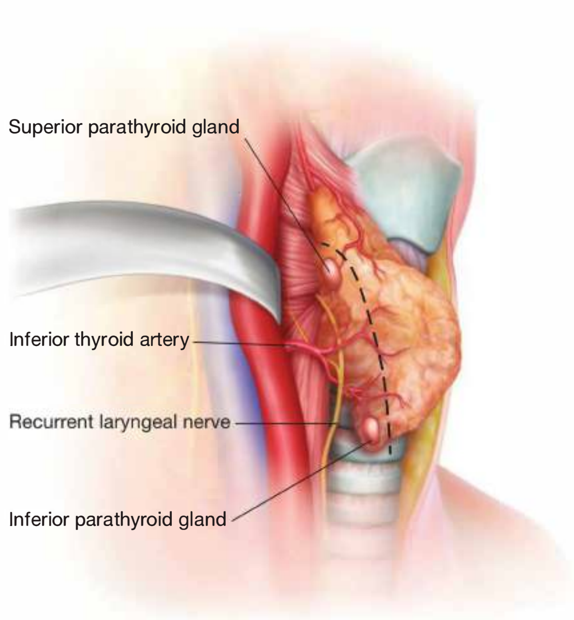

FIG 8 ● Division of the inferior thyroid artery. The tertiary branches of the inferior thyroid artery are ligated at the thyroid capsule to prevent injury to the recurrent laryngeal nerve and the blood supply to the parathyroid glands. The *dotted line* denotes the area of dissection.

PARATHYROID PRESERVATION

- The inferior and superior parathyroid glands should be identified and preserved. This is accomplished by careful dissection and reflection of them in a posterolateral direction away from the thyroid. The main trunk of the inferior thyroid artery should not be ligated as it typically provides the blood supply to both parathyroid glands.

TRANSECTION OF THE THYROID

- A thyroid lobectomy requires transection of the thyroid at the junction of the isthmus and contralateral lobe. If this junction is small, a Harmonic scalpel can transect this area while providing good hemostasis. If the area is bulky or a Harmonic scalpel is not available, a clamp can be placed across the area of transection. A knife is then used to transect the thyroid and the specimen is removed (**FIG 9**). A running absorbable suture can be placed as a hemostatic stitch underneath the clamp.

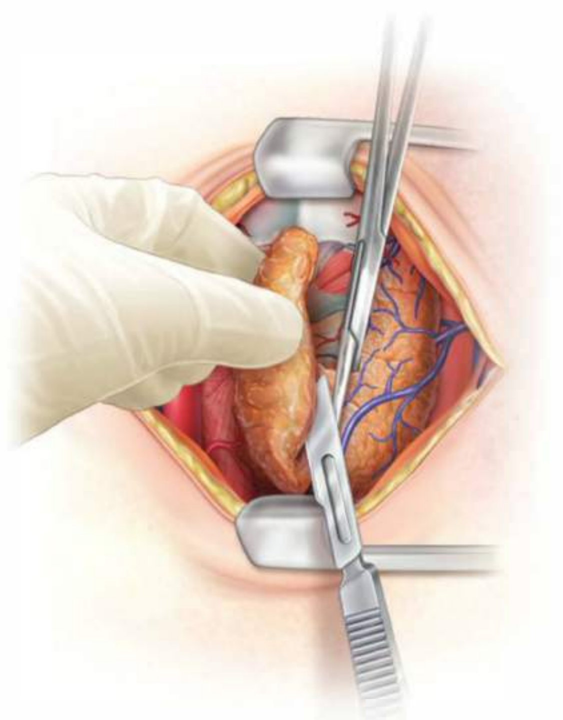

FIG 9 ● Transection of the thyroid. The junction between the isthmus and contralateral lobe is transected to remove the specimen.

CLOSURE

- Prior to closure, the surgical field is meticulously evaluated for hemostasis. Small occult bleeding can lead to clinically significant neck hematomas if not controlled.
- The parathyroid glands are evaluated once more for viability. Additionally, the lobectomy specimen should be examined for the inadvertent removal of a normal parathyroid gland. If either situation arises, the parathyroid gland should be minced up and implanted into the ipsilateral sternocleidomastoid.
- The recurrent laryngeal nerve is examined with visual inspection or nerve monitoring to ensure an intact circuit.
- After adequate hemostasis and inspection, the strap muscles are reapproximated with absorbable interrupted sutures (FIG 10). Placement of these sutures requires care to avoid injury to the anterior jugular veins.
- The platysma is reapproximated with buried interrupted sutures.
- The skin can be closed in a variety of ways. If the wound appears to be under tension during closure, removal of the shoulder roll can help. Our practice is to close the skin with a knotless running subcuticular Prolene stitch followed by the placement of skin glue. Once the glue dries, the Prolene is removed and Steri-Strips are placed as a dry dressing over the incision. Other alternatives to reapproximate the skin include the use of a running absorbable suture or the use of skin glue exclusively.

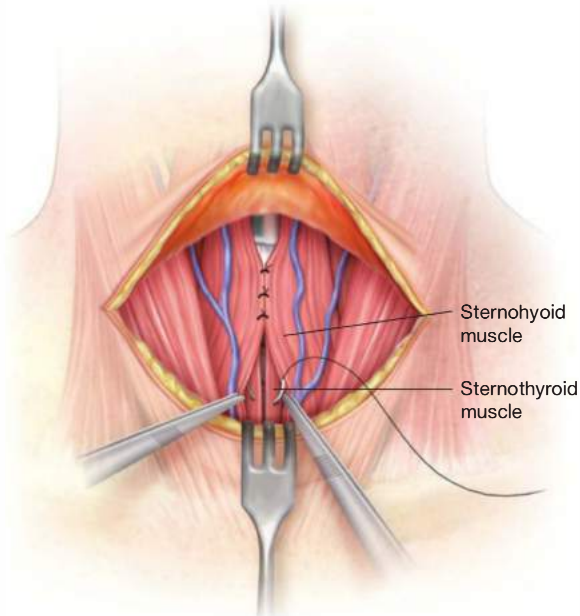

FIG 10 ● Closing the strap muscles. The strap muscles are reapproximated with interrupted sutures.

PEARLS AND PITFALLS

Incision aesthetics	■ A natural skin crease should be used if present. ■ An incision too cephalad is very noticeable with normal clothing. ■ An incision too caudal can increase the risk of keloid formation.
Parathyroid preservation	■ If a parathyroid gland cannot be preserved, it should be placed into cold saline for preservation. ■ A small portion of the parathyroid gland should be sent for frozen section to confirm normal parathyroid tissue. ■ The gland should then be minced into small pieces and implanted into the ipsilateral sternocleidomastoid. ■ A clip or permanent suture can mark the autograft sites.
Hemostasis	■ Hemostasis can be evaluated under Valsalva maneuver to look for occult bleeding. ■ Drains are rarely needed and are never a substitute for adequate hemostasis. ■ Electrocautery should be avoided in the area of the recurrent laryngeal nerve.
Large substernal goiter	■ Most substernal goiters located above the brachiocephalic vein can be removed through a cervical incision. ■ Dissection of the superior pole and early transection of the isthmus can provide added mobility needed to pull up a goiter from behind the sternum. ■ The patient should be counseled and the chest prepped in case a mini-sternotomy is needed.

POSTOPERATIVE CARE

- The patient should be monitored in the postoperative area for a few hours to ensure no significant hematoma develops.
- An ice pack may be placed over the neck to assist with pain and swelling. Once the patient is sufficiently awake, the diet may be advanced as tolerated.
- After a period of monitoring, most patients may be safely discharged home after a thyroid lobectomy. Patients should expect to resume their normal activities within a few days of surgery.
- Most patients will not require thyroid hormone replacement after a lobectomy if the remaining lobe is normal. Thyroid hormone levels should be checked about 2 months after surgery to ensure the other lobe is adequately functioning.

COMPLICATIONS

- Hematoma
- Hypocalcemia
- Hoarseness
- Vocal cord paralysis
- Wound infection

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Chapter 36 Total Thyroidectomy

Saïd C. Azoury Martha A. Zeiger

DEFINITION

- Total thyroidectomy involves removal of all thyroid tissue, including both lobes and isthmus, while preserving the parathyroid glands, the recurrent laryngeal nerve (RLN), and the external branch of the superior laryngeal nerve.

ANATOMY

- The thyroid gland typically weighs 20 g and has a right and left lobe bridged by a narrow isthmus.
- The thyroid gland is located in the central compartment of the anterior neck below the thyroid cartilage.
- The thyroid cartilage forms the laryngeal prominence or the "Adam's apple."
- The thyroid lobes lie medial to the carotid sheaths and sternocleidomastoid muscles.
- The anterolateral surface of the gland is covered by the sternothyroid and sternohyoid muscles (**FIG 1**).
- The "thyroid sheath" is a connective tissue expansion of the pretracheal fascia and envelops the thyroid, condensing posteromedially into the ligament of Berry.
- The thyroid gland receives its blood supply from the superior and inferior thyroid arteries.
- The superior thyroid artery arises from the ipsilateral external carotid artery and the superior thyroid vein runs with the artery.
- The middle thyroid vein drains into the ipsilateral internal jugular. The inferior thyroid artery originates from the thyrocervical trunk. The left RLN arises from the vagus at the level of the aortic arch and loops around the ligamentum arteriosum; the right RLN loops around the right subclavian artery (**FIG 2**).

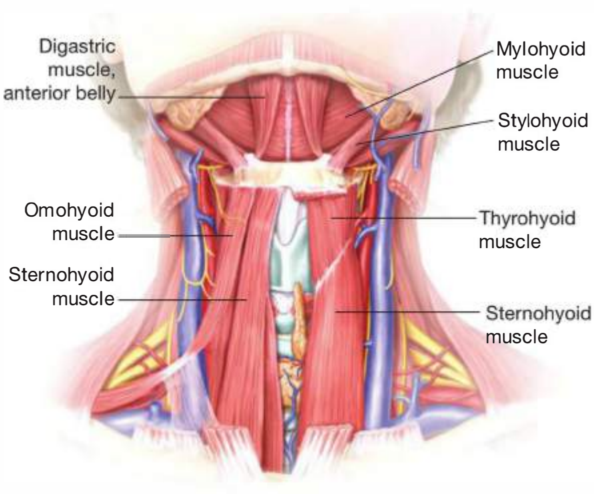

FIG 1 • Strap muscles of the neck.

- The right RLN may be nonrecurrent in 0.5% to 1% of individuals.
- The RLN innervates all the intrinsic muscles of the larynx except the cricothyroid muscles.
- The internal branch of the superior laryngeal nerve is the sensory nerve for the supraglottic larynx. The external branch of the superior laryngeal nerve lies on the inferior pharyngeal constrictor muscle and descends alongside the superior thyroid vessels before innervating the cricothyroid muscle.
- The superior parathyroid glands are generally located posterior to the superior thyroid lobe and the RLN. The inferior parathyroid locations are more variable but oftentimes are located anterior to the inferior thyroid lobes and RLN or on the inferolateral aspect of the lobes.

INDICATIONS FOR TOTAL THYROIDECTOMY

Graves' Disease[1–3]

Thyroid Cancer

- In general, total thyroidectomy is indicated for follicular or papillary thyroid cancer.[4–6] Patients may also need a concomitant central lymph node dissection.[4–6] Total thyroidectomy with central lymph node dissection is typically indicated for medullary thyroid cancer.[7]

Multinodular Goiter

- Total thyroidectomy is indicated for symptomatic multinodular goiter (MNG) or for patients who have suspicious or indeterminate thyroid nodules on fine needle aspiration biopsy (FNAB).[8–10]

PATIENT HISTORY AND PHYSICAL FINDINGS

History

- Thyroid cancer is more common in extremes of age, younger than 20 or older than 60 years.
- Most thyroid nodules are asymptomatic, and most patients are euthyroid.
- Thyroid nodules are more common in females, but there is a greater risk of malignancy in males.
- One must inquire about a history of radiation therapy and family history of thyroid cancer: Nearly 90% of radiation-associated thyroid cancers are papillary.
- Personal or family history of other endocrine disorders such as a history of thyroid cancer, primary hyperparathyroidism, pancreatic islet cell tumors, pituitary tumors, or adrenal tumors is essential to understand a patient's risk.
- Medullary thyroid cancer is a known component of multiple endocrine neoplasia 2 (MEN2).
- Weight gain, fatigue, depression, constipation, dry skin, and brittle nails are symptoms of hypothyroidism; weight loss, weakness, anxiety, palpitations, and diarrhea are symptoms of hyperthyroidism; both are key elements of the review of systems portion of a history.

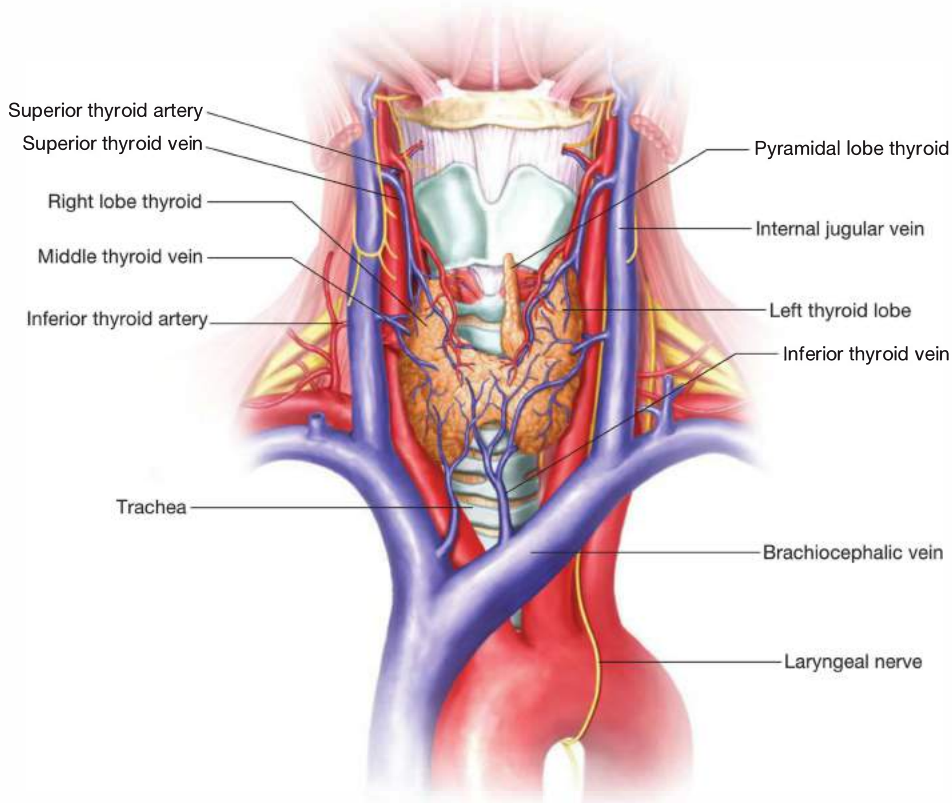

FIG 2 ● Anatomic location of thyroid gland and vascular anatomy.

- One should inquire about symptoms of dysphagia, dyspnea, voice change, cough, or trouble breathing.

Physical Exam

- Size of thyroid nodules, firmness of the nodules, and the presence of substernal extension are important to assess.
- Findings suggestive of cancer include nodule fixation, hard texture, and associated cervical lymphadenopathy.
- Important eye signs include stare, lid lag, dryness, diplopia, or exophthalmos (**FIG 3**); all of which can suggest Graves' disease.

FIG 3 ● Graves' ophthalmopathy: prominent stare.

- Extremities should be examined for pretibial myxedema (waxy, discolored induration, and swelling) that can be associated with severe hypothyroidism.

IMAGING AND OTHER DIAGNOSTIC STUDIES

Thyroid-Stimulating Hormone (Normally 0.5 to 5 μU/mL)

- A serum thyroid-stimulating hormone (TSH) should be measured to determine if the patient is hypo-, hyper-, or euthyroid. There is an inverse relationship between the free thyroxine (T4) level and the TSH concentration.

Free Thyroxine (Normally 12 to 28 pmol/L)

- Free T4 is a sensitive and accurate measurement of biologically active thyroid hormone.
- In early hyperthyroidism, total T4 levels are normal but free T4 levels are elevated.
- Hyperfunctioning nodules are much less likely to harbor malignancy.

Serum Thyroglobulin

- Thyroglobulin is primarily used to detect recurrent thyroid cancer.

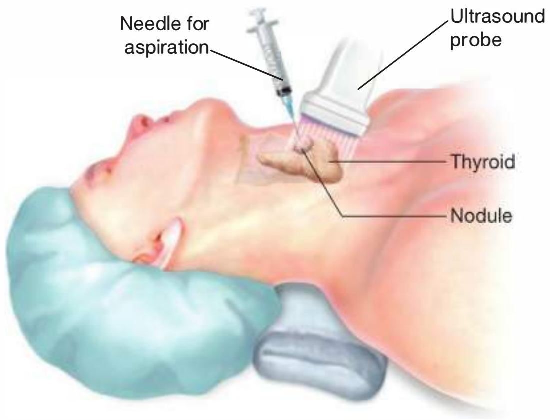

FIG 4 ● FNA of thyroid nodule.

Fine Needle Aspiration Biopsy

- Ultrasound-guided needle aspiration is performed using 23- to 27-gauge needles and a 10-mL syringe (FIG 4).
- FNAB specimens are classified as malignant, benign, indeterminate (atypical cells of undetermined significance, suspicious for follicular or Hürthle cell neoplasm, or suspicious for malignancy), or insufficient for diagnosis.
- Overall sensitivity of FNAB is 95% to 98%.[7]

Iodine Scintigraphy

- Elevated iodine uptake with diffuse uptake and enlargement is consistent with Graves' disease.
- The risk of malignancy in "hot" lesions is extremely low. Iodine scintigraphy should only be used if the patient is hyperthyroid and has nodular disease to determine if a nodule is responsible for the hyperthyroidism.

Antithyroglobulin and Antithyroid Peroxidase Antibodies

- Anti-thyroid peroxidase (anti-TPO) antibodies are associated with Hashimoto's thyroiditis. Antithyroglobulin (anti-Tg), if present, makes following patients with thyroid cancer for Tg elevation unreliable.

High-Resolution Ultrasonography

- Ultrasound is recommended to determine the number, size, and characteristics of the thyroid nodules.
- Increased intranodular vascularity, irregular margins, the so-called "halo sign" or anechoic rim, microcalcifications, and hypoechogenicity are generally associated with a malignancy.
- Cervical ultrasound to assess for lymphadenopathy is recommended for suspicious or malignant thyroid nodules.

Computed Tomography

- Computed tomography (CT) imaging is indicated for substernal goiters or if a cancer is large or appears fixed to surrounding anatomic structures.

NONOPERATIVE MANAGEMENT

Antithyroid Drugs: Propylthiouracil and Methimazole

- When used for Graves' Disease, generally, propylthiouracil (PTU) (100 to 300 mg three times daily) or methimazole (10 to 30 mg three times daily) are the antithyroid drugs of choice.
- Both drugs inhibit the organic binding of iodine and thyroperoxidase coupling of iodotyrosines. PTU also inhibits the peripheral conversion of T4 to triiodothyronine (T3).

Radioactive Iodine Therapy

- Radioiodine therapy has been the preferred treatment for most patients with Graves' disease.
- Radioiodine therapy is indicated postoperatively for patients with thyroid cancer who have a high risk of recurrence.

Close Follow-up

- Patients with asymptomatic and benign thyroid nodules should be followed with serial neck ultrasounds and repeat fine needle aspiration (FNA) as needed.
- Patients may need longitudinal neck ultrasounds and repeat FNA.

SURGICAL MANAGEMENT

- The use of total thyroidectomy for benign disease has increased over the last 15 years in the United States from 17.6% (1993–1997) to 39.6% (2003–2007) compared with 82.4% and 60.4% for partial thyroidectomy over the same periods.[11]
- Total thyroidectomy for Graves' is the gold standard advocated by endocrine surgeons.
- In one study of patients with Graves' disease, reasons for having thyroid surgery were persistent disease despite medical therapy (46.6%), patient preference (24.1%), MNG/cold nodules (20.3%), failed radioactive iodine (RAI) treatment (16%), and ophthalmopathy (12.1%).[12]
- In general, the indication for total thyroidectomy should be considered in cases of suspicious or definite malignant nodules; the presence of thyroid nodules; and a history of head and neck irradiation, Graves' disease, large or substernal goiter, or symptomatic goiter (dysphagia, pressure, dyspnea).
- The most important goals of surgery for MNG are to prevent recurrence after surgery and to definitively diagnose thyroid nodules that were indeterminate or suspicious preoperatively.
- The advantage of total thyroidectomy, compared to subtotal thyroidectomy, for treatment of Graves' is the avoidance of recurrent hyperthyroidism, which has been reported to be as high as 22% following subtotal thyroidectomy.[7,13,14]
- Advantages of total thyroidectomy over thyroid lobectomy for well-differentiated thyroid carcinoma (WDTC) include the fact that papillary thyroid cancer can be multifocal, facilitation of radioiodine imaging and ablation for residual metastatic disease, and the use of serum thyroglobulin for postoperative disease surveillance.
- Surgery is often recommended for patients with severe ophthalmopathy; this condition can be worsened by RAI.
- Surgery is appropriate in children and in pregnant women with Graves' disease.[15]
- Surgery is indicated for a substernal goiter because these are usually symptomatic and substernal nodules cannot be assessed by FNA.

Preoperative Planning

- Thyroid scintigraphy is only indicated in a subset of patients with hyperthyroidism.
- FNA under ultrasound guidance is the gold standard when there is a suspicion for thyroid cancer and should be performed if a nodule is found to be greater than 1 cm and/or if the nodule has suspicious ultrasound characteristics.[7] FNA provides quick and specific information that helps to guide definitive surgical management.
- High-resolution ultrasound of the neck can be used to evaluate for cervical lymphadenopathy.
- Laryngoscopy is often used before surgery whether for benign or malignant disease, especially for patients with voice changes, to determine the extent and any involvement of surrounding structures including the RLN.

Intraoperative Positioning of the Patient

- Patient is placed in supine position with arms tucked at the sides.
- A soft roll is placed lengthwise beneath the shoulders to extend the neck, and a soft foam "donut-shaped" rest is used to stabilize the head.
- Patient is further placed in a *semi-Fowler's position*, with the head of the bed at approximately 30 degrees (**FIG 5**).

FIG 5 ● Semi-Fowler's position.

FIG 6 ● RLN nerve monitoring wires anchored to the patient's shoulder, out of the way of the neck and the sterile operating field.

- The RLN nerve monitoring wires are anchored to the patient's shoulder, out of the way of the neck and the sterile operating field (**FIG 6**).

Approach

- During surgery, great care should be taken to identify the recurrent and superior laryngeal nerves, the parathyroid glands, and their vascular supply. Parathyroid glands can be distinguished from surrounding structures by their fine surface vascular pattern and brown hue.
- Intraoperative nerve monitoring with electrode attached to endotracheal tube allows for stimulation and detection of the RLN and superior laryngeal nerves.
- Due to the vascularity of the thyroid gland, many surgeons use LigaSure rather than bipolar cautery, ties, or clips.[16] The duration of the procedure with the use of the LigaSure is significantly shorter, and there are fewer complications compared to the classic "tie and knot" technique.[16]
- There is no statistical difference noted in the literature when comparing suture tying and Harmonic scalpel complications.[17,18]
- Clips can also be used for hemostasis on the specimen side.

TOTAL THYROIDECTOMY

- With the patient lying supine in a semi-Fowler's position with the arms tucked at the sides, the anterior surface of the neck is prepped and draped, exposing the anterior neck from the sternal notch to the chin and from both anterior borders of the sternocleidomastoid muscles (**FIG 7**).
- Transverse curvilinear collar incision is made approximately two fingerbreadths above the sternal notch, along a normal skin crease. The length of the incision varies depending on the patient's body habitus and the size of the thyroid gland (**FIG 8**).
- The subcutaneous tissue and platysma are divided, and skin flaps are raised in a subplatysmal plane from the sternal notch inferiorly to the level of the thyroid cartilage superiorly and the sternocleidomastoid muscles laterally. Skin hooks aid with the exposure and flap elevations (**FIG 9**).
- Strap muscles are separated in the midline from the thyroid cartilage to the sternal notch and are reflected laterally (**FIG 10**).

FIG 7 ● Patient prepped and draped, with thyroid cartilage and sternal notch anatomic landmarks marked out as well as the proposed incision.

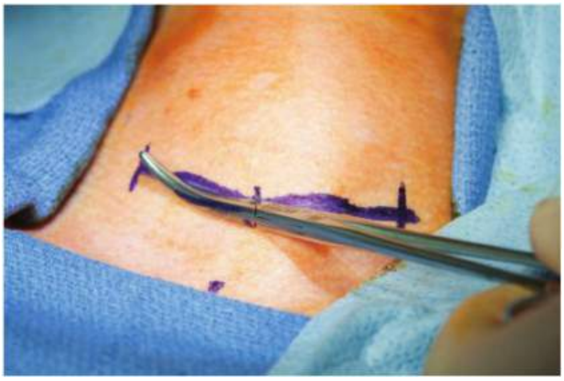

FIG 8 ● Incision marking.

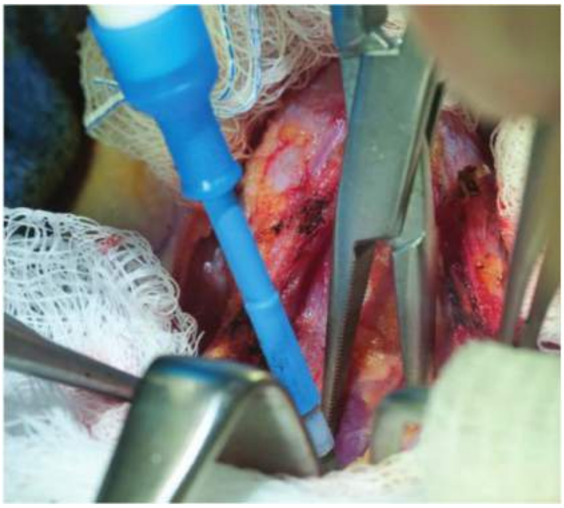

FIG 10 ● Strap muscles are separated in the midline from thyroid cartilage to the sternal notch using electrocautery.

- Horizontal division of the sternohyoid and sternothyroid muscles may be necessary to fully expose a large thyroid gland (**FIG 11**).
- If the pyramidal lobe is easily identified during this phase of the operation, it can be dissected free from its attachments and ligated to allow for greater mobility of the gland (**FIG 12**).
- Typically, the middle thyroid veins are the first vessels identified in the dissection and are ligated and divided (**FIG 13**).
- Superior pole vessels are then identified by exerting traction on the upper pole of the gland, oftentimes using a Babcock clamp to aid with the retraction. The superior thyroid vessels are individually ligated, and we typically use the LigaSure for this (**FIG 14**).

FIG 9 ● Skin hooks aiding with the exposure and flap elevations to allow for subplatysmal dissection.

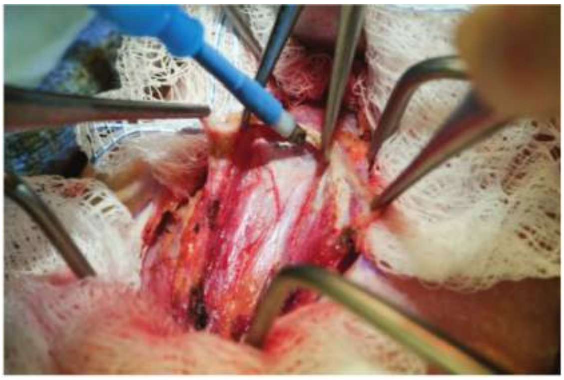

FIG 11 ● Division of sternothyroid muscles helps to fully expose the thyroid gland.

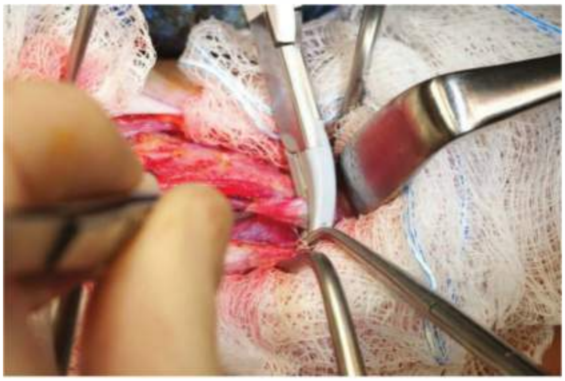

FIG 12 ● Dissection and mobilization of the pyramidal lobe and ligation of its attachments.

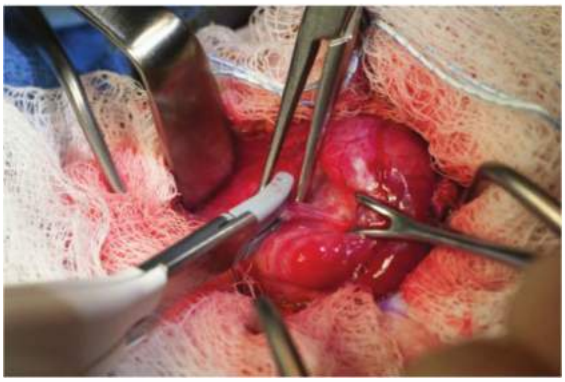

FIG 13 ● Ligation of the middle thyroid vein.

FIG 14 ● Superior pole vessels are identified and individually ligated.

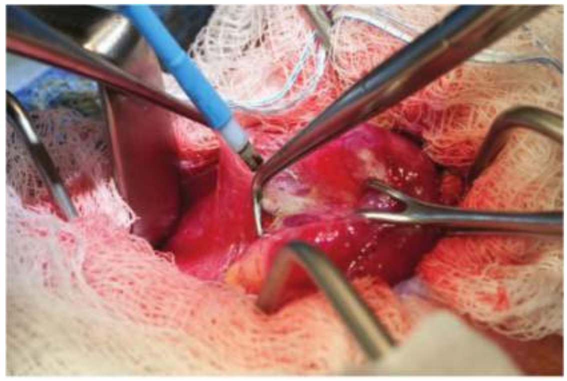

FIG 15 ● Subcapsular dissection is carried close to thyroid gland to avoid injury to the external branch of the superior laryngeal nerve.

- Subcapsular dissection is carried close to thyroid gland to avoid injury to the external branch of the superior laryngeal nerve (**FIG 15**).
- Areolar tissue between the common carotid artery and the thyroid lobe is dissected using a combination of blunt dissection, electrocautery, and LigaSure, helping to facilitate anteromedial thyroid lobe rotation (**FIG 16**).
- The inferior thyroid artery is identified, and its close proximity to the RLN then allows for easy identification of the nerve. The RLN is then traced through its entire course and preserved (**FIG 17**).
- Intraoperative nerve monitoring is often used to help confirm the location and integrity of the nerve (**FIG 18**).
- The inferior pole of the thyroid gland is mobilized once the RLN is identified, and this is done by ligating the branches of the arteries and veins close to the thyroid

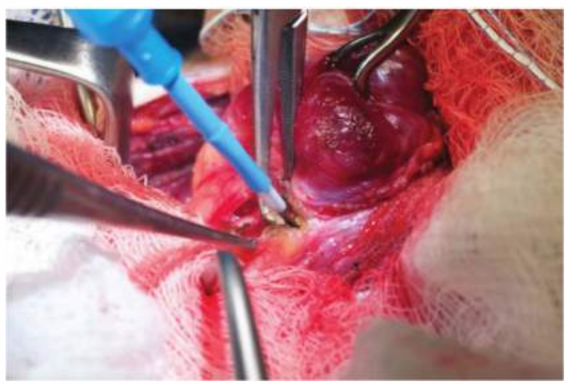

FIG 16 ● Areolar tissue between the common carotid artery and thyroid lobe is dissected with electrocautery.

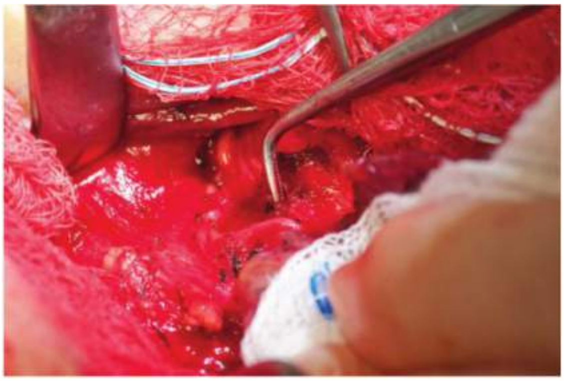

FIG 17 ● The thyroid gland is rotated anteromedially, and the recurrent laryngeal nerve is traced along its entire course. Note the RLN at the tip of the right angle.

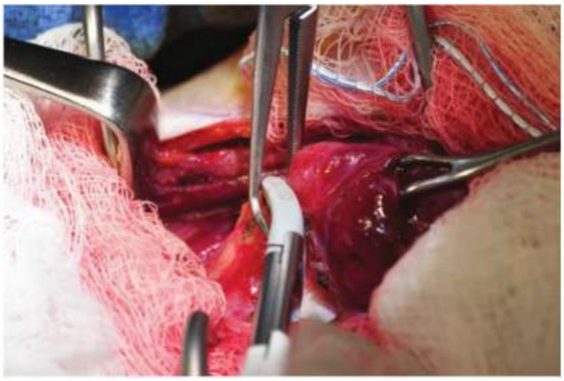

FIG 19 ● Ligation of the inferior thyroid vessels close to the gland.

gland. By ligating the vessels close to the gland, the blood supply to the inferior parathyroid gland is therefore preserved (**FIG 19**).

- The anterior surface of the trachea is then exposed (**FIG 20**), and simultaneous anteromedial retraction of the superior and inferior poles of the thyroid enhances the exposure of the RLN (**FIG 21**).
- The remaining branches of the inferior thyroid artery are ligated and divided close to the thyroid parenchyma using various techniques including surgical clip and tie or LigaSure (**FIG 22**).
- The remaining thyroid lobe and ligament of Berry are separated from the RLN, preserving the blood supply to the superior parathyroid gland (**FIG 23**).
- Once the lobe of the thyroid gland has been separated from the RLN, the remainder of the ligament of Berry can be divided, separating the isthmus form the trachea (**FIG 24**).

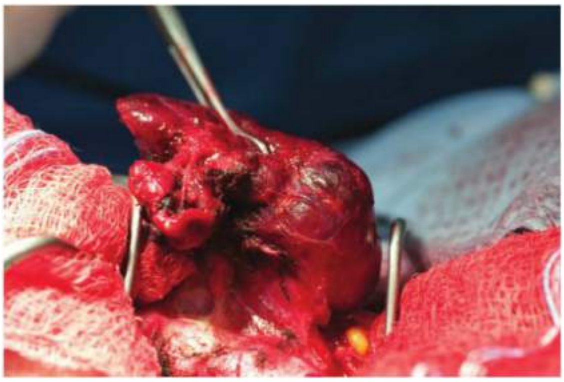

FIG 20 ● Anterior surface of the trachea exposed.

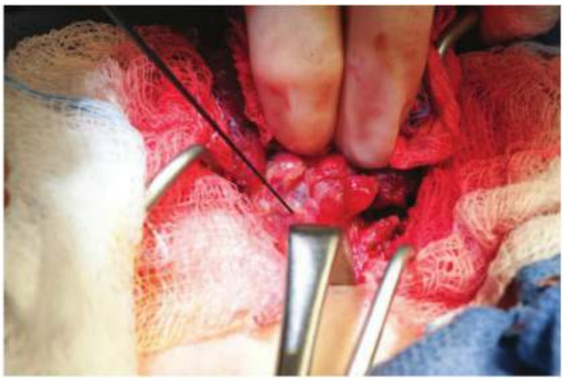

FIG 18 ● Intraoperative nerve monitoring being used to help with identifying the RLN and confirming its integrity.

FIG 21 ● RLN exposed, with the gland anteromedially retracted and countertraction applied to the trachea.

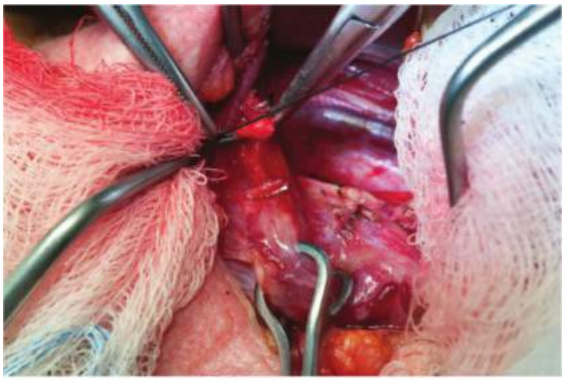

FIG 22 ● Inferior thyroid pole vessels are ligated and divided close to the thyroid gland, with careful attention paid to the blood supply of the parathyroid glands.

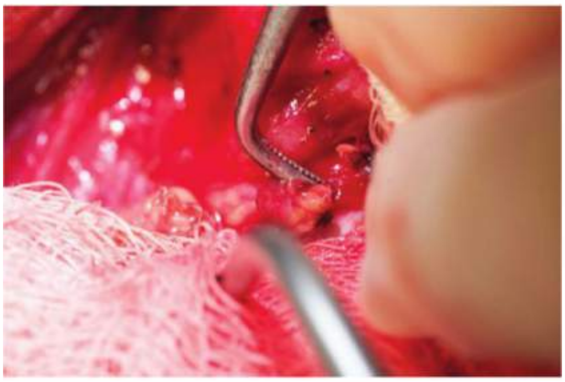

FIG 23 ● Parathyroid gland dissected free and preserved with its blood supply seen at the tip of the right angle.

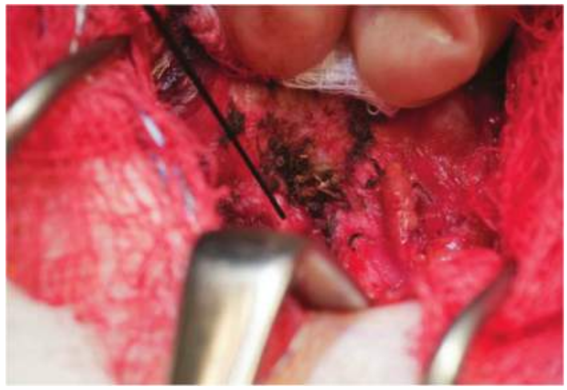

FIG 25 ● Integrity of the RLN is confirmed, both by visual inspection and with the nerve probe.

- The contralateral lobe is resected in an identical fashion, and after complete removal, the integrity of the RLN is confirmed, both by visual inspection and with the nerve probe (**FIG 25**).
- The trachea is left exposed and hemostasis is then attained, followed by irrigation with normal saline (**FIG 26**).
- The sternohyoid muscles are reapproximated in the midline using a running or locking suture, through only fascia and not muscle. The inferior aspect is left open over a distance of 1 to 2 cm to allow blood to decompress into the subcutaneous space if bleeding develops (**FIG 27**).
- The platysmal muscle layer is then reapproximated using simple interrupted suture (**FIG 28**).
- A subcuticular running suture technique, with a free knotless tail left on either end of the incision, is used to closely reapproximate the skin. Careful attention is paid to the cosmesis of the closure (**FIG 29**).
- A single Steri-Strip is placed horizontally in the direction of the incision, and a suture tail is left free on either end of the incision (**FIG 30**).

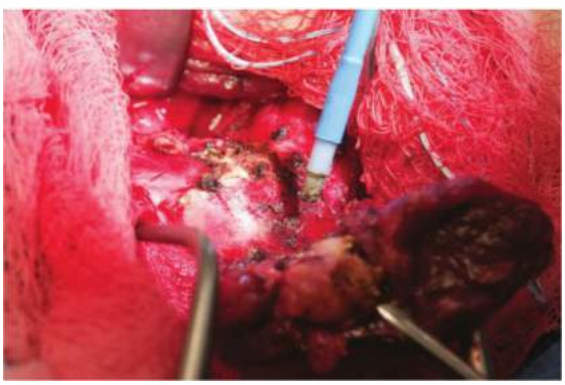

FIG 24 ● Traction placed on the thyroid gland as the ligament of berry is divided, thereby releasing the gland from its tracheal attachment.

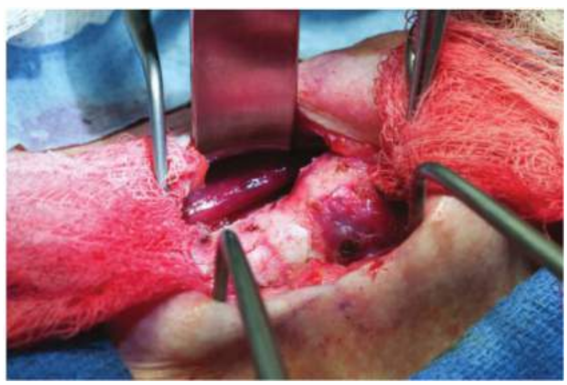

FIG 26 ● The trachea is left exposed and hemostasis is then attained, followed by irrigation with normal saline.

FIG 27 ● Sternohyoid muscles reapproximated in midline with inferior margin left open.

FIG 28 ● Platysmal muscle layer reapproximated in the midline with simple interrupted suture.

FIG 29 ● Subcuticular running suture technique.

FIG 30 ● Steri-Strip applied along the length of the incision.

PEARLS AND PITFALLS

Subcapsular dissection	■ A subcapsular dissection, in close proximity to the thyroid capsule, is the approach of choice, taking meticulous care to preserve blood flow to parathyroid glands, and identify the RLNs, protecting them all the way to their insertion in the cricopharyngeus muscle. This approach helps minimize the risk of postoperative hypocalcemia and nerve injury.
Gentle retraction	■ This simple subtlety of surgeon's technique helps to avoid nerve injury and preserve vascular supply to the parathyroid glands.
Intraoperative nerve monitoring	■ Easy to setup and aids with the identification of the RLN, oftentimes before visualization. It allows for functional assessment of an anatomically intact RLN and also permits vagal nerve identification to confirm RLN function when visual identification is difficult. Pitfall of this is that it is expensive, requires a learning curve, and may be associated with false-positive or false-negative nerve signals if not properly interpreted.
Vessel ligation	■ The Harmonic scalpel and LigaSure have been shown to result in decrease length of operation.
Closure of strap muscles	■ Strap muscles are approximated in the midline with a running, locking suture, and 1 to 2 cm is left open at its inferior margin. This will allow blood to escape into the subcutaneous space in the event of a postoperative hemorrhage, so that pressure against the airway is minimized. Platysmal muscles are reapproximated using a simple interrupted technique; again, in the event of a hematoma, the individual sutures can be cut to allow for simple evacuation.
Use of a neck drain	■ Drains are almost never used.
Skin closure	■ A 4-0 subcuticular stitch is used. A suture tail is left at the corner of each end of the skin incision, and piece of Steri-Strip is applied horizontally along the incision. If the wound needs to be redressed, the original dressing is removed, and the two ends of the sutures can be used to produce countertraction on either end of the incision and a new Steri-Strip can then be neatly applied.

POSTOPERATIVE CARE

- Total or ionized calcium are checked on the morning of postoperative day 1, as some reports have shown that nearly one-third of patients will have mild temporary hypocalcemia within the first 1 to 2 days after surgery.[9]
- Calcium supplementation is administered based on how low the postoperative calcium level is and as needed for any numbness or tingling.
- Levothyroxine (1.6 μg/kg/day) is prescribed and started 3 days after surgery, unless the patient is already on supplementation or is hyperthyroid; TSH suppression with levothyroxine is thought to improve recurrence and survival rates in cancer patients.
- Laryngoscopy is indicated postoperatively if the patient complains of hoarseness or for any voice changes in order to assess for RLN or vocal cord damage.
- For those with locally advanced disease or with macroscopic residual tumor, radioactive ^{131}I therapy is given adjuvantly. Serum thyroglobulin is followed postoperatively to detect persistent or metastatic disease.
- For patients with WDTC that is greater than 1.5 cm, RAI remnant ablation is oftentimes recommended, especially if there is residual remnant tissue, nodal metastasis, extrathyroidal extension, or distant disease.
- Ultrasonography is indicated yearly for the first 2 years after treatment; thyroid function is measured directly by free T4 and indirectly by TSH.

OUTCOMES

- MNG is more likely to recur after bilateral subtotal thyroidectomy than after total or near-total thyroidectomy, with relapse rates after subtotal thyroidectomy reported to be as high as 9% to 43%; and the risk of malignancy in remaining thyroid tissue, 4% to 17%.[9]
- It is important to emphasize that reoperative thyroid surgery is associated with more risk of complications that the first operation.

COMPLICATIONS

- Transient or permanent RLN injury
- Bilateral RLN injury
- Transient or permanent hypoparathyroidism
- Injury to the external branch of the superior laryngeal nerve
- Postoperative neck hematoma
- Surgical site infection

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Chapter **37**

Thyroidectomy for Substernal Goiters

Andrew G. Shuman Ashok R. Shaha

DEFINITION

- A goiter refers to any abnormal thyroid enlargement secondary to nutritional deficiency, endocrine disease, or neoplasm. In general terms, substernal goiter applies to conditions in which the majority of the thyroid volume lies below the thoracic inlet.

PATIENT HISTORY AND PHYSICAL FINDINGS

- A comprehensive medical history is obligatory, including assessment of the indications for surgery, consideration of medical comorbidities, and ensuring that patients are medically optimized and risk-stratified for surgery. Any prior operative records and pathology reports should be reviewed in advance.
- A detailed physical examination is mandatory, including consideration of upper airway patency and visualization of the larynx to assess vocal fold mobility.
- Flexible fiberoptic laryngoscopy is helpful in evaluating glottic function and assessing the airway.

IMAGING AND OTHER DIAGNOSTIC STUDIES

- Cross-sectional imaging (usually computerized tomography) is invaluable in defining the intrathoracic anatomic extent of the mass and its relationship to critical cervical and intrathoracic structures.[1]
- Intravenous contrast may delay the ability to use radioactive iodine but should be used whenever anatomic considerations may affect the surgical planning or technique.
- Ultrasound may also be employed but is of limited use in assessing the intrathoracic extent of disease.
- A thoughtful approach to the airway is necessary. In addition to history, physical examination, and imaging studies, exclusion of cardiopulmonary factors affecting respiration is important.
- Spirometry and flow-volume loops are useful adjuncts in order to understand the underlying respiratory physiology. However, surgical decisions are made based on functional and anatomic considerations rather than strictly physiologic tests.
- Preoperative laboratory studies should include thyroid function testing and thyroglobulin.
- In the case of a thyroid mass or nodule, fine needle aspiration (preferably image-guided) with cytologic evaluation should be attempted prior to surgery.

SURGICAL MANAGEMENT

- Consideration for removal of substernal goiters is multifactorial.[2]
- Indications for an operation may relate to the need to make a diagnosis, extirpate malignancy, ameliorate compression of the upper aerodigestive tract, or relieve venous outflow obstruction (superior vena cava syndrome).
- In most patients meeting criteria for surgery, medical options other than watchful waiting are limited.
- Given that most goiter operations are elective, prudent and deliberate preoperative planning and counseling are essential. The indications, risks, benefits, and alternatives of surgery versus expectant management should be discussed.

Preoperative Planning

- Preoperative communication with anesthesia is critical. Although most patients can be readily intubated, airway compression or deviation must be considered. Atraumatic intubation is necessary.[3]
- The endotracheal tube cuff should be well below the vocal folds to avoid both glottic trauma and inadvertent extubation, as the endotracheal tube has a tendency to be displaced with movement during surgery.
- Thoracic surgeons should provide preoperative input and be available to assist in cases in which their presence may be needed.
- Options such as small endotracheal tubes, endotracheal tubes facilitating nerve monitoring, and/or fiberoptic bronchoscopy/intubation should be discussed prior to induction with anesthesia.
- Fiberoptic intubation is rarely necessary, although adjunctive technologies, such as the GlideScope®, may be useful.

Positioning

- The patient is positioned supine with gentle neck extension. Effort should be made to prepare and drape in a manner that facilitates some movement of the head and neck while preserving the sterile field.
- Overextension of the neck may put the recurrent laryngeal nerves (RLNs) under tension and make them more difficult to identify.
- Even if sternotomy is not planned, the chest should be prepped for access in case of either an emergency or the inability to free the gland transcervically.

Anatomy

- The tuberculum of Zuckerkandl is a posterolateral prominence of thyroid tissue that frequently approximates the location of the RLN.[4]
- Berry's ligament is a condensation of the pretracheal fascia that attaches the thyroid to the airway. Small vessels run along the ligament, and it may be in close proximity to the RLN, requiring careful attention in order to ensure preservation of the nerve when the thyroid is being mobilized.
- In general, the substernal component of the thyroid gland originates from one lobe. Left substernal goiters are anteriorly displaced by the aortic arch. Right substernal goiters are frequently nestled between the superior vena cava and the prevertebral muscles (**FIG 1**).
- Posterior mediastinal goiters are rare, but when present, the RLN may be anteriorly displaced.
- In rare cases, substernal goiters may not be contiguous with the cervical thyroid gland.

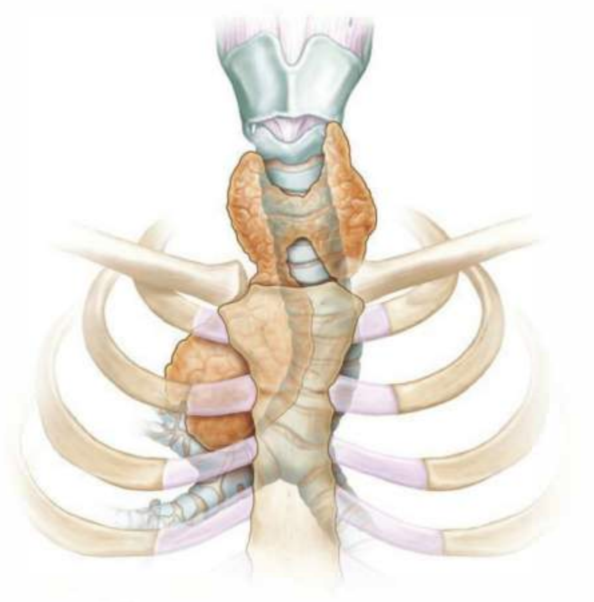

FIG 1 ● Anatomy of substernal goiter. The substernal component of the thyroid gland usually originates from one lobe. Left substernal goiters are anteriorly displaced by the aortic arch. Right substernal goiters (pictured) are frequently nestled between the superior vena cava and the prevertebral muscles.

Approach

- The cervical vascular supply, anterior position, and rarity of bilateral intrathoracic extension typically facilitate complete removal of substernal goiters transcervically.[5]
- Less than 10% of substernal goiters require sternotomy or thoracotomy.
- Relative indications for sternotomy include the following:
  - Prior mediastinal surgery
  - Retroesophageal/posterior mediastinal location
  - Goiter abutting the carina
  - Intrathoracic malignancy with extrathyroidal extension
  - Intimate association with the great vessels
  - Massive substernal goiters that physically cannot be removed through the neck
- When sternotomy is indicated, a "T" incision is frequently preferred.
- Transcervical dissection and ligation of vessels occur prior to opening the chest. However, in cases with venous obstruction, sternotomy precedes vessel ligation in order to limit intrathoracic venous distension.
- The sternotomy may be partial or complete.
- Care is necessary in order to identify and manage aberrant mediastinal vascular tributaries supplying the thyroid gland.
- The intrathoracic trajectory of the RLNs can be identified and preserved under direct vision.
- Lateral thoracotomy typically provides suboptimal visualization of critical structures but may be preferred in specific cases.
- Video-assisted thoracic surgery may also be considered.

TECHNIQUES

INCISION AND EXPOSURE

- Exposure is critical, as satisfactory access facilitates appropriate visualization. Thus, a generous transverse neck incision is planned within an existing neck crease, approximating the level of the cricoid cartilage.
- The strap muscles are identified and divided along the midline raphe. In order to obtain sufficient access, the strap muscles are transected at least on the side of intrathoracic extension (FIG 2).

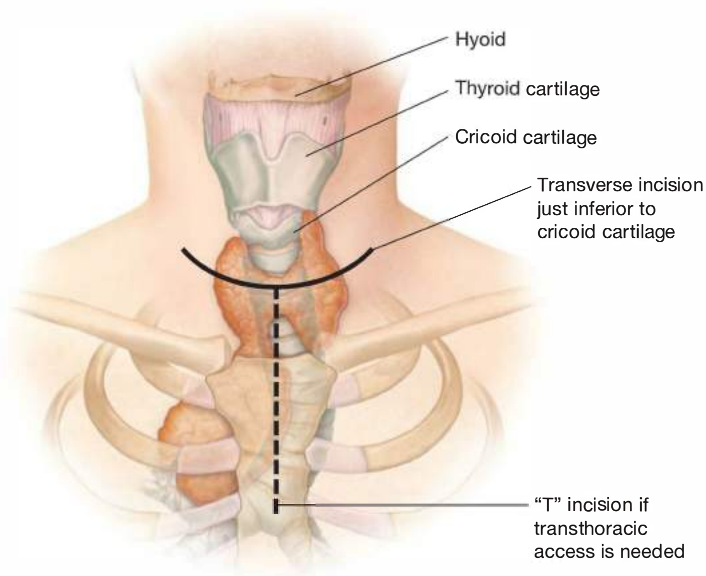

FIG 2 ● Incision and exposure. The patient is positioned supine with gentle neck extension. A generous transverse neck incision is planned within an existing neck crease, approximating the level of the cricoid cartilage. The chest should be prepped within the field. When sternotomy is indicated, a "T" incision is preferred.

MOBILIZATION OF THYROID GLAND

- As the thyroid is gently and bluntly freed from surrounding areolar tissue, meticulous attention is necessary to ensure extracapsular dissection in order to maintain a bloodless field.
- The middle thyroid vein is isolated and divided.
- The superior parathyroid gland is identified and preserved, given that the inferior glands are at higher risk for injury during dissection of the substernal extent of the thyroid gland.
- When necessary, devascularized or excised parathyroid glands may be autotransplanted into the sternocleidomastoid muscle. Perform frozen section confirmation of histology prior to reimplantation.
- The superior thyroid pedicle is isolated and divided close to the superior pole, taking care not to injure the superior laryngeal nerve or superior parathyroid gland.

IDENTIFICATION OF RECURRENT LARYNGEAL NERVE

- The RLN is identified. The size and bulk of the thyroid gland may make this dissection difficult, and the nerve may be displaced from its standard anatomic position. In general, its entry into the larynx at the cricothyroid joint is the most consistent and reliable location for identification.
- The RLN is traced and exposed inferiorly. In cases in which the substernal goiter is posteriorly positioned, the nerve is likely to be displaced anteriorly, putting it at higher risk for injury.
- In some cases, the thyroid gland will need to be displaced in order to facilitate nerve dissection, which involves retrograde dissection of the RLN from the cricothyroid joint inferiorly while displacing the thyroid gland anteromedially ("toboggan approach") (**FIG 3**).
- The RLN may branch prior to its entry into the larynx, and such anatomic variations should be expected. Anterior divisions of the nerve are more likely to be motor branches.

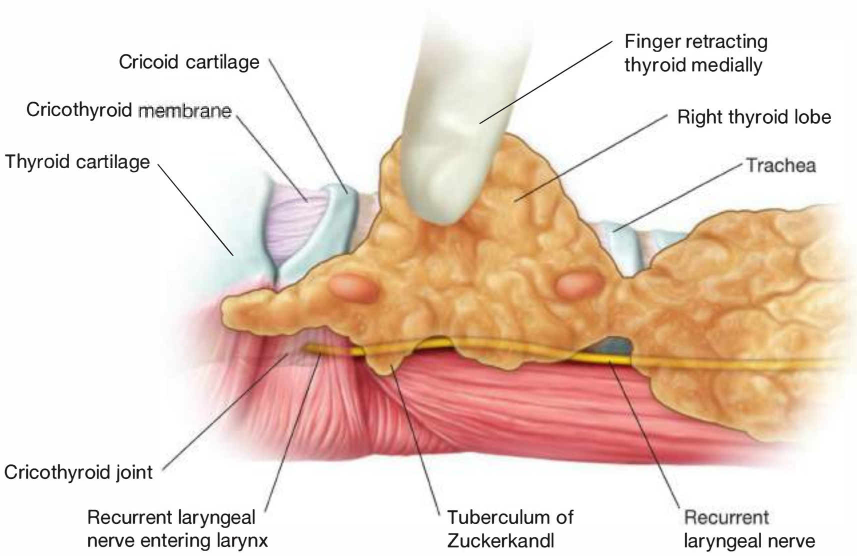

FIG 3 ● Identification of RLN. The RLN's entry into the larynx at the cricothyroid joint is the most consistent and reliable location for identification. The RLN is traced and exposed inferiorly. In some cases, the thyroid gland will need to be displaced in order to facilitate nerve dissection, which involves retrograde dissection of the RLN from the cricothyroid joint inferiorly while displacing the thyroid gland anteromedially ("toboggan approach").

LIGATION OF THE INFERIOR PEDICLE AND MOBILIZATION

- The inferior thyroid vessels are isolated and divided meticulously. Damage to these vessels during mobilization can cause intrathoracic hemorrhage not amenable to transcervical hemostasis.
- Gentle, blunt substernal dissection should commence laterally, under the sternocleidomastoid muscle, and progress medially. It may be useful to divide the sternal head of this muscle to improve access. Small venous tributaries are frequently encountered and divided.
- Hemoclips, LigaSure™, or other hemostatic adjunctive devices may be employed at the surgeon's discretion (**FIGS 4** and **5**).

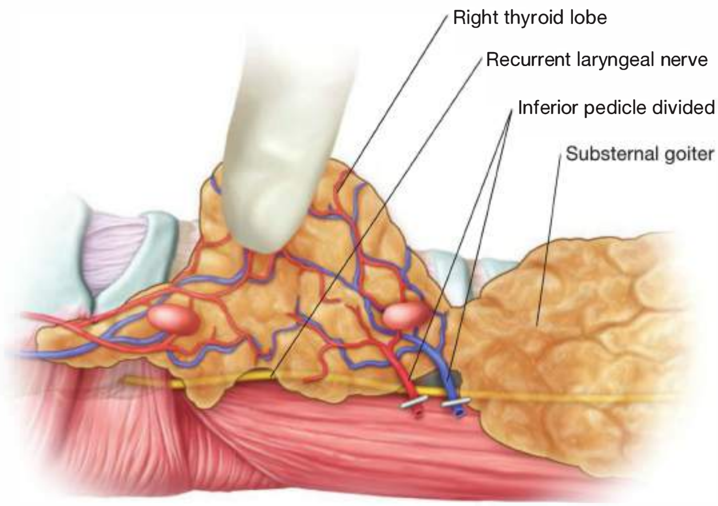

FIG 4 ● Ligation of the inferior pedicle. The inferior thyroid vessels are isolated and divided meticulously. Damage to these vessels during mobilization can cause intrathoracic hemorrhage not amenable to transcervical hemostasis. It may be difficult to visualize and preserve the ipsilateral inferior parathyroid gland.

FIG 5 ● Mobilization of substernal goiter. Gentle, blunt substernal finger dissection should commence laterally, under the sternocleidomastoid muscle, and progress medially.

CONTRALATERAL DISSECTION

- The procedure is repeated on the other thyroid lobe.
- Typically, the lobe with substernal extension is removed first in order to ensure that the RLN is preserved prior to contralateral dissection. If the nerve monitor is being used, it is appropriate to test the dissected nerve's integrity prior to contralateral surgery.
- Care should be taken when freeing the gland off of the cricothyroid joint and Berry's ligament, as small vessels can cause bleeding that obscures visualization of the RLN.

TECHNIQUES

CLOSURE

- Closed suction drain placement is frequently indicated due to the large potential space created by expansive substernal goiters.
- Wound closure is performed in the standard manner, taking care to reapproximate divided muscles (sternocleidomastoid and straps). The midline raphe between the strap muscles should be loosely approximated to facilitate egress of blood and transudate and to mitigate airway compression in the case of an expansile hematoma.
- The method of skin closure is at the discretion of the surgeon (**FIG 6**).
- Smooth extubation and anesthetic emergence is important in order to limit sudden increases in intrathoracic pressure. If airway concerns are present, delayed extubation can be considered.

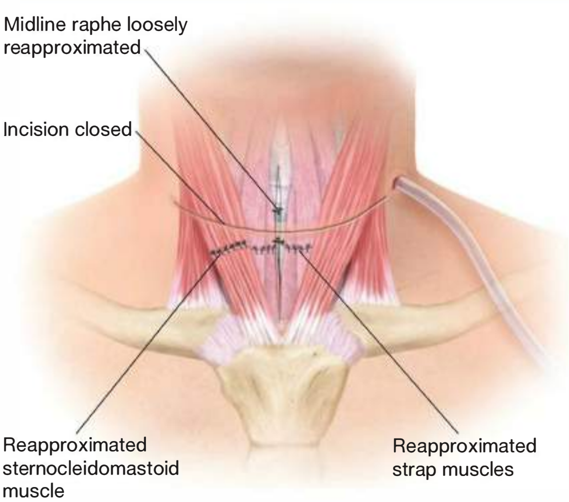

FIG 6 ● Closure. Take care to reapproximate divided muscles (sternocleidomastoid and straps). The midline raphe between the strap muscles should be loosely approximated to facilitate egress of blood and transudate. Closed suction drain placement is frequently indicated.

PEARLS AND PITFALLS

Indications	■ Given that most goiter operations are elective, prudent and deliberate preoperative planning and counseling are essential.
Approach	■ Sternotomy is rarely necessary for removal of a substernal thyroid gland.
Positioning	■ The patient should be placed supine with gentle neck extension and draped in a manner that facilitates movement of the head and neck.
Airway	■ Although most patients can be readily intubated, airway compression or deviation must be considered. Because the endotracheal tube has a tendency to become displaced during surgical manipulation, confirm that the cuff is well below the vocal folds.
Exposure	■ Satisfactory access is critical for safety and visualization. Use a generous transverse neck incision and consider dividing strap muscles at least on the side of intrathoracic extension.
Plane of dissection	■ As the thyroid is mobilized, meticulous attention is necessary to ensure extracapsular dissection in order to maintain a bloodless field.
Management of parathyroid glands	■ The inferior glands are at higher risk for injury or devascularization during dissection of the substernal extent of the thyroid gland. Thus, make sure to identify and preserve the superior parathyroid glands.

POSTOPERATIVE CARE

- Check postoperative serum calcium levels. The use of intraoperative and/or postoperative parathyroid hormone levels is optional. Decisions regarding calcium supplementation and further laboratory studies should be based on individual circumstances, laboratory findings, and clinician preferences.
- Patients should be informed to call 911 if they develop any sudden difficulty breathing or neck swelling.
- Patients should be encouraged to ambulate early and perform pulmonary toilet, although they should restrict from strenuous physical activity and heavy lifting for a few weeks.

COMPLICATIONS

- Surgical site infection—In general, strict adherence to aseptic technique and maintenance of the sterile field assures that surgical site infections are uncommon in patients without underlying risk factors. Perioperative antibiotics should be administered in accordance with established guidelines.[6]
- Seroma—Some degree of seroma formation within the operative bed is inevitable. Intervention rarely becomes necessary.
- Intraoperative hemorrhage—Meticulous technique including limiting shearing/tearing vessels and maintaining an

intact thyroid capsule are critical. Rarely, uncontrolled intrathoracic hemorrhage will require emergent sternotomy and/or aggressive resuscitation.

- Hematoma—Approximately 1% to 3% of cases will develop a postoperative hematoma that requires intervention. All cases of expansile hematomas require consideration of airway compression and prompt attention.
- Nerve injury—The RLNs are susceptible to injury both within the neck and chest. Rates of injury are slightly higher in cases of substernal goiter than in standard thyroidectomies.
- Hypoparathyroidism—Inferior parathyroid glands are more difficult to identify and preserve with substernal goiters, making identification and meticulous preservation of superior glands critical.
- Hemothorax/pneumothorax—Intrathoracic complications are quite rare. Routine postoperative chest x-ray should be considered.
- Tracheomalacia—Despite frequent tracheal deviation and/or compression, clinically significant tracheomalacia is rare. The adult airway is quite resilient, and even long-standing compression will not often be problematic.

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Chapter 38

Subtotal Thyroidectomy for Graves' Disease

Edwin L. Kaplan Raymon H. Grogan

DEFINITION

- Subtotal thyroidectomy means the removal of most of both lobes of the thyroid, but some thyroid tissue is intentionally left on one or both sides of the neck.
  - Total thyroidectomy alone or with appropriate neck dissections is the procedure of choice for most thyroid cancers and is discussed in Part 5, Chapter 36.
  - Thyroid lobectomy is used for some unilateral benign colloid nodules or goiters and for many indeterminate thyroid lesions; that is, when the fine needle aspirate demonstrates a possible follicular neoplasm or a follicular lesion of undetermined significance (FLUS) that requires operation (see Part 5, Chapter 35).
  - Subtotal thyroidectomy is frequently used in the treatment of *benign* thyroid diseases such as nontoxic or toxic multinodular goiters, especially when the disease is bilateral and commonly in the treatment of Graves' disease, although near-total or total thyroidectomy may be more appropriate in some patients.
  - The purpose of subtotal thyroidectomy is to reduce the incidence of postoperative complications of total thyroidectomy—permanent hypoparathyroidism and recurrent laryngeal nerve injury—and to leave functional thyroid tissue in the neck of some patients. Although the rate of complications of total thyroidectomy is low in the hands of expert thyroid surgeons, most surgeons would agree and most studies have demonstrated a lower incidence of complications when subtotal thyroidectomy is performed.
  - This section will briefly discuss the diagnosis and preoperative assessment of patients with benign thyroid conditions and will illustrate the preoperative management and surgical technique when performing *a subtotal thyroidectomy for Graves' disease.*

PATIENT HISTORY AND PHYSICAL FINDINGS

- In order to differentiate these benign thyroid conditions, a careful history and physical examination are first necessary.
- History: Of greatest importance is a previous history of low-dose (or high-dose) radiation to the neck, which is associated with an increased risk of thyroid cancer. Also important are the metabolic status of the patient and whether or not there are symptoms of respiratory impairment, pressure on the trachea, or difficulty swallowing from an enlarged thyroid or from thyroid nodules.
  - Major symptoms of hypothyroidism
    - Severe fatigue, weight gain, dry skin, irregular menstrual periods, constipation, depression, hair loss, brittle nails, feeling cold, slowness of speech, and puffiness. In its most severe form, hypothyroid coma may rarely occur.
  - Major symptoms of hyperthyroidism (thyrotoxicosis)
    - Weight loss despite a normal or an increased appetite, rapid or irregular heartbeat, nervousness, anxiety, irritability, tremor, sweating, changes in menstrual pattern, increased sensitivity to heat, more frequent bowel movements, fatigue, muscle weakness, difficulty sleeping, and fine brittle hair. In its most severe form, thyroid storm might occur.
  - Respiratory and compressive changes and difficulty swallowing
    - Nodules of the thyroid or an enlarged thyroid (goiter) may cause pain and tenderness in the neck as well as trouble breathing. As the thyroid enlarges, the trachea can be compressed and narrowed and eventually respiratory impairment may occur resulting in coughing, shortness of breath, and stridorous breathing. Rarely, an enlarged goiter can result in recurrent laryngeal nerve impairment with hoarseness. Pressure from a goiter or from thyroid nodules can also result in trouble swallowing.
  - Physical findings
    - The physician should assess the size of the thyroid gland and the size, consistency, number, and position of any thyroid nodules; whether or not the trachea is deviated; and if any enlarged and abnormal lymph nodes are present in the central or lateral neck. Finally, the physician should assess whether there are any signs of thyrotoxicosis in general or evidence of manifestations of Graves' disease such as exophthalmos, pretibial myxedema, and a diffuse goiter with a bruit.

IMAGING AND OTHER DIAGNOSTIC STUDIES

- Thyroid function tests
  - Almost all patients with hypothyroidism have an elevated thyrotropin (TSH) level with low free thyroxine (FT4) and triiodothyroxine (T3) values.
  - Almost all thyrotoxic patients have a suppressed TSH with elevated FT4 and T3 values.
- Tests for autoimmunity
  - In Hashimoto's disease and Graves' disease, antibodies to thyroid peroxidase (anti-TPO antibodies) are found in up to 90% of patients, whereas antithyroglobulin (anti-TG) antibodies are found in approximately 50%. Elevated anti-TSH receptor antibodies (TSab) are also commonly detected in patients with Graves' disease and these thyroid-stimulating immunoglobulins (TSI) are the cause of the thyrotoxicosis of Graves' disease.
- Imaging and nuclear uptake scanning
  - The thyroid uptake of radioiodine or technetium isotopes is usually increased in toxic multinodular goiter, toxic adenoma, and Graves' disease.
  - Nuclear scans may help to differentiate each of these diseases.
    - With toxic multinodular goiter, an enlarged thyroid gland is noted with one or more "hot" areas usually among other "cold" areas.
    - Toxic adenoma. A single hot area is clearly seen which corresponds to the thyroid nodule. The remaining thyroid

tissue is suppressed and barely visualized on the scan.
    - Graves' disease. Both lobes of the thyroid demonstrate increased uptake of isotope on the scan.
- Other imaging studies
    - Ultrasound examinations are commonly used to evaluate the thyroid for nodules and to identify abnormal lymph nodes and have replaced a nuclear scan unless a hot nodule is suspected.
    - Computerized tomography (CT) scan and magnetic resonance imaging (MRI) exams are helpful to evaluate the presence or absence of tracheal compression; abnormal lymph nodes; or the presence, size, and anatomic location of a substernal goiter. These are often reserved for goiters that extend below the clavicle or if significant tracheal narrowing is of concern.
    - The most important test to evaluate a thyroid nodule is a fine needle aspiration (FNA) with cytologic examination. This exam should be used liberally. Usually, it is performed under ultrasound guidance in order to be certain that the nodule in question has correctly been sampled.

DIFFERENTIAL DIAGNOSIS

- A short list of common benign thyroid conditions:
    - Thyroid abnormalities associated with normal thyroid function or hypothyroidism
        - Single colloid nodule or cyst
        - Single microfollicular or macrofollicular adenoma
        - Multinodular goiter
        - Hashimoto's thyroiditis
    - Thyroid abnormalities associated with thyrotoxicosis
        - Toxic adenoma
        - Toxic multinodular goiter
        - Graves' disease
            - Graves' disease is an autoimmune disease characterized by a goiter, thyrotoxicosis, and exophthalmic eye disease. Less commonly, pretibial myxedema is also present. It is closely related to Hashimoto's thyroiditis, which usually presents with hypothyroidism.
            - It was described first in the English language by Caleb Perry (1755–1822) but commonly bears the name of the Irish physician, Robert Graves. On the European continent, it is called Basedow's disease.
            - As an autoimmune thyroid disease, it exhibits both antibodies and cell-mediated immunity directed to thyroid peroxidase (TPO) and thyroglobulin (TG) as well as stimulating antibodies against the TSH receptor (called TSab, but formerly called long-acting thyroid stimulator [LATS]). Antibodies against eye muscle and fibroblasts are also found in the serum of same patients with severe Graves' ophthalmopathy.
            - Incidence of Graves' disease
                - Found in women 5 to 8 times more commonly than in men
                - Thirty cases per 108,000 population annually in Ohmstead County, Minnesota
                - Increases in incidence during each decade from adolescence to 60 years of age
                - Six percent of all Americans have autoimmune thyroid disease.

SURGICAL MANAGEMENT

- A thyroidectomy is usually indicated for the following reasons:
    - To treat thyroid malignancies and some benign thyroid nodules
    - To establish a definitive diagnosis when diagnosis by FNA is equivocal, nondiagnostic, or indeterminate
    - To alleviate pressure symptoms or respiratory difficulties associated with a malignant or a benign process
    - To remove a substernal goiter
    - To remove an unsightly goiter
    - As definitive therapy for individuals with thyrotoxicosis—selected patients with hot nodules, toxic multinodular goiter, and Graves' disease
- Preparation for surgery
    - Most patients undergoing a thyroid operation are euthyroid and require no specific preoperative preparation related to their thyroid gland. Determination of serum calcium and parathyroid hormone (PTH) levels may be helpful. Endoscopic or indirect laryngoscopy might be helpful for all patients preoperatively but definitely should be done in those who are hoarse or who have had a change in voice and in others who have had a prior thyroid, parathyroid, carotid, lateral neck, anterior cervical disc, or chest operation in order to detect the possibility of a recurrent laryngeal nerve injury.
- Hypothyroidism
    - Modest hypothyroidism is of little concern when treating a surgical patient; however, severe hypothyroidism can be a significant risk factor. Severe hypothyroidism can be diagnosed clinically by myxedema as well as by slowness of affect, speech, and reflexes. Circulating thyroxine and triiodothyronine values are low. The serum TSH level is high in all cases of hypothyroidism that are not caused by pituitary insufficiency. In the presence of *severe* hypothyroidism, both the morbidity and the mortality of surgery are increased as a result of the effects of both the anesthesia and the operation. Such patients have a higher incidence of perioperative hypotension, cardiovascular problems, gastrointestinal hypomotility, prolonged anesthetic recovery, and neuropsychiatric disturbances. They metabolize drugs slowly and are very sensitive to all medications. Therefore, when severe myxedema is present, it is preferable to defer elective surgery until a euthyroid state is achieved.
- Hyperthyroidism
    - Toxic multinodular goiter and a toxic adenoma are usually treated to a euthyroid state with an antithyroid medication such as methimazole (Tapazole) or propylthiouracil (PTU), and the possible use of a beta-adrenergic blocker such as propranolol. Radioiodine therapy may sometimes be used as definitive therapy.
    - Operative therapy for a toxic multinodular goiter is usually a subtotal or total thyroidectomy. For a toxic adenoma, enucleation of the nodule or a thyroid lobectomy is curative because a hot nodule is almost always benign. This can be confirmed preoperatively by FNA evaluation. Furthermore, because most of the thyroid tissue remains after enucleation, the majority of patients become euthyroid postoperatively without the need for thyroid hormone replacement.
- Treatment of patients with Graves' disease
    - In the United States, most patients with thyrotoxicosis have Graves' disease. Furthermore, in the United States,

over 90% of all patients with Graves' disease are treated with radioiodine therapy.
- Operative indications for Graves' disease may include very young patients, others with very large goiters, some pregnant women, and those with suspicious thyroid nodules or severe ophthalmopathy.
- For greatest safety, patients with Graves' disease should be treated preoperatively with PTU or methimazole and iodine drops to restore a euthyroid state and to prevent *thyroid storm*. Thyroid storm is the name for the most severe manifestations of thyrotoxicosis including a very rapid heart rate or cardiac arrhythmias, fever, disorientation, hypotension, coma, and even death. In the past, mortality of thyroid storm was very high, but now, with the use of beta-blockers, antithyroid medications, iodine, oxygen, glucose, possibly adrenocortical steroids, and intensive care measures, the death rate has been greatly reduced. Both anesthesia and operation on a poorly prepared thyrotoxic patient are the leading precipitating factors for this event. Furthermore, operation on an unprepared Graves' gland can be more difficult because severe bleeding may occur because the thyroid is often soft and very vascular. With proper preoperative preparation, however, operation on the thyroid gland in Graves' disease can be performed safely.

- Preparation of Graves' patient for operation
  - In *mild* cases of thyrotoxicosis with Graves' disease, iodine therapy alone has been used for preoperative preparation, although we do not recommend this approach routinely. Lugol's solution or a saturated solution of potassium iodide (SSKI), two or three drops twice daily, is given for 8 to 10 days preoperatively. This medication is taken in milk or orange juice to make it more palatable. Iodine therapy suppresses thyroid hormone release only in Graves' disease and should not be given to patients with toxic nodular goiter or toxic adenoma.
  - Most patients with Graves' disease are treated initially with antithyroid drugs, PTU or more commonly, methimazole (Tapazole) until they approach a euthyroid state. Then iodine is added to the regimen for 8 to 10 days before surgery. The iodine decreases the vascularity and increases the firmness of the gland. Sometimes, thyroxine is added to this regimen to prevent hypothyroidism and to decrease the size of the gland. Beta-adrenergic blockers such as propranolol (Inderal) are used commonly with the antithyroid drugs to decrease the pulse rate and eliminate the tremor. Other preoperative protocols using propranolol alone or with Lugol's solution are sometimes necessary, especially when allergic reactions to antithyroid medications have occurred. However, we do not use these routinely because they appear to be less safe.

OPERATION

- Following general anesthesia, the patient is placed in a supine position with the neck extended. A low collar incision is made, usually in a skin crease, and carried down through the subcutaneous tissue and platysma muscle. Currently, small incisions are the rule unless a large goiter is present.
- Superior and inferior subplatysmal flaps are developed, and the strap muscles are divided vertically in the midline and retracted laterally. Often, a large pyramidal lobe is present (**FIG 1**, **left**).

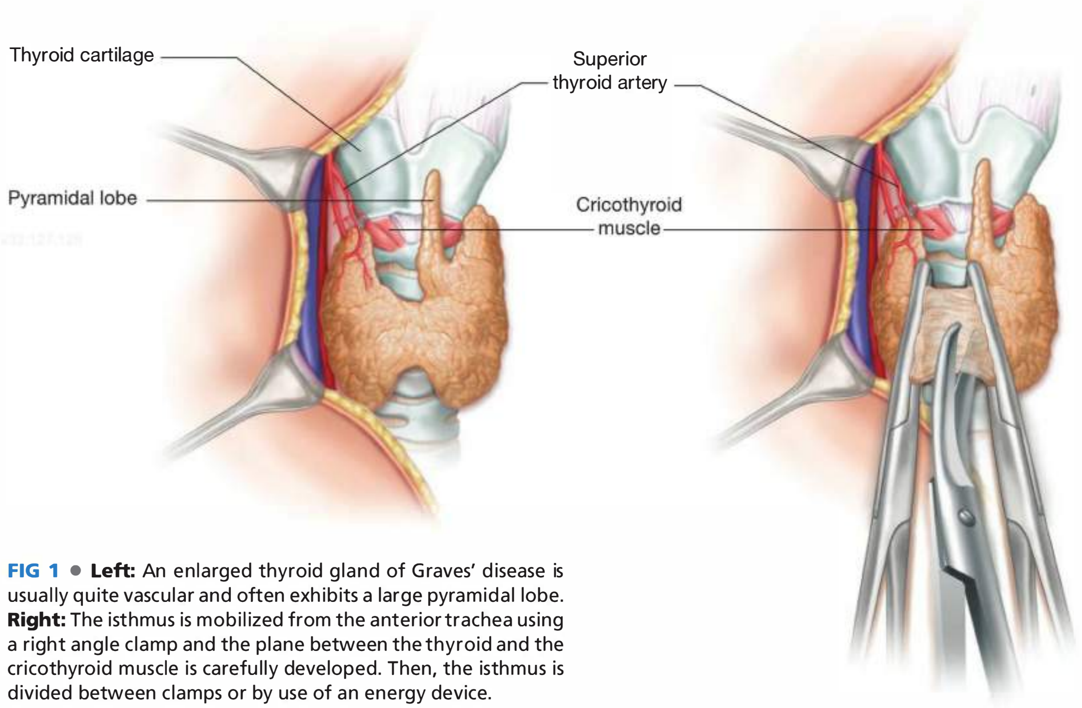

FIG 1 ● **Left:** An enlarged thyroid gland of Graves' disease is usually quite vascular and often exhibits a large pyramidal lobe. **Right:** The isthmus is mobilized from the anterior trachea using a right angle clamp and the plane between the thyroid and the cricothyroid muscle is carefully developed. Then, the isthmus is divided between clamps or by use of an energy device.

- The thyroid isthmus is clamped and divided early in the course of operation for most patients with Graves' disease (**FIG 1**, **right**). Alternatively, an energy device can be used to transect the isthmus.
- The isthmus on each side is then sharply dissected from the front of the trachea in order to improve mobilization of the gland. The isthmus on each side is oversewn for hemostasis (**FIG 2**). The medial side of the thyroid lobe to be operated on first is then carefully dissected in a superficial plane toward the upper pole, developing a plane between the thyroid lobe and the cricothyroid muscle. Care is taken to preserve and not damage the external branch of the superior laryngeal nerve and the cricothyroid muscle.
- The thyroid lobe to be operated on first is mobilized by dividing the areolar tissue and any small vessels along its lateral surface.
- The upper pole vessels are then individually ligated along the front surface of the upper pole and not more cephalad in the neck. The right angle is kept "pointing out laterally" to prevent damage to the external branch of the superior laryngeal nerve (**FIG 2**). This nerve can often be visualized if the area is carefully evaluated.
- The thyroid lobe is then retracted medially again and the middle thyroid vein is identified, ligated, and divided (**FIG 3**). This vein is usually in a plane superficial to the inferior thyroid artery and to the recurrent laryngeal nerve, but all structures should be carefully evaluated before ligation.
- The inferior thyroid artery, a branch of the thyrocervical trunk which runs medially and enters the field deep to the carotid artery, as well as the recurrent laryngeal nerve are now carefully identified (**FIG 4**). Whenever

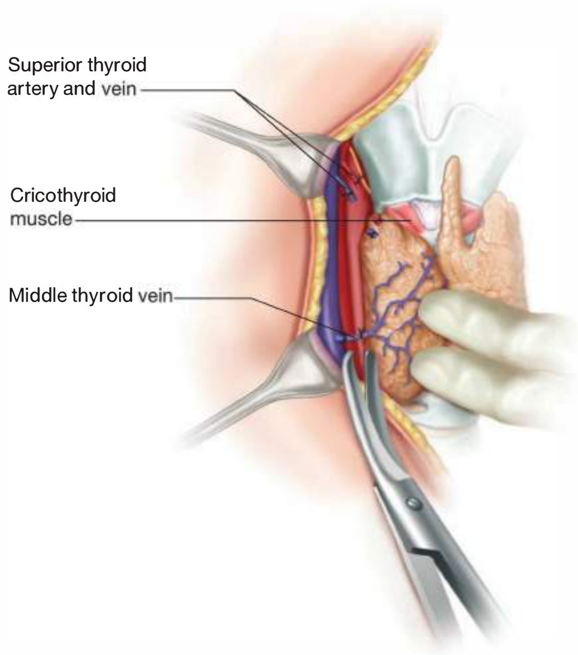

FIG 3 ● The thyroid lobe is retracted medially and care is taken to clearly identify the middle thyroid vein and to ligate and divide it. Be certain that the vein is separate from other structures before dividing it in order to avoid injury to the recurrent laryngeal nerve.

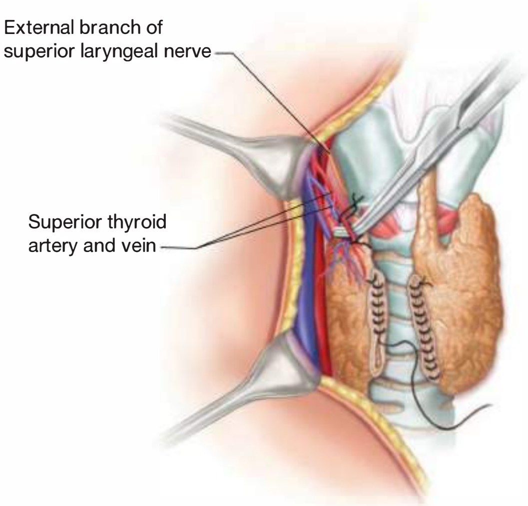

FIG 2 ● If the isthmus was clamped, it is oversewn by a running horizontal mattress suture behind the hemostat followed by a "baseball stitch" for hemostasis. The upper pole vessels are individually ligated on the anterior surface of the upper thyroid pole and divided. The points of the right angle should face away from the trachea and care is taken to identify the external branch of the superior laryngeal nerve when possible and not to injure it.

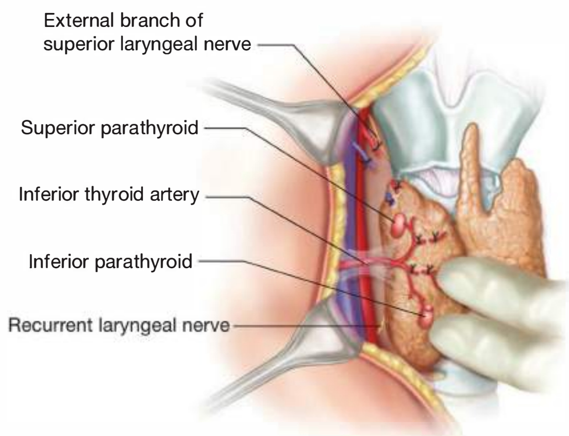

FIG 4 ● With further blunt dissection, the inferior thyroid artery, which runs transversely toward the thyroid lobe, is identified and the recurrent nerve is visualized. The inferior thyroid artery is not ligated as a single trunk but rather individual branches of it are ligated and divided on the surface of the lobe, and the lower parathyroid gland is moved off the thyroid lobe with its blood supply intact.

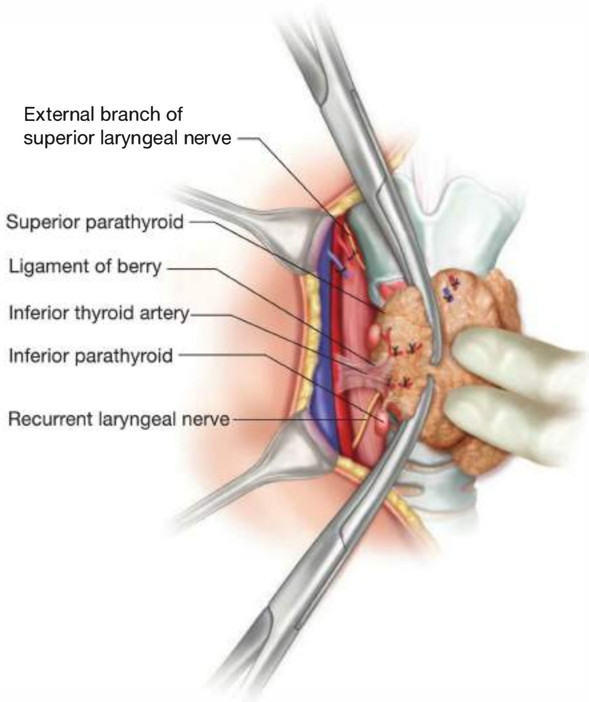

FIG 5 ● The recurrent laryngeal nerve should be visualized and followed up toward the ligament of Berry. The nerve should be treated gently and tissues "unroofed" from its anterior surface. Clamps are then applied (or an energy device used) only after the recurrent laryngeal nerve and parathyroids are seen to be safely preserved.

possible, the inferior thyroid artery is not ligated as a single trunk because this might devascularize the parathyroid glands. Rather, the small branches of the artery are individually ligated and divided along the surface of the thyroid lobe. The inferior parathyroid gland, which often is present high along the lower thyroid lobe, is mobilized with its blood supply and moved more posteriorly and laterally off the thyroid lobe.

- The carotid artery is now retracted laterally and the recurrent laryngeal nerve is more carefully identified, usually in the lower neck, and followed in an inferior to superior direction by "unroofing" the tissues from the front of the nerve (**FIG 5**). Remember that on the right side, the recurrent laryngeal nerve takes an oblique course from lateral to medial and from deep to superficial. On the left side, the nerve usually runs straight upward and is usually found in the lower neck much more medially than on the right side within or near the tracheoesophageal groove.
- If a subtotal lobectomy is to be done, before any clamps are placed on the thyroid lobe, the surgeon must be certain that the recurrent nerve has been identified and followed in a cephalad direction to near the ligament of Berry and that the nerve and parathyroid glands are clearly posterior and away from the sites to be clamped. Then hemostats are applied to the tissue and most of the lobe is resected (**FIG 5**). The remaining small thyroid remnant is oversewn for hemostasis. This resection can also be accomplished by using an energy device if one is far enough from the nerve so the heat does not damage it. Do not perform a subtotal thyroid lobectomy without visualizing the recurrent laryngeal nerve, for this is unsafe.
- At the end of the procedure for Graves' disease (**FIG 6**), a small, well-vascularized remnant of thyroid tissue can be left on each side, a procedure called bilateral subtotal lobectomies. In other instances, to achieve the same

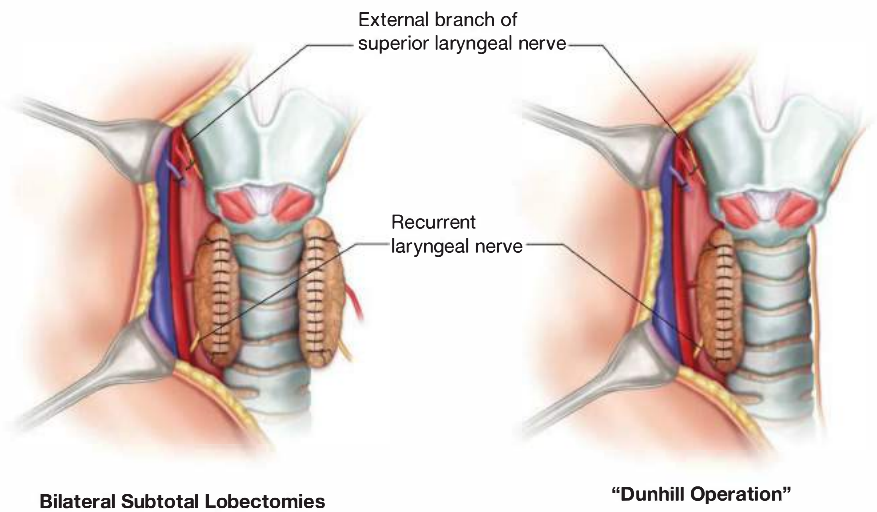

FIG 6 ● At the end of an operation for Graves' disease, each recurrent laryngeal nerve has been identified and preserved, and the parathyroid glands have been spared. Either small thyroid remnants are left bilaterally **(left)** or a total lobectomy and contralateral subtotal lobectomy **(right)** are performed, often called a "Dunhill operation."

result, a lobectomy can be performed on one side with a subtotal lobectomy on the other side, often called a Dunhill operation from the Australian surgeon who popularized this technique. Whichever operation is performed, it is important to leave small thyroid remnants especially in young patients in order to prevent a recurrence of disease. When severe ophthalmopathy is present, a total thyroidectomy may be most appropriate and many surgeons recommend total thyroidectomy instead of subtotal thyroidectomy more commonly for patients with graves' disease. However, always remember that Graves' disease is a benign disorder and our aim is to do an operation that does not cause a nerve injury or hypoparathyroidism.

- Many surgeons find a recurrent laryngeal nerve monitor to be helpful; although in current practice, its use is not mandatory.
- Finally, as stated, instead of suturing the thyroid, an energy device may be used. However, be careful when using these instruments, especially near the recurrent laryngeal nerve for the heat generated may damage it.

PEARLS AND PITFALLS

Preoperative considerations	■ When operating on the thyroid, some surgeons raise the head of the bed. Although this may seem attractive because it decreases venous bleeding, it is more dangerous because it increases the chance of an air embolism if a major vein is opened during the dissection. ■ The operation for Graves' disease is often more difficult than for colloid nodular disease because of an increase in vascularity and "stickiness" in some cases. Treatment with iodine preoperatively has been shown to decrease the blood flow to the thyroid. ■ Although it may be best to check the vocal cords preoperatively in all patients, the surgeon must be sure that both vocal cords are moving well in any patient who has had a previous neck or chest operation or in others who are hoarse.
Recurrent laryngeal nerve	■ Always visually identify the recurrent laryngeal nerve, carefully "unroof" it, and gently follow its course. Although temporary nerve injuries may occur when this practice is followed, rarely will the injury be permanent. ■ Remember that nonrecurrent recurrent laryngeal nerves may occur especially on the right side of the neck. Each is associated with a vascular anomaly. ■ Use of a recurrent laryngeal nerve monitor may be helpful especially in a reoperative thyroidectomy. However, this technique has not been shown to reduce nerve injuries and sometimes can be misleading to the casual user. ■ If the nerve monitor demonstrates the loss of recurrent laryngeal nerve function on the first side of the neck, one should strongly consider halting the operation or limiting the contralateral resection in order to prevent the possibility of a bilateral nerve injury if one proceeds.
Parathyroid	■ Carefully search for and try to save each parathyroid gland with a good blood supply. ■ Do not ligate the inferior thyroid artery as a single trunk. Rather, ligate small branches on the surface of the thyroid lobe in order to preserve the delicate blood supply to the parathyroid glands. ■ Autotransplant each parathyroid gland that looks devascularized, if it does not bleed well on biopsy or if it is accidently removed.
Postoperative care	■ Observe patients carefully postoperatively. Delayed bleeding with a hematoma can occur. ■ A postoperative neck hematoma is an emergency which requires rapid return to the operating room or opening of the wound at the bedside if respiratory symptoms are present. ■ In the postoperative care of a patient with Graves' disease, one cannot reliably use the TSH value alone to assess thyroid function, for the TSH value may stay suppressed even for weeks postoperatively if the patient was still thyrotoxic at the time of operation. The FT4 is usually a better indicator of function in the early postoperative course.

POSTOPERATIVE CARE

- In the recovery room, the patient should be observed for difficulty breathing and for swelling of the neck, which might indicate postoperative bleeding or hematoma. Return the patient to the operating room as an emergency if an expanding hematoma is recognized. Some surgeons advise endoscopic evaluation of the vocal cords in each patient; however, this should definitely be done if respiratory impairment is present.
- A serum calcium and PTH value is helpful. Some obtain a PTH in the recovery room; however, the authors generally wait until the morning of the first operative day to routinely obtain these results. Patients with Graves' disease may be more prone to manifesting hypocalcemia than others, partly due to bone hunger.
- Severe symptomatic hypocalcemia may require intravenous calcium therapy followed by oral calcium and vitamin D therapy. However, most patients are treated with oral calcium, which is given liberally and do very well. Thyroid

Table 1: Ablative Treatment of Graves' Disease with Thyrotoxicosis

Method	Dose or Extent of Surgery	Onset of Response	Complications	Remarks
Surgery	Subtotal excision of gland	Immediate	Mortality <1% Permanent hypothyroidism 20%–30% or greater[a] Recurrent hyperthyroidism <15%[a] Vocal cord paralysis approximately 1% Hypoparathyroidism approximately 1%	Applicable in young patients, pregnant women, large goiter, or nodular gland
Radioiodine 5–10 mCi		Several weeks to months	Permanent hypothyroidism, at least 50%–70%, often with delayed onset; multiple treatments sometimes necessary in large goiters	Avoid in children or pregnant women

[a]*Depends on size of thyroid remnant which is left in neck. As more tissue is removed, the incidence of hypothyroidism is increased but recurrence rate is diminished.*

replacement is given to many patients soon after surgery unless they are still thyrotoxic with a tachycardia. Although TSH is usually the best indicator of thyroid function, the FT4 is often a better indication in Graves' patients postoperatively because their TSH value may be suppressed for a considerable period of time.

OUTCOMES

- Although radioiodine therapy is the usual treatment, thyroidectomy is a very successful treatment for the thyrotoxicosis of Graves' disease in selected patients (Table 1). A major benefit is the rapid return to a euthyroid state, which is much quicker than following radioiodine therapy. It can be used in very young patients and during pregnancy if necessary. In each of these instances, radioiodine therapy is contraindicated. It removes the goiter and any thyroid nodules which are present. Finally, in patients with severe ophthalmopathy, many studies have shown improvement of eye changes or stabilization in others following thyroidectomy, whereas following radioiodine, the eye changes in some patients become worse.
- Postoperative thyroid function is directly related to the size of the thyroid remnants which are left in the neck. The larger the size of the remnant thyroid, the greater the rate of recurrence of thyrotoxicosis. Most patients and endocrinologists want a cure for the thyrotoxicosis and thus small thyroid remnants are preferable. In young patients, the chance of recurrence is greater and very small remnants should be used. In patients with severe ophthalmopathy, total thyroidectomy should be performed and may be most beneficial. Finally, subtotal or near-total thyroidectomy results in a lower incidence of complications than total thyroidectomy in most surgeons' practice and thus remains the surgical procedure of choice, especially in young children.

COMPLICATIONS

- Thyroid storm
- Postoperative hemorrhage (with respiratory distress)
- Injury to the external branch of the superior laryngeal nerve
- Unilateral or bilateral recurrent laryngeal nerve injury
- Temporary or permanent hypoparathyroidism

SUGGESTED READINGS

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Chapter 39

Minimally Invasive Video-Assisted Thyroidectomy

Paolo Miccoli Gabriele Materazzi

DEFINITION

- Minimally invasive video-assisted thyroidectomy (MIVAT) is an endoscopic procedure characterized by the use of external retraction, avoiding any gas inflation, in order to create an operative space in the neck.
- This approach to the thyroid has been used at our Department of Surgery for the last 15 years on more than 3,500 patients with results that can successfully rival those of standard open surgery.
- This is not an appropriate operation for any patient with thyroid disease; patients must be strictly selected. Only 10% to 30% of the cases[1] are appropriate for a MIVAT procedure.

PATIENT HISTORY AND PHYSICAL FINDINGS

- The inclusion criteria and the main contraindications are summarized in the following text. The most significant limit is represented by the size of both the nodule(s) and/or the gland as measured by means of an accurate ultrasonographic study obtained preoperatively. In countries where goiter is endemic, the gland volume can be relevantly independent from the nodule volume, and this aspect might be responsible for the necessity of converting the procedure.
- Ultrasonography can also be useful to exclude the presence of thyroiditis, which might make the dissection troublesome. In case ultrasonography only gives the suspicion of thyroiditis, autoantibodies should be measured in the serum. If thyroiditis is diagnosed preoperatively, this is a consideration to MIVAT.
- One of the most controversial aspects regarding the appropriateness of MIVAT is in the treatment of malignant thyroid disease. "Low-risk" papillary carcinoma constitutes an ideal indication for MIVAT,[2,3] but it is important to take into account the possibility of lymph node involvement in the neck. Great caution should be taken when there is the possibility of either metastatic lymph nodes or extracapsular invasion of the gland, both of which represent a contraindication to the minimally invasive endoscopic procedure.
- Indications
  - Multinodular goiter (thyroid volume less than 25 mL and nodules smaller than 3 cm)
  - Low-risk papillary carcinoma
  - Graves' disease
  - Microfollicular/Hürthle cell adenoma
  - *RET* gene mutation carriers (familial medullary thyroid carcinoma)
- Contraindications
  - Absolute
    - Previous neck surgery
    - Acute thyroiditis
    - Metastatic carcinoma (levels II to VI)
    - Locally advanced carcinoma
    - Sporadic medullary carcinoma
  - Relative
    - Previous neck irradiation
    - Short neck in an obese patient
    - Chronic thyroiditis

IMAGING AND OTHER DIAGNOSTIC STUDIES

- All patients should undergo (1) neck ultrasound in order to evaluate thyroid gland total volume (this should be less than 25 mL) and diameter of nodule/s (these should be less than 3 cm); (2) fine needle aspiration cytology of suspicious nodules; (3) blood tests in order to exclude thyrotoxicosis and acute thyroiditis before surgery; (4) basal serum calcitonin dosage is strongly suggested in order to exclude medullary carcinoma, which is a contraindication to MIVAT; (5) routine preoperative laryngoscopy is strongly recommended in all patients in order to identify asymptomatic vocal cord palsy.

TECHNIQUES

POSITIONING OF THE PATIENT AND DRAPING

- Patient is positioned in supine position without neck extension (FIG 1). Hyperextension must be avoided because it would reduce the operative space. Conventional neck preparation and draping is obtained. The skin is protected by means of a sterile film (Tegaderm®).

FIG 1 • Position of the patient on the operative table: Neck is not extended and skin is covered by sterile drapes.

POSITIONING OF THE SURGICAL TEAM

- Operation is performed by four surgeons: The first surgeon is on the right side of the table, the first assistant is on the left side of the table. The second assistant, who is holding the retractors, is at the head of the table. The third assistant, who is holding the endoscope, is on the left side of the table.The scrub nurse is behind the surgeon on the right side of the table (**FIG 2**).

FIG 2 ● Operating room setup: Team

- The surgeon is on the right side of the table.
- The first assistant is on the left side of the table (opposite the surgeon).
- The second assistant is at the head of the table.
- The third assistant is on the left side of the table.
- The scrub nurse is behind the surgeon on the right side of the table.

INSTRUMENTATION

- Forward-oblique telescope 30 degrees, diameter 5 mm, length 30 cm; suction dissector with cutoff hole, with stylet, blunt, length 21 cm; ear forceps, very thin, serrated, working length 12.5 cm; conventional tissue retractor army navy type; small tissue retractor, double-ended, length 12 cm; clip applier for vascular clips; straight scissors, length 12.5 cm, Harmonic Scalpel CS14; electrocautery (monopolar) (**FIG 3**).

FIG 3 ● Instrumentation for MIVAT.

INCISION AND PREPARATION OF THE OPERATIVE SPACE

- A 1.5-cm horizontal skin incision is performed 2 cm above the sternal notch in the central cervical area (**FIG 4**). Subcutaneous fat and platysma are carefully dissected so as to avoid any minimum bleeding.
- Two small retractors are used to expose the midline, which has to be incised for 2 to 3 cm in an absolutely bloodless plane (**FIG 5**).
- The blunt dissection of the thyroid lobe from the strap muscles is performed through the skin incision by gentle retraction and using tiny spatulas. When the thyroid lobe is almost completely dissected from the strap muscles,

FIG 4 ● A 1.5-cm horizontal skin incision is performed 2 cm above the sternal notch in the central cervical area.

larger and deeper retractors (army navy type) can be inserted and they will maintain the operative space during all the endoscopic part of the procedure (FIG 6).

- Then, a 30-degree, 5-mm or 7-mm endoscope is introduced through the skin incision: From this moment on, the procedure is entirely endoscopic until the extraction of the lobe of the gland. Preparation of the thyrotracheal groove is completed under endoscopic vision by using small (2 mm in diameter) instruments such as spatulas, forceps, spatula-sucker, and scissors.

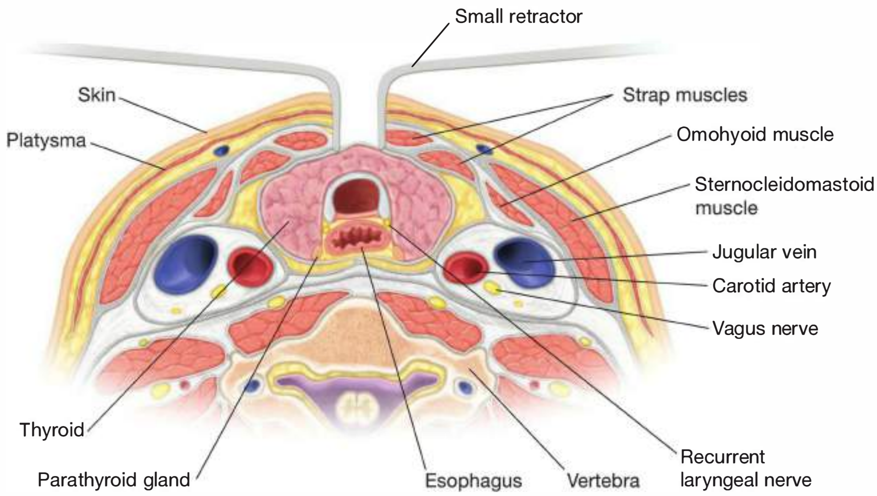

FIG 5 ● Two small retractors are used to expose the midline, which has to be incised for 2 to 3 cm on an absolutely bloodless plane.

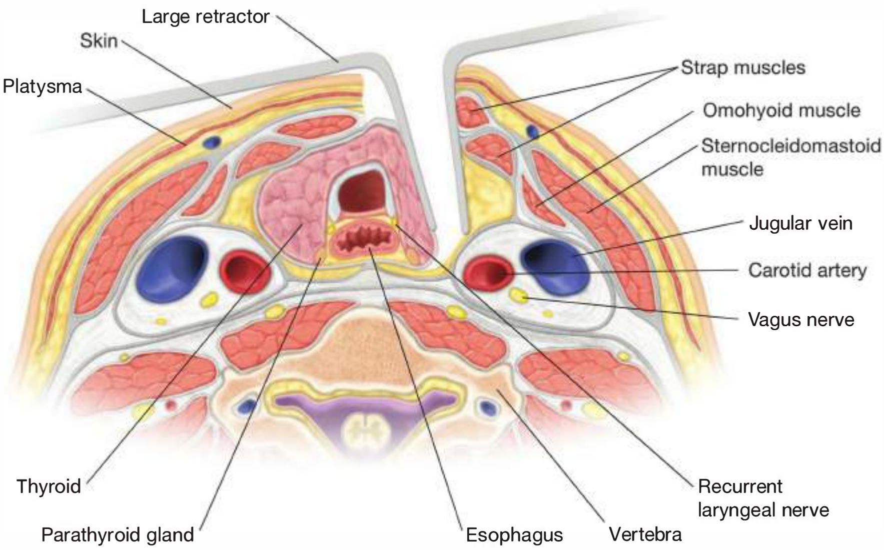

FIG 6 ● Access to the operative space during MIVAT: when the thyroid lobe is almost completely dissected from the strap muscles, larger and deeper retractors (army navy type) can be inserted and they will maintain the operative space during all the endoscopic part of the procedure.

SECTION OF THE MAIN THYROID VESSELS

- The first vessel to be ligated is the middle vein, when present, or the small veins between jugular vein and thyroid capsule. This step allows a better preparation of the thyrotracheal groove where the recurrent nerve will be later searched.
- During this step, the endoscope has to be held inside the camera with the 30-degree tip looking downward and in an orthogonal axis with the thyroid lobe and trachea.
- A further step is represented by the exposure of the upper pedicle, which must be carefully prepared, until an optimal visualization of the different branches is achieved. During this step, the endoscope should be rotated to 180 degrees with the 30-degree tip looking upward (**FIG 7**) and held in a parallel direction with the

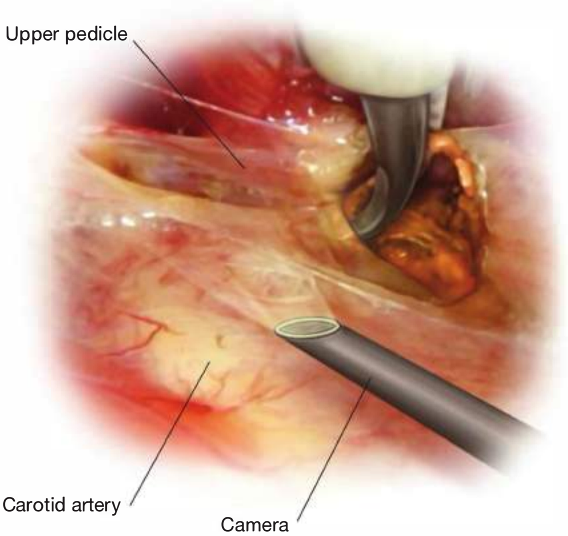

FIG 7 ● Upper pole section: During this step, the endoscope should be rotated to 180 degrees with the 30-degree tip looking upward and held in a parallel direction with the thyroid lobe and trachea in order to better visualize the upper portion of the operative space where the superior thyroid vein and artery are running.

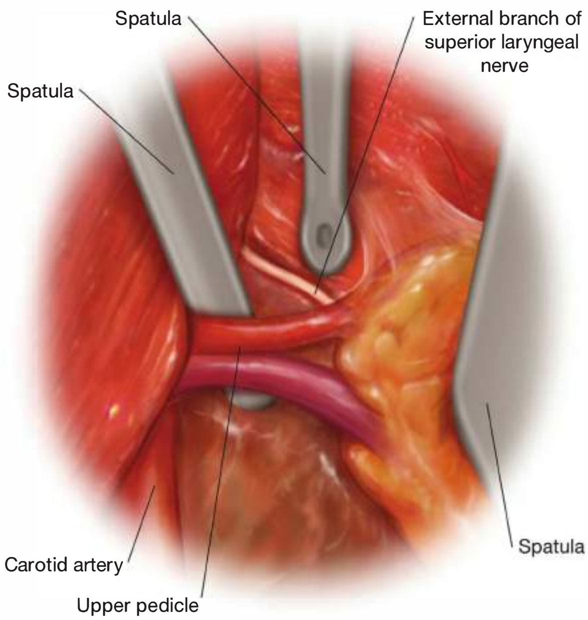

FIG 8 ● Identification of the external branch of the superior laryngeal nerve: The vessels (right side) are prepared by retracting downward and medially the thyroid lobe by means of the retractor and the spatula. A further spatula can be used to pull the vessels laterally. This will allow the external branch of the superior laryngeal nerve (SLN) to be easily identified during most procedures.

thyroid lobe and trachea in order to better visualize the upper portion of the operative space where the superior thyroid vein and artery are running.

- The upper pedicle is then prepared by retracting downward and medially the thyroid lobe by means of the retractor and the spatula. A further spatula can be used to pull the vessels laterally. This will allow the external branch of the superior laryngeal nerve to be easily identified during most procedures (**FIG 8**). Its injury can be avoided by keeping the inactive blade of Harmonic® in the posterior position so as to not transmit the heat to this delicate structure. At this point in time, section of the upper pedicle can be obtained by harmonic scalpel en bloc or selectively, depending on the diameter of the single vessels and/or the anatomic situation (**FIG 9**).

FIG 9 ● Section of the upper pedicle (left side) by harmonic scalpel. The inactive blade must be on the larynx in order to avoid any injury on laryngeal muscles and superior laryngeal nerve.

INFERIOR LARYNGEAL NERVE AND PARATHYROID GLANDS IDENTIFICATION AND DISSECTION

- After retracting medially and lifting up the thyroid lobe, the fascia can be opened by a gentle spatula retraction. During this step, the endoscope should be repositioned in an orthogonal axis with the thyroid lobe and trachea, looking downward with its 30-degree angle (**FIG 10**). The recurrent laryngeal nerve appears generally at this point in time, lying in the thyrotracheal groove, posterior to the Zuckerkandl tuberculum (posterior lobe), which is an important landmark in this step. This way, the recurrent nerve and the parathyroid glands are dissected and freed from the thyroid (**FIG 11A,B**).
- Dissection of the entire nerve from the mediastinum to its entrance into the larynx is not mandatory and might result in a time waste during the endoscopic phase. It is correct and very safe to identify the laryngeal nerve, to free it from the thyroid capsule as much as possible, but it is important to stress that the complete dissection of the nerve can be more easily obtained during the subsequent step, under direct vision, when the thyroid lobe has already been extracted.
- Both parathyroid glands are generally easily visualized during the endoscopic step; thanks to the camera magnification. Their vascular supply is preserved by selective division of the branches of the inferior thyroid artery. During dissection, when dealing with large vessels or small vessels close to the nerve, hemostasis can be achieved by 3-mm titanium vascular clips.

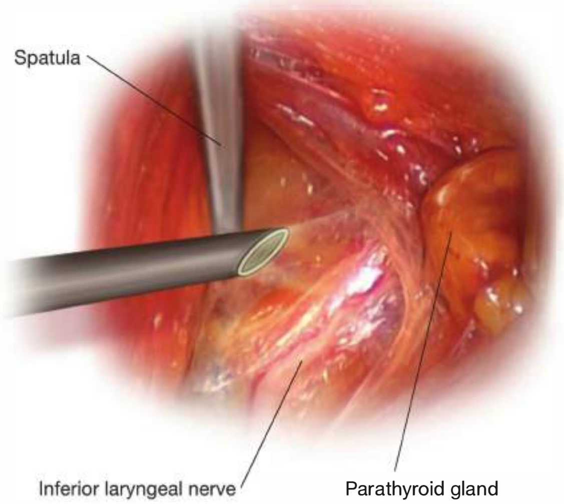

FIG 10 ● Inferior laryngeal nerve and parathyroids dissection: During this step, the endoscope should be repositioned in an orthogonal axis with the thyroid lobe and trachea, looking downward with its 30-degree angle.

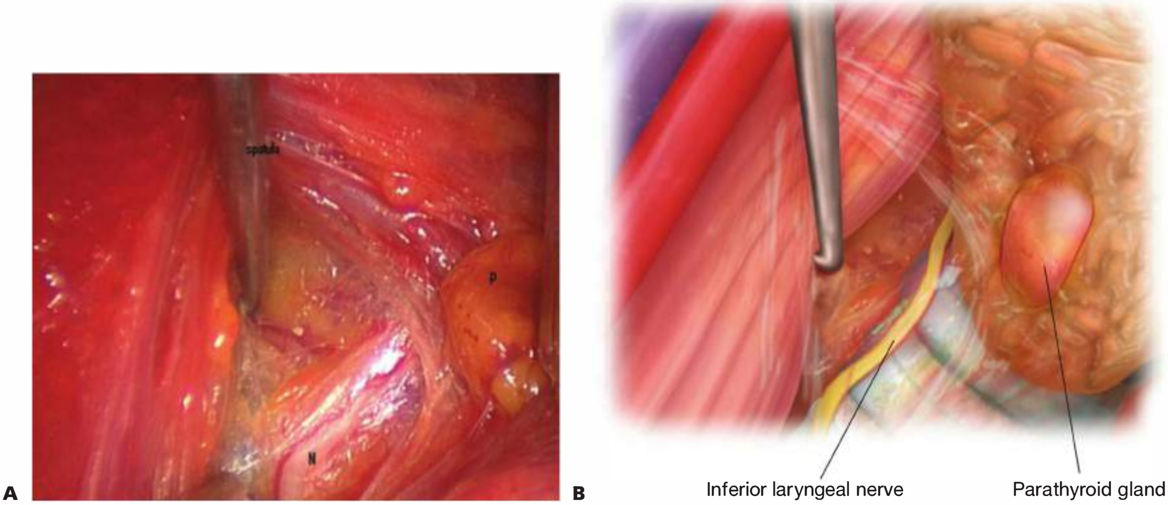

FIG 11 ● **A.** Endoscopic vision: dissection of the inferior laryngeal nerve. The recurrent laryngeal nerve *(n)* appears lying in the thyrotracheal groove. Parathyroid gland is also well visible *(p)*. **B.** Illustration of this step.

EXTRACTION OF THE LOBE AND RESECTION

- At this point in time, the lobe is completely freed. The endoscope and the retractors can be removed and the upper portion of the gland rotated and pulled out using conventional forceps. A gentle traction over the lobe allows the complete exteriorization of the gland (FIG 12). The operation is now conducted as an open surgery under direct vision. The lobe is freed from the trachea by ligating the small vessels and dissecting the Berry ligament. It is very important to check once again the laryngeal nerve at this point in time, so to avoid its injury before the final step. The isthmus is then dissected from the trachea and divided. After completely exposing the trachea, the lobe is finally removed.

FIG 12 ● Thyroid lobe extraction. A gentle traction over the lobe allows the complete exteriorization of the gland.

CLOSURE

- Drainage is not necessary. The midline is then approached by a single stitch; platysma is closed by a subcuticular suture and a cyanoacrylate sealant is used for the skin (FIGS 13 and 14).

FIG 13 ● Skin is reapproximated and closed by means of glue.

FIG 14 ● MIVAT: final result.

PEARLS AND PITFALLS

Indications	■ Perform preoperative ultrasound in order to evaluate thyroid volume (less than 25 mL) and nodule diameter (less than 3 cm). ■ Exclude thyrotoxicosis and acute thyroiditis ■ Exclude locally advanced or metastatic carcinoma
Incision	■ Create a central cervical incision two fingers above the sternal notch in order to easily allow for eventual conversion to cervicotomy. ■ Use a thin film of sterile drape on the electrocautery blade, leaving just the tip able to coagulate, in order to avoid damage to the skin or the superficial planes. ■ Avoid any bleeding from the anterior jugular veins.
Section of upper pedicle	■ The correct position of the retractors (both the first one on the strap muscles and the second one on the upper part of the thyroid lobe) is very important during this step, in order to obtain the best visualization of the vessels. ■ The endoscope should be rotated 180 degrees with the 30-degree tip looking upward.
Recurrent laryngeal nerve dissection	■ Avoid electrocautery (bipolar or monopolar) until both laryngeal nerves have been exposed. The Harmonic® device is used for almost all the vascular structures; but if the vessel is running particularly close to the inferior laryngeal nerve, then hemostasis is achieved by means of small vascular clips.
Closure	■ Close the midline with one single stitch, leaving some space in between the strap muscles, allowing quick blood evacuation in case of compressive hematoma.

POSTOPERATIVE CARE

- After surgery, patients undergoing MIVAT require strict observation during the first 5 to 10 hours on the ward. Dysphonia, airway obstruction, and neck swelling must be carefully checked. No drain is left, so careful surveillance for postoperative hematomas is required during the immediate postoperative period. Postoperative bleeding risk is very low and dramatically decreases after 5 hours.
- In case of postoperative hematoma, if compressive symptoms and airway obstruction are present, reintervention and immediate hematoma evacuation is required.
- Patients can start oral intake on the evening of the operative day and will be discharged the day after. On the first and second postoperative days, serum calcium must be checked in order to control hypoparathyroidism by substitutive therapy, as described in Table 1.
- Wound care is not really necessary after MIVAT because of the glue covering the skin, and postoperative pain will be controlled by means of both intravenous (IV) or oral analgesics.
- Voice impairments and subjective or objective dysphonia requires an immediate postoperative vocal cord check by an otolaryngologist. In the case of a normal postoperative course, a vocal cord check can be delayed until after 3 months.

Table 1: Management of Postoperative Hypocalcemia

Management of Hypocalcemia following Thyroidectomy on the First Postoperative Day	
Acute symptomatic	Calcium gluconate IV
Asymptomatic calcium ≤7.5 mg/dL[a]	Calcium (3 g) + vitamin D (0.5 μg) per os daily
Asymptomatic calcium 7.5–7.9 mg/dL	Calcium (1.5 g) per os daily

[a]Normal range: 8 to 10 mg/dL.

COMPLICATIONS

- Transient hypoparathyroidism and definitive hypoparathyroidism
- Transient monolateral inferior laryngeal nerve palsy and definitive monolateral inferior laryngeal nerve palsy
- Transient bilateral inferior laryngeal nerve palsy and definitive bilateral inferior laryngeal nerve palsy
- Hematoma (subcutaneous-conservative treatment; below strap muscles-reoperation)
  - Seroma
  - Wound infection

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Chapter **40**

Lymph Node Dissection in Thyroid Cancer

Gerard M. Doherty

DEFINITION

- Most thyroid cancer develops from the follicular cells of the thyroid gland (differentiated thyroid cancer includes papillary and follicular subtypes).
- Rare thyroid cancers develop from the C cells of the thyroid gland (medullary thyroid cancer).
- Thyroid cancer of any subtype can be associated with lymph node metastases in the neck.
- Clinical circumstances can indicate the need for cervical lymphadenectomy either as a therapeutic intervention for known metastases or as a prophylactic procedure for the diagnosis or therapy of occult metastases.
- The lymph node compartments of the neck are divided into "levels" to allow communication of the affected and dissected areas (**FIG 1**).
  - Level 6 is also known as the central neck and includes the lymph nodes medial to the carotid sheath on each side and bounded by the hyoid bone superiorly and the sternum inferiorly.
  - Levels 1 through 5 are also known as the lateral neck and include all of the node compartments lateral to the carotid sheath on each side.

PATIENT HISTORY AND PHYSICAL FINDINGS

- Thyroid cancer lymph node metastases can be palpable or, more often, nonpalpable but identifiable by imaging. Very small foci of thyroid cancer in lymph nodes may only be evident at microscopic pathology examination.

IMAGING AND OTHER DIAGNOSTIC STUDIES

- Patients with thyroid cancer should each have a staging ultrasound examination prior to operation.[1] This allows mapping of the lymph node status of each compartment in the neck (**FIG 2**).
- The level 6 lymph nodes are the most difficult to evaluate by ultrasound when the thyroid gland is still present, as these structures are in the same compartment.
- Patients with large tumors or gross adenopathy may be best studied by computed tomography (CT) scan with contrast or magnetic resonance scanning, as these modalities allow better examination of the areas low in the neck that may be obscured by gross disease on ultrasound (**FIG 3**).

SURGICAL MANAGEMENT

- Dissection of the level 6 lymph nodes is generally performed in conjunction with total thyroidectomy.
- The level 6 lymph nodes are removed by clearing the soft tissue that surrounds the thyroid gland. No additional incision or mobilization is necessary.
- Clearing these level 6 nodes involves additional manipulation of the soft tissue and vascular supply that surrounds the parathyroid glands. With these glands at additional risk of being damaged during operation, the performance of parathyroid autograft is particularly important to avoid permanent hypoparathyroidism[2] (**FIG 4**).

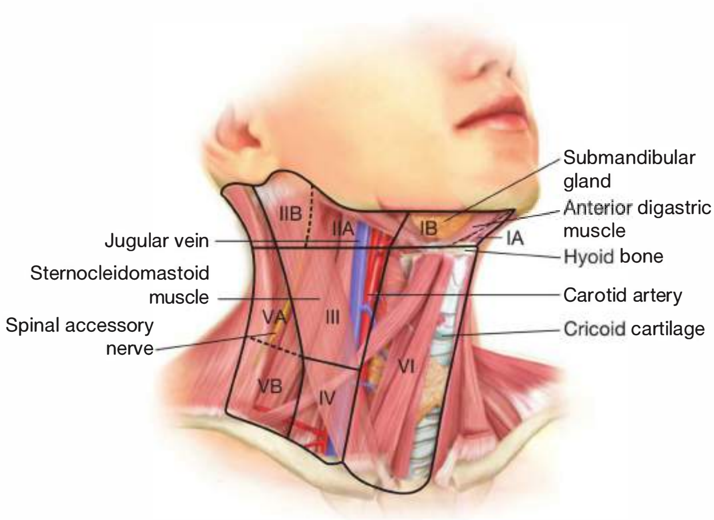

FIG 1 • Lymph node levels in the neck.

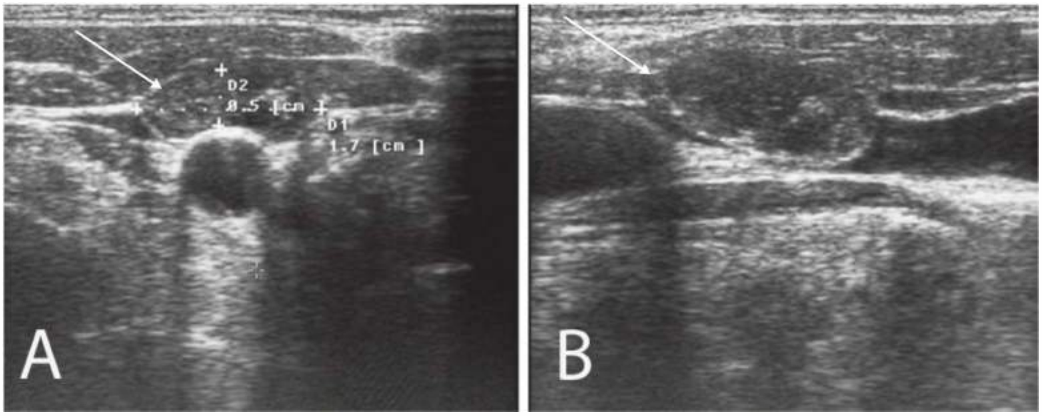

FIG 2 ● Ultrasound demonstration of metastatic lymph nodes in thyroid cancer. **Panel A** shows a transverse view *(arrow)*, and **panel B** shows the longitudinal view *(arrow)*.

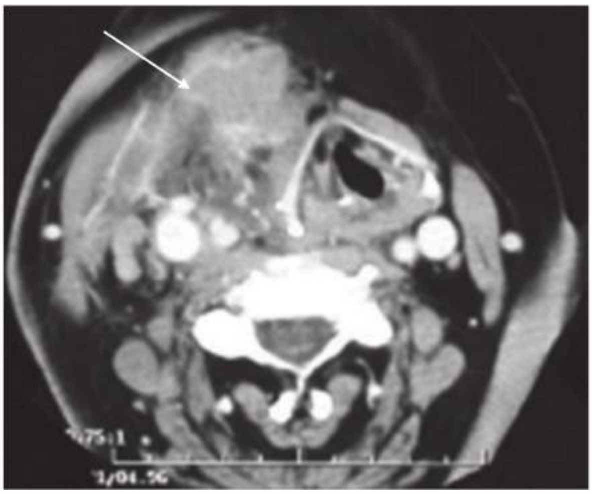

FIG 3 ● CT scan of recurrent nodal disease in the lateral neck impinging upon the central compartment *(arrow)*. CT is useful in this instance as ultrasound cannot completely define the anatomy.

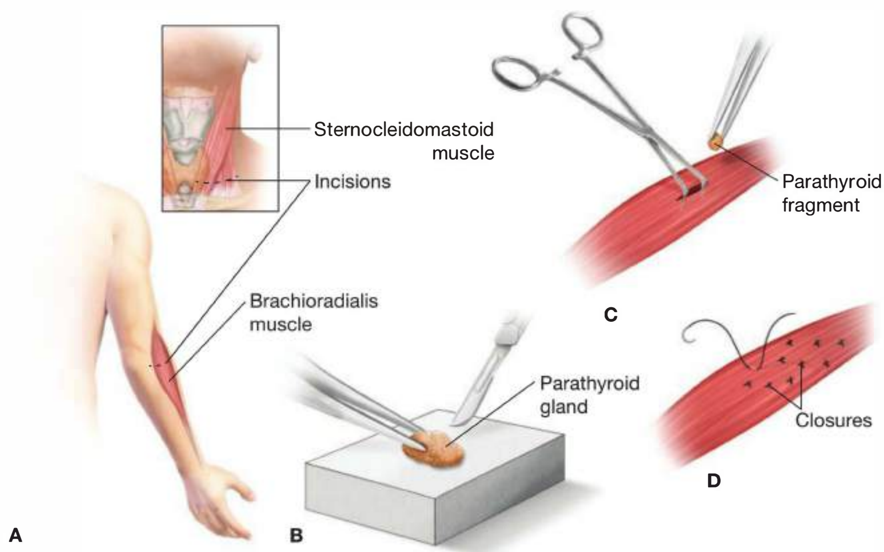

FIG 4 ● Schematic of parathyroid autograft. If a parathyroid gland has been devascularized during dissection, then the best management is parathyroid autograft. **A.** Parathyroid glands can be grafted into any muscle; common choices include the neck muscles for normal glands and the brachioradialis muscle for abnormal glands. **B.** The gland should be minced into small pieces (1- to 2-mm in each dimension). **C,D.** The fragments are placed into individual muscle pockets. The pockets are secured with a stitch. The grafts typically require 10 to 12 weeks before measurable function.

Preoperative Planning

- Review of the preoperative ultrasound findings is critical to the proper inclusion of all suspicious lymph nodes.
- Especially in reoperations, ultrasound in the operating room after the induction of anesthesia and positioning can be helpful to localize small lymph nodes.
- A nerve stimulating and monitoring system can be helpful and is commonly used to identify and to test function of motor nerves during dissection. Testing of the vagus nerve is probably best accomplished by using a specialized nerve stimulator that includes electromyography (EMG) monitoring pads on the endotracheal tube to detect vocalis muscle contraction. Testing of motor nerves for which the enervated muscle is visible can be done with a simple nerve stimulator.

Positioning

- The patient should be supine and the head may be raised above the heart to decrease venous congestion in the neck (FIG 5).
- Airway management is of particular concern. Preoperative anesthesiology consultation should alleviate positioning concerns while ensuring proper airway safety during the procedure.
- A towel roll or thyroid air pillow can be placed beneath the shoulder blades to facilitate neck extension.
- Arms should be tucked.

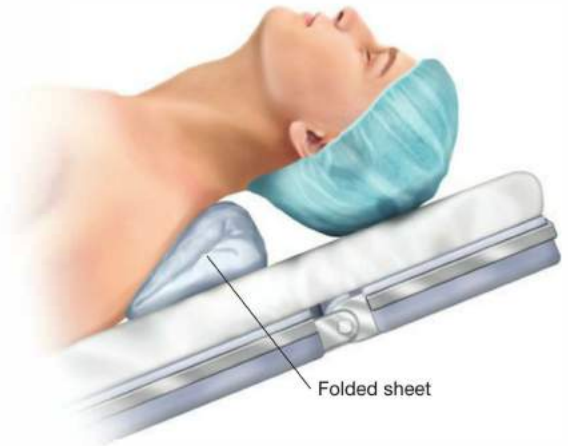

FIG 5 ● Position of the neck should emphasize extension, but support. Overextension of the neck or lack of support for the head and neck can cause avoidable posterior neck stiffness postoperatively.

TECHNIQUES

INCISION

- If a thyroidectomy is performed during the same anesthetic, the incision is extended laterally toward the posterior aspect of the neck; if not, then the dissection can generally be completed through a transverse incision at the level of the lower edge of the cricoid cartilage from the edge of the trachea to the anterior border of the trapezius muscle. The goal is to provide exposure of the anterolateral neck and posterior triangles.

RAISING SKIN AND PLATYSMA MUSCLE FLAPS

- Flaps are made superiorly, inferiorly, and posteriorly (FIG 6). The flaps should be in a plane superficial to the external jugular vein and should extend broadly over the compartments to be dissected. The facial vein can be divided and retracted superiorly. This has some benefit to retract and protect the marginal mandibular branch of the facial nerve. Erb's point can be identified as the area where the greater auricular nerve comes around the posterior edge of the sternocleidomastoid (SCM) muscle. This site is important to identify in order to protect the superficial sensory nerves that converge at that site.

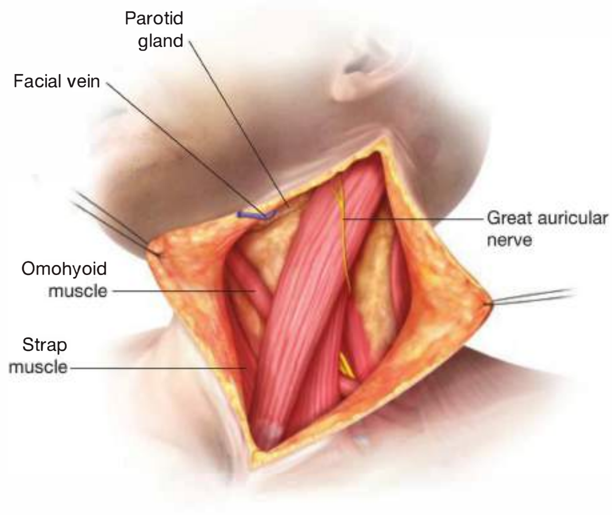

FIG 6 ● The subplatysmal flaps should be generous to avoid struggling at the margins of dissection later in the case.

MOBILIZING THE STERNOCLEIDOMASTOID MUSCLE

- The fascia over the middle of the SCM muscle is incised longitudinally with careful preservation of the greater auricular nerve.
- The fascia is then stripped from the muscle over a broad area, unwrapping the muscle and following the fascial plane around the front edge of the muscle to its deep surface. The plane is continued deep to the muscle back to its posterior edge.
- The sensory nerves at Erb's point (greater auricular, lesser occipital, transverse cervical, and supraclavicular) are all preserved.
- The SCM muscle is encircled with a Penrose drain for traction to provide exposure (**FIG 7**).
- The omohyoid muscle is divided to improve exposure of the underlying nodal packet.

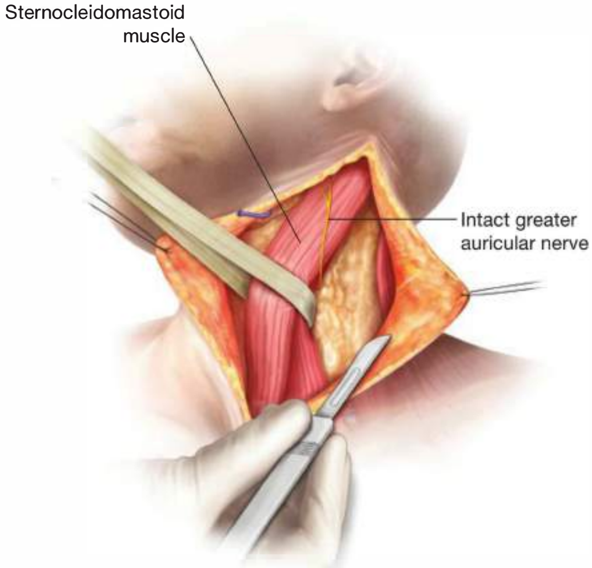

FIG 7 ● Once the SCM muscle has been mobilized, the fascia over the node packet can be incised laterally. This will allow separation of the fatty soft tissue from the anterior edge of the trapezius muscle. Great care is needed to identify the spinal accessory nerve without injury.

DISSECTION OF SOFT TISSUE SPECIMEN

- Dissection of the nodal packet can be initiated in a number of places (**FIG 8**). The posterior triangle is a common choice. The superficial fascia along the anterior edge of the trapezius muscle is carefully incised along the muscle edge to avoid inadvertent division of the spinal accessory motor nerve.
- The nodal packet attachments to the trapezius are taken down initially with blunt dissection, especially prior to identification of the spinal accessory nerve. Unless there is direct involvement of the nerve by tumor, the nerve should be preserved.
- The specimen is dissected from lateral to medial with attention to the underlying structures.
  - The supraclavicular sensory nerves fan out from Erb's point and divide the level 5 specimen into superficial and deep components. Removal of all nodes with preservation of the major branches of these nerves requires recognition of this and careful dissection.
- Once the dissection reaches the area deep to the SCM muscle, the jugular nodes (levels 2 to 4) are dissected either starting from the top (level 2) or the bottom (level 4) of the jugular chain, removing these nodes en bloc with the posterior triangle specimen.
- The jugular vein is generally preserved unless there is involvement of the vein by direct invasion or tumor thrombus. If the vein cannot be preserved, it is included in the specimen. There is no morbidity of including this in a unilateral dissection.
- The specimen is removed en bloc, marked, and prepared for pathologic examination.

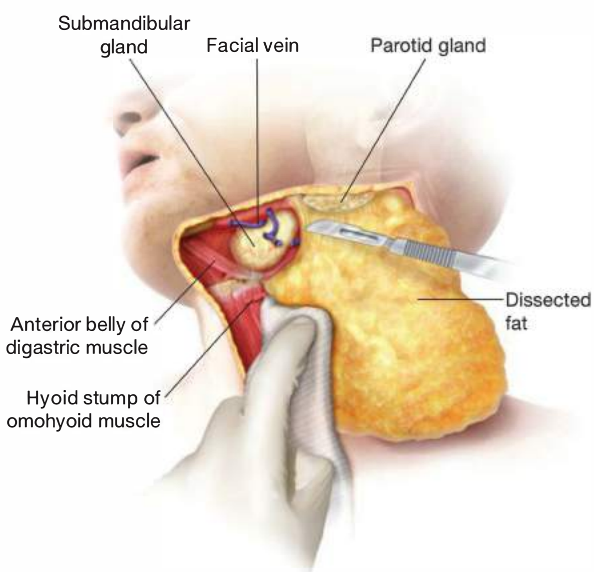

FIG 8 ● The dissection progresses with mobilization of the soft tissues away from the jugular vein (SCM not shown).

INSPECTION AND CLOSURE

- Once the specimen has been removed, the field is carefully inspected for residual soft tissue that can be removed (FIG 9). Nerves are tested for confirmation of function findings and hemostasis is ensured. Special inspection at the base of the jugular vein should ensure that there is no evidence of chyle leak.
  - A small drain is often placed to remove serum or chyle that could accumulate. If the operation has been straightforward and the disease burden low, then this may be omitted.
- The wound is closed in two layers, the platysma muscle layer with interrupted absorbable suture and the skin by whatever cosmetically advantageous method the surgeon chooses.

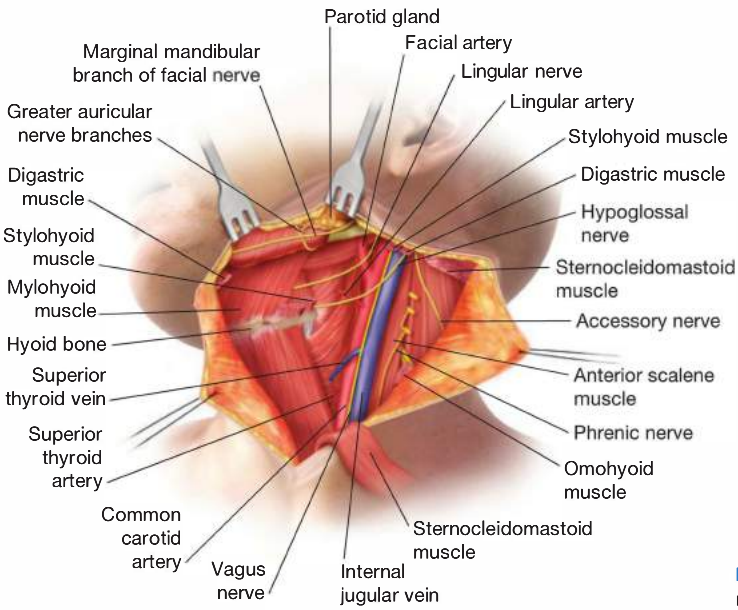

FIG 9 ● Anatomy of the neck after the node-bearing soft tissues have been removed.

PEARLS AND PITFALLS

Indications	■ Prophylactic lateral neck dissection is not generally indicated for thyroid cancer.
Raising of flaps	■ The flaps plane must be accurately placed deep to platysma and superficial to external jugular vessels.
Mobilizing SCM muscle	■ Avoid injury to the sensory nerves at Erb's point.
Dissecting specimen	■ Identify the spinal accessory nerve early to avoid injury.
Ensuring hemostasis	■ Small venous branches in the soft tissue deep to the clavicle, at the inferior margin of the dissection, can cause bothersome bleeding.
Avoiding chyle leak	■ Pay careful attention to clear fluid welling up near the inferior-most visible portion of the jugular vein, on either side but especially the left.

POSTOPERATIVE CARE

- Drains should be inspected for lymphatic leak and patients instructed on drain care.
- Drains should be removed once output decreases to 30 mL or less per day.

OUTCOMES

- Functional outcomes are excellent if nerves are preserved.
- A minority of patients requires physical therapy to regain full range of shoulder motion.

COMPLICATIONS

- Nerve injury: spinal accessory nerve; vagus or recurrent laryngeal nerve injury (if central neck dissection is included in the procedure); brachial plexus
- Vascular injury: internal jugular vein; carotid artery causing neck hematoma, which can progress to airway compromise
- Thoracic duct injury leading to lymphatic leak, possibly requiring operative intervention for thoracic duct ligation
- Regional disease recurrence

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Chapter 41

Open Neck Exploration for Primary Hyperparathyroidism

Christopher R. McHenry

DEFINITION

- An open neck exploration for hyperparathyroidism (HPT) is defined as exposure of an abnormal parathyroid gland or glands using standard operative techniques through a single incision without endoscopic or videoscopic assistance. This includes bilateral neck exploration for patients with multiglandular disease and unilateral focused parathyroidectomy with intraoperative parathyroid hormone (PTH) monitoring for a single adenoma localized preoperatively.

DIFFERENTIAL DIAGNOSIS

- Primary HPT and malignancy account for 80% of all causes of hypercalcemia.
- Primary HPT accounts for 50% to 60% of all cases of hypercalcemia diagnosed in an ambulatory setting and approximately 30% of cases diagnosed in a hospital setting.
- There are many less common causes for hypercalcemia (Table 1).
- In patients with primary HPT, 85% to 90% will have a single adenoma, 5% to 10% hyperplasia, 3% to 4% double adenoma, and less than 1% carcinoma.

Table 1: Causes of Hypercalcemia

Hyperparathyroidism
Primary and tertiary
Malignancy
Osteolytic bone metastases
Tumor production of PTH-related polypeptide
Squamous cell carcinoma of the lung
Renal cell carcinoma
Bladder cancer
Hematologic malignancies
Leukemia
Lymphoma
Multiple myeloma
Granulomatous disease
Tuberculosis
Sarcoidosis
Fungal infection
Medications
Calcium
Vitamin A or D intoxication
Lithium
Thiazides
Milk-alkali syndrome
Miscellaneous
Hyperthyroidism
Paget's disease
Immobilization
Familial hypocalciuric hypercalcemia

PTH, parathyroid hormone.

PATIENT HISTORY AND PHYSICAL FINDINGS

- Primary HPT occurs in 1 out of every 500 women and 1 out of every 2,000 men. It most commonly occurs in women between the ages of 50 and 60 years.
- Most patients with primary HPT are diagnosed as a result of the incidental hypercalcemia detected on blood work that is obtained for an unrelated medical problem. Patients often have nonspecific symptoms such as fatigue, weakness, constipation, and depression.
- Patients with primary HPT may present with plethora of clinical manifestations (Table 2). Nephrolithiasis is the most common metabolic complication of primary HPT occurring in 15% to 20% of patients; however, only 2% to 5% of patients with kidney stones have primary HPT.
- Approximately 3% of patients may present with hyperparathyroid crisis manifested by severe hypercalcemia (serum calcium >14 mg/dL), nausea, vomiting, dehydration, and central nervous system dysfunction including coma.[1]
- Primary HPT is associated with a higher risk of cardiovascular disease and mortality that decreases after parathyroidectomy.[2]
- A prior history of head or neck radiation in childhood, radioiodine treatment, and long-term lithium therapy are associated with a greater prevalence of primary HPT.
- In 5% of patients, primary HPT is an inherited syndrome, underscoring the importance of obtaining a thorough family history. Familial HPT is inherited as an autosomal dominant

Table 2: Clinical Manifestation of Primary Hyperparathyroidism

Renal	**Psychiatric**
Nephrolithiasis	Depression
Nephrocalcinosis	Lethargy
Polyuria	Memory loss
Renal insufficiency	Confusion
	Hallucinations
	Coma
Skeletal	**Neuromuscular**
Generalized bone or joint pain	Fatigue
Osteopenia	Weakness
Osteoporosis	Malaise
Gout	
Pseudogout	
Pathologic bone fracture	
Osteitis fibrosa cystica	
Gastrointestinal	**Cardiovascular**
Constipation	Exacerbation of hypertension
Peptic ulcer disease	Cardiac calcification
Pancreatitis	Left ventricular hypertrophy
Nausea	Decreased QT interval
Vomiting	Conduction abnormalities
Abdominal pain	Heart block

Table 3: Familial Hyperparathyroidism
A. Familial isolated hyperparathyroidism
B. MEN I
Primary hyperparathyroidism
Gastroenteropancreatic tumors
Pituitary adenoma
Adrenocortical and thyroid tumors
Lipomas
Meningiomas
Facial angiofibromas
Bronchial, gastric, and thymic carcinoid tumors
C. MEN IIA
Medullary thyroid cancer
Pheochromocytoma
Primary hyperparathyroidism
Lichen planus amyloidosis
Hirschsprung disease
D. Hyperparathyroidism–jaw tumor syndrome
Ossifying fibromas of the mandible or maxilla
Renal cysts, hamartomas, and Wilms tumor
Uterine adenosarcoma, adenofibroma, leiomyoma, adenomyosis, and endometrial hyperplasia

syndrome with primary HPT occurring as an isolated entity or as part of multiple endocrine neoplasia (MEN) I, MEN IIA, or the hyperparathyroidism–jaw tumor syndrome (Table 3). Patients with hyperparathyroidism–jaw tumor syndrome have more severe hypercalcemia and a 10% to 15% incidence of parathyroid cancer.

- In most patients with primary HPT, the physical examination is normal. Less than 5% of patients with primary HPT will have a palpable parathyroid tumor. Patients with hyperparathyroid crisis are more likely to have a palpable neck mass.
- A palpable neck mass in patients with primary HPT should raise suspicion for parathyroid cancer or an associated thyroid nodule.
- Rare patients may have band keratopathy, a condition characterized by calcium phosphate deposition in the cornea, which can be identified by slit lamp examination.

IMAGING AND OTHER DIAGNOSTIC STUDIES

- A diagnosis of primary HPT is made by an elevated serum calcium level and an elevated or inappropriately normal intact serum PTH level.
- Up to 20% of patients have normocalcemic primary HPT with a serum calcium level in the normal range. Most patients with normocalcemic primary HPT are diagnosed as a result of evaluation for kidney stones, osteoporosis, or osteopenia. Vitamin D deficiency, excess phosphate intake, low calcium set point, and hypo- or hypermagnesemia may be contributory factors to normocalcemic HPT.
- Patients with primary HPT may have low or low normal serum phosphate and high serum chloride, alkaline phosphatase, and uric acid levels. Alkaline phosphatase is elevated in patients with bone disease.
- Patients may also have a mild metabolic acidosis, which occurs because of the inhibitory effect of PTH on phosphorus and bicarbonate reabsorption in the kidney.
- Prior to the introduction of sensitive immunoradiometric and chemiluminescence assays for measurement of intact PTH levels, a chloride to phosphorus ratio greater than 33:1 was used to make the diagnosis of primary HPT.
- Blood urea nitrogen, serum creatinine, and glomerular filtration rate should be measured and followed, because renal insufficiency is a known complication of primary HPT.
- Bone mineral density should be measured at the lumbar spine, hip, and distal radius using dual energy x-ray absorptiometry.
- A calcium:creatinine clearance ratio should be determined if familial hypocalciuric hypercalcemia (FHH) is suspected. FHH is a rare autosomal dominant disorder characterized by asymptomatic hypercalcemia, hypocalciuria, and variable PTH elevation that results from a higher renal setpoint for calcium secretion. Patients with FHH have one or more first-degree relatives with hypercalcemia, a calcium:creatinine clearance less than 0.01, and a 24-hour urine calcium less than 100 mg. Parathyroidectomy is not indicated.
- Once a diagnosis of primary HPT has been established, imaging should be performed to localize an abnormal parathyroid gland or glands. When an abnormal parathyroid gland can be localized preoperatively, a focused parathyroidectomy can be performed with intraoperative PTH measurement to confirm cure of the primary HPT. This minimizes dissection, shortens the operation, and reduces cost.
- Localization studies should only be performed once a diagnosis of HPT has been established and a decision to proceed with surgical therapy has been made. The role of localization studies is to help determine the site of the incision and where in the neck to begin the exploration.
- Office-based, high-resolution ultrasonography is the initial imaging study performed. A parathyroid adenoma appears as a homogeneous, hypoechoic, oval- or bean-shaped mass posterior to the thyroid gland (**FIG 1**). Occasionally, a parathyroid adenoma may be multilobulated. Ultrasound is also of value in identifying concomitant nodular thyroid disease.
- Technetium-99m-sestamibi with single-photon emission computed tomography (SPECT) is a combined functional and anatomic imaging study, which is obtained prior to operation. It is particularly beneficial for identifying ectopic parathyroid glands (**FIG 2**).
- Four-dimensional computed tomography and positron emission tomography/computed tomography (PET/CT) fusion imaging are other potentially valuable imaging studies to help localize abnormal parathyroid glands but are usually reserved for patients with persistent or recurrent HPT.

FIG 1 ● High-resolution ultrasound image of 1.32 × 0.77 cm homogenous, hypoechoic mass inferior to the right lobe of the thyroid gland in a sagittal view. At operation, this was confirmed to be a right inferior parathyroid adenoma.

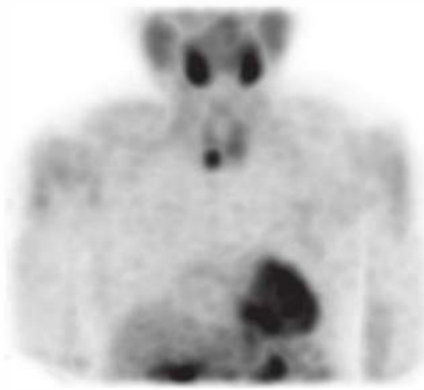


FIG 2 ● Technetium-99m-sestamibi image demonstrating abnormal radiotracer accumulation inferior to the inferior pole of the right lobe of the thyroid gland.

- Intraoperative PTH monitoring is most valuable in patients with discordant lesions on ultrasound and technetium-99m-sestamibi. It has been suggested that intraoperative PTH monitoring is unnecessary in patients with concordant lesions detected on ultrasound and technetium-99m-sestamibi imaging.

SURGICAL MANAGEMENT

- All patients with primary HPT should be presented with option of surgical therapy, because parathyroidectomy is the only curative treatment. The classical symptoms of primary HPT (nephrolithiasis, osteoporosis, osteitis fibrosa cystica, and neuromuscular dysfunction) are well-established indications for surgery.
- In patients with asymptomatic primary HPT, indications for surgical therapy have been defined by the 2008 revised consensus guidelines sponsored by the National Institutes of Health[3] (Table 4). Parathyroidectomy is recommended in all patients younger than 50 years of age because at least 25% will develop one or more complications of HPT during their lifetime, which can be irreversible. Significant hypercalcemia, renal dysfunction, reduction in bone mineral density, and inability or unwillingness to participate in subsequent medical surveillance and follow-up are other indications for parathyroidectomy in patients with asymptomatic primary HPT.

Table 4: Indications for Surgical Therapy in Patients with Asymptomatic Primary Hyperparathyroidism as Established by the 2008 Revised National Institutes of Health Consensus Guidelines

Serum calcium >1 mg/dL above the upper limit of the normal range
Glomerular filtration rate <60 mL/min
Decreased bone density: T score of −2.5 or less at lumbar spine, femoral neck, hip, or distal radius
Age <50 years
When routine follow-up and medical surveillance is problematic or not possible

- Open neck exploration for primary HPT is performed as an outpatient procedure under general anesthesia or local anesthesia with sedation. Various intraoperative adjuncts may be used including ultrasound, PTH monitoring, and radio guidance.
- Intraoperative ultrasound may be used to help determine the best site for the incision.
- Intraoperative PTH monitoring may be used to help determine that all hyperfunctioning parathyroid tissue has been excised and to confirm cure of primary HPT.
- Administration of technetium-99m-sestamibi prior to operation and use of a gamma probe intraoperatively is used by some surgeons to help localize abnormal parathyroid tissue and confirm ex vivo that a sestamibi-avid parathyroid gland has been removed and that no sestamibi-avid glands remain in the neck. Some of the limitations of this technique include that hyperplastic parathyroid glands are most often not sestamibi-avid, and thyroid nodules may also retain sestamibi, producing false-positive results.
- For a single adenoma localized preoperatively, a unilateral focused parathyroidectomy with intraoperative PTH monitoring to confirm cure of primary HPT is performed.
- Bilateral neck exploration is indicated for patients with negative preoperative imaging or when bilateral disease is detected preoperatively and for patients with a higher likelihood of multiglandular disease such as patients with MEN I, MEN IIA, or lithium-associated HPT. It may also be necessary for patients with associated thyroid disease. Bilateral neck exploration may also be preferentially used in all patients with primary HPT.
- Patients with a double adenoma are treated with resection of the two enlarged glands.
- Patients with parathyroid hyperplasia are preferentially treated with subtotal parathyroidectomy, leaving a well-vascularized parathyroid remnant that approximates the weight and size of one normal parathyroid gland. A bilateral transcervical thymectomy is also performed because of a 5% to 15% incidence of supernumerary parathyroid glands, which are most commonly found in the thymus. Alternatively, a total parathyroidectomy and parathyroid autotransplantation into the brachioradialis muscle of the nondominant forearm may be performed (see Part 5, Chapter 42).
- Patients with parathyroid cancer are treated with an en bloc resection of the tumor and the surrounding structures that are invaded. This usually involves resection of the lobe of the thyroid gland and the strap muscles.
- Patients with parathyroid cancer usually present with marked elevation in serum calcium and PTH levels and they may have a palpable neck mass. Parathyroid cancer typically has a gray-white appearance and diagnosis is confirmed by the presence of local invasion of surrounding structures (**FIG 3**).

Preoperative Planning

- Serum levels of 25-hydroxy-vitamin D and alkaline phosphatase are measured preoperatively. Patients with low 25-hydroxy-vitamin D and elevated alkaline phosphatase levels are at increased risk for symptomatic postoperative hypocalcemia.

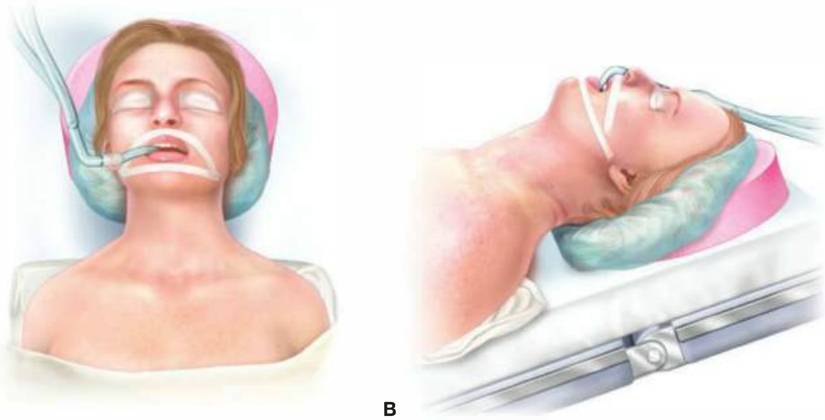
FIG 3 ● A parathyroid cancer with its typical gray-white appearance and the lobe of the thyroid gland, which was invaded by the cancer.

- A sequential compression device is preferably used for prophylaxis against deep vein thrombosis to minimize the risk of postoperative neck hematoma, which may occur with the use of subcutaneous heparin or Lovenox. Routine surgical antimicrobial prophylaxis is unnecessary.
- No special preoperative preparation is required except for patients who present with hyperparathyroid crisis. Hydration with a saline infusion, calciuresis, bisphosphonate therapy, and/or a calcimimetic agent are used to correct severe life-threatening hypercalcemia before proceeding with parathyroidectomy.[1]

TECHNIQUES

POSITIONING

- The patient is positioned on the operating table with a roll placed lengthwise beneath the shoulders, the neck extended, and the head on a soft foam headrest. The patient's arms are tucked at the side (**FIG 4**).
- The bed is placed in slight reverse Trendelenburg to reduce venous pressure. The ventilatory tubing is directed off the back of the operating table to optimize the working space for the surgeon and assistants (**FIG 4**).
- The surgical field is widely prepped with ChloraPrep and allowed to dry for 3 minutes before sterile drapes are applied.



A **B**

FIG 4 ● Anteroposterior and lateral views of patient who is positioned for parathyroid surgery. The patient's neck is extended with a soft roll placed beneath the shoulder blades and their head positioned on a soft foam pillow. The bed is placed in approximately 30 degrees of reverse Trendelenburg. The ventilator tubing is passed of the head of the bed.

INCISION

- The surface anatomy of the neck is identified before determining the site of the skin incision (**FIG 5**). For the best cosmetic result, it is often best to mark the site of the incision with the patient standing in the preoperative holding area. This will help to ensure that the incision is within a normal skin crease and is symmetrical. A curvilinear incision is made in the midline of the neck between the cricoid cartilage and the sternal notch.
- The site of the incision is based on preoperative localizing scans, the patient's natural skin creases, and other cosmetic considerations. Intraoperative ultrasound may sometimes be of help to decide the placement of the incision.

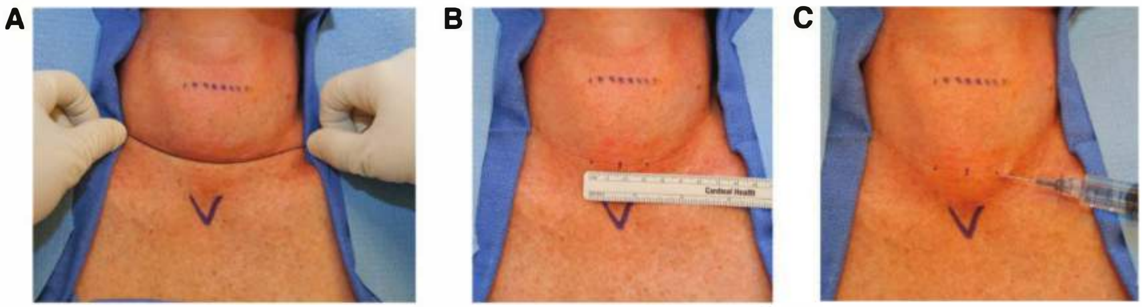


FIG 5 ● **A.** The sternal notch and cricoid cartilage are marked to help decide the most appropriate site for the incision. A 0 silk suture is used to mark the site of the incision. **B.** A 3-cm incision is marked in the midline. **C.** 0.5% Marcaine is used to anesthetize the site of the incision prior to making the incision to establish preoperative analgesia.

- A midline incision is cosmetically preferable and it allows easy access to both sides of the neck for exploration.
- Applying gentle pressure to the neck using a 0 silk suture marks the site of the incision. This is important to maintain symmetry and ensure a curvilinear incision (**FIG 5**).
- The midpoint of the incision is marked on the skin using the midpoint of the sternal notch as a landmark.
- A 2- to 4-cm incision in the midline of the neck is used for parathyroidectomy (**FIG 5**). Patients with a short, thick neck and/or morbid obesity may require a longer incision to improve exposure.
- 0.5% bupivacaine is used to anesthetize the site of the incision prior to making the incision to establish preemptive analgesia (**FIG 5**). This helps enhance patient comfort postoperatively.
- A no. 15 blade scalpel is used to incise the skin. The electrocautery is used to divide the subcutaneous tissue and the platysma muscle.

CREATION OF A WORKING SPACE

- Skin flaps are raised in a subplatysmal plane using skin hooks and small Richardson retractors to elevate the skin (**FIG 6**).
- The anterior jugular veins are identified and the plane of dissection is established immediately anterior to the veins (**FIG 6**).
- The superior skin flap is raised to the prominence of the thyroid cartilage and the inferior skin flap is raised to the sternal notch.
- The sternal heads of the sternocleidomastoid muscle are exposed laterally.

FIG 6 ● **(A)** Superior skin flaps raised in a subplatysmal plane using the anterior jugular veins (**B** and **C**) to create the plane of dissection.

EXPOSURE OF THE THYROID GLAND

- The sternohyoid muscles are separated in the midline along the median raphe with the electrocautery from the sternal notch inferiorly to the thyroid cartilage superiorly (**FIG 7**). The median raphe is an avascular plane consisting of the investing fascia of the thyroid gland.
- Separation of the sternohyoid muscles exposes the thyroid gland.
- The sternothyroid muscle is then dissected and elevated from the surface of the thyroid lobe (**FIG 8**). This is accomplished by blunt and sharp dissection of the intervening loose areolar tissue.

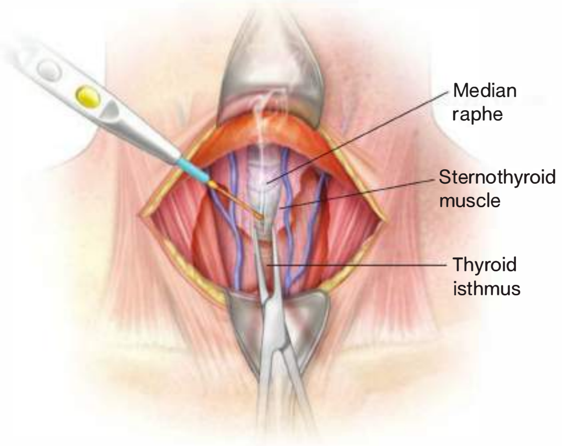


FIG 7 ● The sternothyroid muscles are separated along the median raphe to expose the underlying thyroid gland.

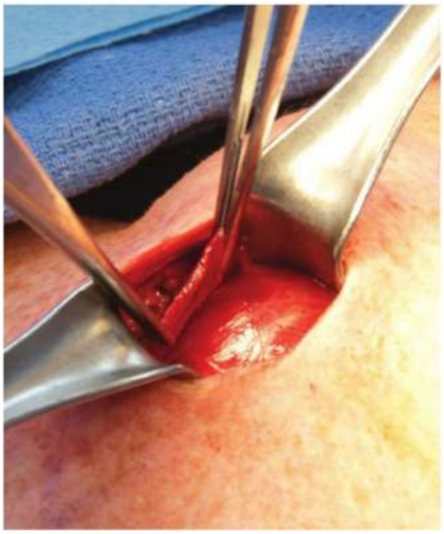


FIG 8 ● The sternothyroid muscle is gently retracted with forceps and is freed from the underlying thyroid lobe.

MOBILIZATION OF THE THYROID LOBE AND EXPOSURE OF AN ABNORMAL PARATHYROID GLAND

- The sternothyroid and the sternohyoid muscles are retracted laterally.
- The lobe of the thyroid gland is elevated anteriorly and medially. An Allis clamp applied to the thyroid lobe facilitates retraction and optimizes exposure in a small working space.
- The middle thyroid vein is identified. It may be divided if necessary for improved exposure.
- It is important to maintain a bloodless field. Blood staining of the tissues can make it more difficult to identify normal and abnormal parathyroid tissue.
- The initial search for an abnormal parathyroid gland is based on preoperative localization studies. Exploration of the normal anatomic location for a superior or inferior parathyroid gland is completed first.
- Abnormal parathyroid glands are larger, more firm, and darker in color than normal parathyroid glands (**FIG 9**).
- In adults, a normal parathyroid gland is yellow-tan in color and oval-, spherical- or bean-shaped. It is usually 5 mm in maximum dimension and, on average, weighs 35 to 50 mg (**FIG 10**). In general, there is no need to biopsy a normal-appearing parathyroid gland.
- The normal location for a superior parathyroid gland is posterior and superior to the recurrent laryngeal nerve. It is approximately 1 cm cephalad to the junction of the inferior thyroid artery and the recurrent laryngeal nerve where the recurrent laryngeal nerve enters the

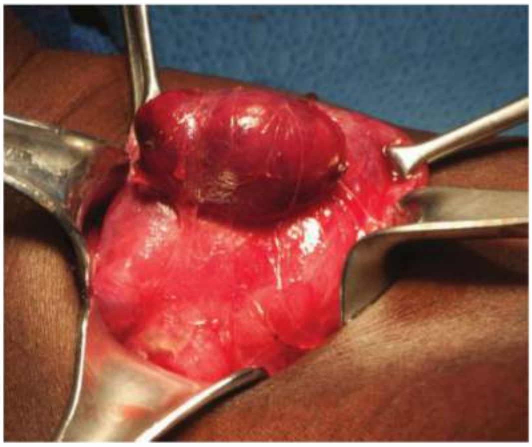


FIG 9 ● Anteromedial rotation of the lobe of the thyroid gland to expose a large abnormal parathyroid gland that is firm and dark in color.

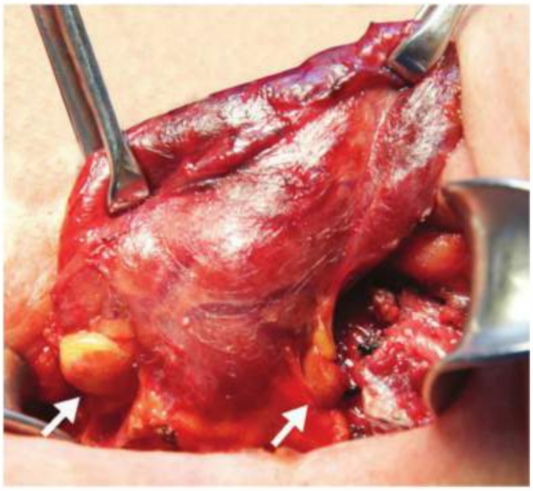


FIG 10 ● Two normal parathyroid glands are seen in their normal anatomic position *(arrows)*. Both have a typical yellow-tan color and are oval in shape. The superior parathyroid gland is surrounded by the adipose tissue.

larynx posterior to the inferior pharyngeal constrictor muscle (FIG 11).

- The normal location for an inferior parathyroid gland is approximately 1 cm caudal to the junction of the inferior thyroid artery and the recurrent laryngeal nerve on the posterior lateral aspect of the inferior pole of the thyroid lobe. It is usually anterior to the recurrent laryngeal nerve (FIG 11).
- Approximately 16% of patients with primary HPT will have ectopic parathyroid glands.[4] The inferior parathyroid gland is more likely to be in an ectopic location related to its more extensive embryologic migration.
- When a parathyroid gland is not found in its normal anatomic location, a search for an ectopic gland should be completed.
- The most common location for an ectopic inferior parathyroid gland is in the thymus. Other ectopic locations are the thyrothymic ligament, the anterior superior mediastinum, intrathyroidal, the carotid sheath, and undescended in a submandibular location (see Part 5, Chapter 42 and Part 5, Chapter 45).
- The most common location for an ectopic superior parathyroid gland is the tracheoesophageal groove. Other ectopic locations are retroesophageal, retropharyngeal, posterior mediastinal, and intrathyroidal.
- A transcervical thymectomy is performed to resect an intrathymic parathyroid adenoma. This is accomplished by exposing the cervical tongue of the thymus beneath the sternothyroid muscle. The thymus is anterior to the inferior thyroid veins and is often immediately adjacent to the inferior pole of the thyroid lobe. The recurrent laryngeal nerve is routinely exposed and dissected into the chest to avoid injury. The connective tissue anterior to the thymus is divided. The thymic veins, which drain into the innominate veins, are divided with an electrothermal bipolar vessel-sealing system. Gentle traction is applied

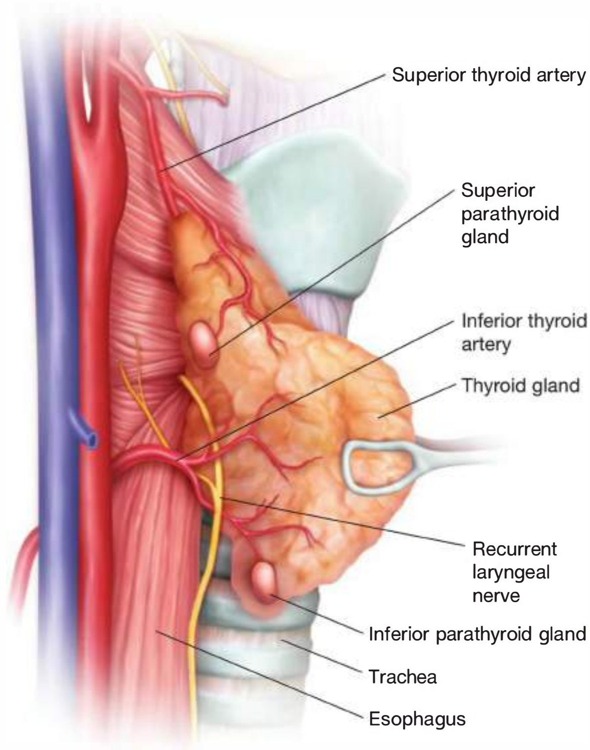


FIG 11 ● Anteromedial rotation of the lobe of the thyroid gland to expose the normal superior and inferior parathyroid glands seen with the right lobe of the thyroid gland retracted anteriorly and medially.

to the cervical tongue of the thymus with a right-angle clamp, progressively elevating more and more of the retrosternal thymic tissue into the operative field.

- An intrathyroidal parathyroid adenoma (FIG 12), found in approximately 1% of patients with primary HPT, can usually be enucleated and does not require resection of the lobe of the thyroid gland.

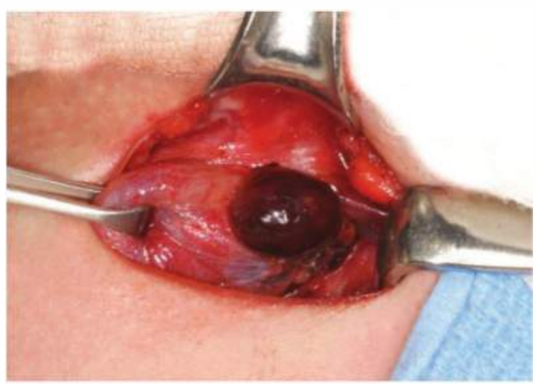


FIG 12 ● Enucleation of an intrathyroidal parathyroid adenoma.

- Division of the superior pole vessels may be helpful when a superior parathyroid gland is not found in its normal anatomic location and it is necessary to search ectopic sites.
- For patients who undergo bilateral neck exploration for multiglandular disease, parathyroid gland location is most often symmetrical.

RESECTION OF AN ABNORMAL PARATHYROID GLAND

- Initially, the enlarged parathyroid gland is dissected anteriorly, laterally, and posteriorly. The medial dissection is left until the end (**FIG 13**).
- An enlarged parathyroid gland is gently mobilized by separating it from the surrounding areolar tissue using blunt dissection with a fine curved hemostat until all that remains is the vascular pedicle.
- Care should be taken to avoid violation of the capsule of the abnormal parathyroid gland, which can lead to parathyroid cell deposition into the soft tissue or parathyromatosis, which is a cause for recurrent HPT.
- The surgeon should always be aware of the recurrent laryngeal nerve, but it is not necessary to routinely expose it nor is nerve monitoring necessary during parathyroidectomy. This is left up to surgeon discretion.
- Care should be taken to stay close to the enlarged parathyroid gland when it is being dissected to avoid injury to the recurrent laryngeal nerve.
- Exposure of the recurrent laryngeal nerve is more often necessary when searching for and removing an enlarged superior parathyroid gland. The superior parathyroid gland is usually posterior to the recurrent laryngeal nerve and the nerve may need to be dissected to resect the gland.
- After mobilization of a parathyroid adenoma has been completed and prior to ligating the vascular pedicle, 3 mL of blood is obtained from the internal jugular vein, a peripheral vein or an arterial line for intraoperative PTH monitoring (**FIG 14**). The vascular pedicle is then ligated and divided and the enlarged parathyroid gland is weighed and submitted to pathology for paraffin evaluation. An additional 3 mL of blood is obtained 5 and 10 minutes after resection of an abnormal parathyroid gland for intraoperative PTH measurement.
- A more than 50% decline in PTH compared to the preexcision or preoperative PTH value is predictive of cure, although a more than 50% decline compared to the preoperative value is preferred before deciding that no additional exploration is necessary. Because of some variability in the half-life of intact PTH, which is normally between 3 and 5 minutes, it may be necessary to obtain an additional intact PTH level before making a decision to proceed with additional exploration. Intact PTH levels that fail to decline by more than 50% suggest that there is persistent hyperfunctioning parathyroid tissue.
- Frozen section exam of an excised parathyroid adenoma is unnecessary if intraoperative PTH monitoring is used. Frozen section exam may be of value to distinguish normal or hyperplastic parathyroid tissue from nodal or thyroid tissue. It may also be useful in patients who undergo thyroidectomy for a nodule with an inconclusive fine needle aspiration biopsy or an incidentally discovered thyroid nodule that has not been previously biopsied.

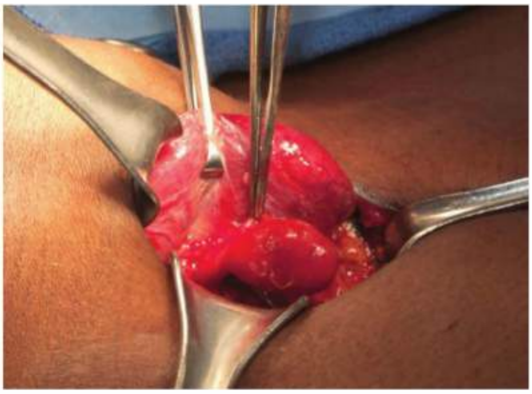


FIG 13 ● A large, superior parathyroid adenoma that has been completely mobilized and all that remains is the medial vascular pedicle.

FIG 14 ● Blood is obtained from the internal jugular vein for intraoperative PTH monitoring. The thyroid lobe is retracted with an Allis clamp. The strap muscles are retracted laterally and the common carotid artery is identified. The internal jugular vein is anterior and lateral to the common carotid artery.

SURGICAL SITE CLOSURE

- The surgical site is closed while awaiting the results of the intraoperative PTH measurements, which have a minimum 20-minute turnaround time. The wound is examined for hemostasis. Venipuncture sites in the internal jugular vein close with some brief, gentle pressure.
- The sternohyoid muscles are reapproximated in the midline with a running absorbable suture, leaving a 3-cm opening at the inferior aspect of the incision (**FIG 15**). This is done to prevent blood from collecting in an enclosed space if bleeding should occur postoperatively. It allows the blood to drain into the subcutaneous space, delaying the onset of respiratory compromise, which occurs from impairment of the venous return from the larynx and laryngeal edema.
- The subcutaneous tissue is reapproximated with absorbable suture. The skin is closed with absorbable suture placed in a subcuticular fashion and Mastisol and Steri-Strips or Dermabond is applied (**FIG 16**).

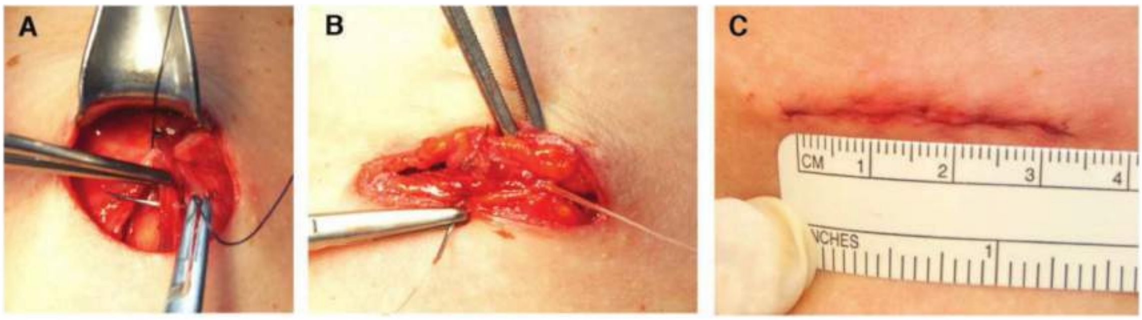


FIG 15 ● **A.** The sternohyoid muscles are reapproximated in the midline with a running absorbable suture. **B.** The subcutaneous tissue is reapproximated in the midline with interrupted absorbable suture. **C.** The skin is closed with an absorbable suture placed in a subcuticular fashion.

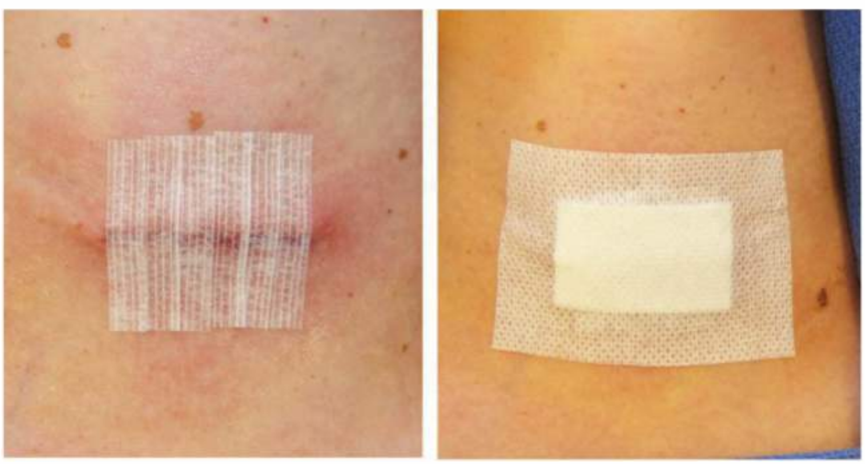


FIG 16 ● Mastisol, Steri-Strips, and a dressing are applied. Alternatively, Dermabond may be used.

PEARLS AND PITFALLS

Incision	■ For the best cosmetic result, mark the site of the incision with the patient standing in the preoperative holding area. This will help to ensure that the incision is within a normal skin crease and is symmetrical.
Raising skin flaps	■ Use the anterior jugular veins to help develop the skin flaps. For the most part, the plane just anterior to the veins is avascular.
Mobilization of the thyroid lobe	■ Use an Allis clamp to apply traction and elevate the thyroid lobe anteromedially. This will allow you to optimize exposure and use a smaller incision.
Parathyroid dissection	■ An enlarged parathyroid gland is surrounded by areolar tissue anteriorly, laterally, and posteriorly. The vascular pedicle is medial in location. The gland is mobilized primarily by blunt dissection, staying close to the gland to avoid the recurrent laryngeal nerve. The vascular pedicle is ligated last. The capsule of the parathyroid gland should not be violated. This can lead to parathyroid cell implantation in the soft tissues (parathyromatosis) and recurrent HPT.
Ectopic parathyroid glands	■ A gland that is described as inferior on a localizing scan may actually be a superior gland that has descended posteriorly from its normal anatomic location. The most common location for a supernumerary or an ectopic inferior parathyroid gland is in the thymus and is resected by performing a transcervical thymectomy. The most common location for an ectopic superior parathyroid gland is in the tracheoesophageal groove. An intrathyroidal parathyroid adenoma can usually be enucleated and normally does not require thyroid lobectomy.
Multiglandular disease	■ Parathyroid glands are most often symmetrical in location.

POSTOPERATIVE CARE

- Patients are discharged home after routine recovery in the postambulatory care unit. They are instructed to keep their dressing on for 48 hours and keep the Steri-Strips on until they return for their first follow-up visit in 2 weeks.
- Patients are instructed about the potential for neck hematoma and symptoms of hypocalcemia. They are told to come directly to the emergency department if they experience neck swelling that is out of the ordinary or they have difficulty breathing. They are asked to call if they develop symptoms of hypocalcemia and are told to begin oral calcium 500 to 1,000 mg three times daily.
- A serum calcium level is obtained at their first follow-up visit and in 6 months to confirm curative parathyroidectomy. Patients are followed yearly thereafter with a serum calcium level to assess for recurrent disease.

OUTCOMES

- The cure rate for primary HPT with parathyroidectomy performed by an experienced surgeon is 95% to 99%.
- Parathyroidectomy for primary HPT results in improvement in health quality-of-life measures including energy level, muscle strength, fine motor skills, and neurocognitive deficits.[5–7]
- Parathyroidectomy for primary HPT results in improvement of bone density.[8]
- After parathyroidectomy, there is complete resolution of the skeletal abnormalities associated with osteitis fibrosa cystica and the reduced concentrating ability of the renal tubules. In 90% of patients, kidney stone formation resolves.
- Parathyroidectomy may halt progressive and irreversible renal insufficiency and hypertension, although hypertension is unlikely to remit.
- The increased cardiovascular mortality associated with primary HPT is reversed with parathyroidectomy.[2]
- Recurrent HPT, defined as hypercalcemia with an elevated or inappropriately normal serum PTH level that develops 6 months following curative parathyroidectomy, occurs in 1% to 3% of patients.
- Approximately 25% of patients have postparathyroidectomy secondary HPT manifested by a normal serum calcium level with an elevated serum PTH level following curative parathyroidectomy. The pathogenesis is not completely understood. Low vitamin D levels, impaired kidney function, and bone remineralization has been suggested as contributory factors. This entity is important to recognize because it can be confused with recurrent disease, but it is rarely of clinical significance.

COMPLICATIONS

- The potential complications from parathyroidectomy include bleeding with neck hematoma that can lead to acute respiratory compromise, hypocalcemia, permanent hypoparathyroidism, recurrent laryngeal nerve injury, transient thyrotoxicosis, and persistent HPT.
- Recurrent laryngeal nerve injury and significant bleeding and neck hematoma are rare following parathyroidectomy, occurring in less than 1% of patients. They occur less often than in patients who undergo thyroidectomy because there is less tissue dissection—most of which is blunt—and no major vessels are ligated and divided.
- Symptomatic hypocalcemia is uncommon after resection of a single adenoma. Patients with elevated preoperative alkaline phosphatase levels are at higher risk for symptomatic hypocalcemia from "bone hunger" following parathyroidectomy. Patients who undergo subtotal or total parathyroidectomy are at higher risk for developing symptomatic postparathyroidectomy hypocalcemia and permanent hypoparathyroidism.
- Permanent hypoparathyroidism may occur in patients following subtotal parathyroidectomy when the remnant fails and total parathyroidectomy when the autotransplant fails.

- Persistent HPT may occur as a result of an ectopic adenoma, a supernumerary parathyroid gland, unrecognized multiglandular disease in patients with false-positive intraoperative PTH results (>50% decline), and an adenoma in a normal anatomic position unrecognized as a result of surgeon inexperience.
- Transient thyrotoxicosis may occur in one-third of patients following parathyroidectomy. It is thought to be the result of thyroid gland manipulation and it is self-limited. Beta-blocker therapy may be used for patients who are symptomatic.
- Recurrent HPT occurs in 1% to 3% of patients and should raise concern for MEN I or MEN IIA.

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Chapter 42

Subtotal Parathyroidectomy or Total with Autologous Graft

Brian D. Saunders

DEFINITION

- Parathyroidectomy is a functional surgical procedure performed to remove all or nearly all of a patient's hyperactive parathyroid tissue. Primary hyperparathyroidism is the most common pathologic entity requiring parathyroidectomy. Although roughly 85% to 90% of primary hyperparathyroidism involves a single overactive parathyroid gland, there are somatic, as well as inherited, conditions that result in multiglandular parathyroid pathology.[1] Further, secondary and occasionally tertiary hyperparathyroidism may require surgical resection of more than one parathyroid gland. Subtotal parathyroidectomy is the removal of all but a small portion of one parathyroid gland from the neck. This usually equates to removing three and a half parathyroid glands. The remnant portion of parathyroid tissue is left on its native blood supply and in its normal anatomic position. An alternative to a subtotal resection of parathyroid tissue is a total or complete removal of parathyroid tissue (e.g., all four glands) and the immediate transplantation of autologous parathyroid tissue into a heterotopic position.

DIFFERENTIAL DIAGNOSIS

- The necessity for a multiglandular resection of parathyroid tissue may be recognized preoperatively or intraoperatively. There are a number of etiologies for hyperparathyroidism that are always multiglandular in nature and, as such, would warrant preoperative planning for either a subtotal parathyroidectomy or a total parathyroidectomy with parathyroid autotransplantation. These include multiple endocrine neoplasia (MEN) type I– and type IIa–related primary hyperparathyroidism and secondary hyperparathyroidism related to renal failure. Other pathophysiologic conditions leading to hyperparathyroidism may involve the overactivity of more than one gland. Intraoperative recognition of multiple enlarged glands, or recognition through intraoperative parathormone monitoring data, may lead the surgeon to subtotally resect the parathyroids or perform a total parathyroidectomy with immediate transplant. These include sporadic primary hyperparathyroidism due to multiglandular hyperplasia, lithium-related primary hyperparathyroidism, tertiary hyperparathyroidism, and CDC73-related causes of hyperparathyroidism.[2] This latter category is a familial hyperparathyroidism caused by germline mutations in the CDC73 gene (also known as HRPT2 or parafibromin) and includes familial, isolated hyperparathyroidism and hyperparathyroidism–jaw tumor syndrome.[3]

PATIENT HISTORY AND PHYSICAL FINDINGS

- Hyperparathyroidism is a biochemical diagnosis. The evaluation of a patient for hyperparathyroidism may begin with an incidental note of an elevated calcium level on a laboratory report or with interrogating a patient's calcium level based on the patient's presenting signs or symptoms. Patients with recurrent nephrolithiasis (especially calcium-based kidney stones) or osteoporotic (e.g., fragility or nontraumatic) bone fractures should be evaluated for hypercalcemia and hyperparathyroidism. Other, less specific, symptoms that may warrant a biochemical investigation for hyperparathyroidism include fatigue; musculoskeletal aches and pains; neurocognitive decline; mood lability; abdominal pain; and recurrent, otherwise unexplained, pancreatitis.
- A detailed family history should be sought to evaluate the possibility of an inherited cause of hyperparathyroidism. The patient should be queried about family members with pituitary tumors, other cases of parathyroid disease, medullary thyroid cancer, pheochromocytomas, enteropancreatic neuroendocrine tumors (especially gastrin-producing tumors), and ossifying fibromas of the mandible.
- Patients with suspected inherited causes of hyperparathyroidism should be counseled to seek genetic counseling and testing as this may impact operative planning, future disease surveillance, and the health of relatives.
- Renal-related secondary hyperparathyroidism is a constant and expected biochemical finding in all patients with chronic kidney dysfunction. The degree of hyperparathormonemia is routinely followed by treating nephrologists, especially in patients who have progressed to some form of renal replacement therapy (peritoneal or hemodialysis). National management guidelines exist for the target parathyroid hormone (PTH) level for each stage of chronic kidney disease.[4]
- Physical examination findings for patients with hyperparathyroidism are uncommon. Certainly, the neck of each patient proposed for a parathyroidectomy should be thoroughly examined. The identification of a palpable mass would warrant further imaging investigation. It is distinctly unusual to palpate a parathyroid adenoma. A palpable mass with severe hyperparathyroidism should raise the specter of the unusual entity of parathyroid carcinoma. Often, though, a palpable central neck mass in a patient with hyperparathyroidism is an incidentally discovered thyroid nodule.
- For patients planned to undergo a total parathyroidectomy with immediate autologous parathyroid transplantation, a detailed inspection of the forearms should be undertaken. It is important to note the handedness of the patient, as the parathyroid autograft is usually placed in the nondominant forearm. In patients with preexisting or impending renal failure, note should be made of arteriovenous fistula position. Great care should be taken to avoid injuring a functional fistula or disturbing the bed of a soon-to-be constructed fistula.

IMAGING AND OTHER DIAGNOSTIC STUDIES

- Hyperparathyroidism (whether primary, secondary, or tertiary) is a biochemical diagnosis. This must be made to the satisfaction of the surgeon prior to contemplating any procedure. The surgeon should consider imaging studies only after a diagnosis has been secured and the need for an operation has been established.
- Known multiglandular parathyroid disease processes that will require preoperative planning for a subtotal parathyroidectomy or a total parathyroidectomy with autologous graft do not require parathyroid imaging as both sides of the neck will need to be explored and all four of the parathyroid glands identified.
- High-resolution ultrasonography of the neck (whether performed by the surgeon or a radiologist) is an excellent modality to attempt to localize enlarged parathyroid glands. Parathyroid adenomas appear as hypoechoic, ovoid masses that are separable from the thyroid gland. Upper parathyroid adenomas that lie in the tracheoesophageal groove will often be mobile with graded compression of the ultrasound probe (**FIG 1A,B**). Parathyroid adenomas adjacent to the thyroid can usually be well seen, although ectopic parathyroid adenomas (e.g., posterior to the clavicular heads) may be difficult to visualize due to limitations of the ultrasound waves in travelling through bone. Ultrasonography will also aid in the identification of concurrent thyroid pathology, which may then be dealt with at the time of the parathyroid operation.
- Nuclear medicine parathyroid scans using technetium sestamibi as a tracer can accurately identify overactive parathyroid glands about 85% of the time.[5] When performed with a concurrent single-photon emission computed tomography (SPECT)/computed tomography (CT) scan, this overlay of functional and structural imaging provides an excellent anatomic map of disease localization invaluable to the operating surgeon (**FIG 2A,B**). One caveat is that small parathyroid adenomas in close association with the thyroid gland may be difficult to visualize with this imaging technique.
- Neck CT scan or magnetic resonance imaging (MRI) is occasionally used to image parathyroid glands. Newer CT scan imaging protocols are becoming more widespread, such as 4D CT scans. This takes advantage of the timing of the intravenous (IV) contrast bolus, the vascularity of the parathyroid tumors, and the delayed washout of hyperactive parathyroid lesions.
- More invasive modalities of parathyroid localization include selective venous sampling for PTH measurement. This technique requires experienced interventional radiologists and is best reserved for the reoperative setting.
- Imaging prior to reoperative parathyroid surgery is essential to minimize exploration in a scarred operative field and to minimize iatrogenic morbidity. It is ideal to have two concordant imaging studies prior to all reoperative parathyroid surgery (see Part 5, Chapter 45).

A

B

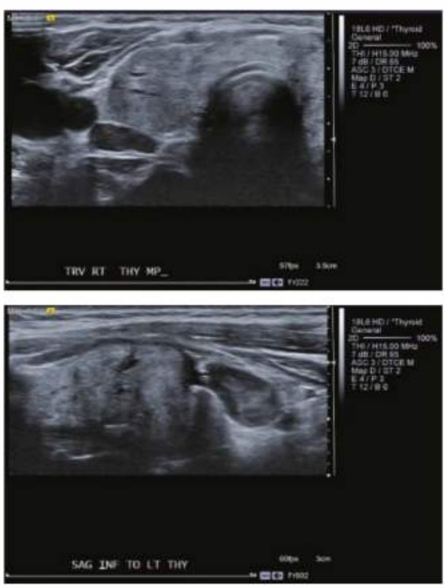


FIG 1 ● High-resolution cervical ultrasound demonstrating clear parathyroid adenomata. **A.** Right thyroid lobe with a hypoechoic right upper parathyroid adenoma in the tracheoesophageal groove. **B.** Sagittal ultrasound view of the left thyroid lobe with a hypoechoic left inferior parathyroid adenoma.

A

B

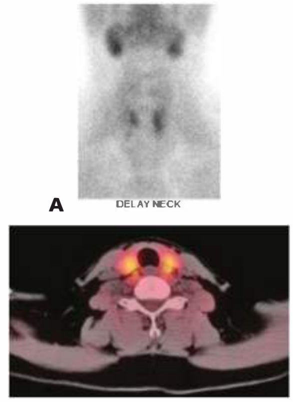


FIG 2 ● Nuclear medicine parathyroid scan. **A.** 2-hour delayed planar view showing bilateral parathyroid adenomata. **B.** Fused sestamibi-SPECT/CT scan showing bilateral sestamibi-avid parathyroid lesions posterior to each lobe of the thyroid gland.

SURGICAL MANAGEMENT

Preoperative Planning

- Prior to any parathyroid operation, all diagnostic biochemical data should be reviewed to confirm to the surgeon's satisfaction that a diagnosis of surgically correctable hyperparathyroidism is present in the patient.
- If an autologous parathyroid transplant is planned, confirmation with the patient as to which upper extremity will be the recipient site should be sought.
- The wound classification for parathyroid surgery is clean. It is rare for parenteral antibiotics to be indicated prior to parathyroid surgery. Individual patient characteristics (e.g., cardiac valvular lesions, implanted prosthetic hardware), however, should always be considered.
- Local or general anesthesia may be used.

Positioning

- The patient is positioned supine on the operating room (OR) table with the arms tucked either at the sides or lying on the abdomen. A sheet, fastened with towel clips, is used to secure the arms next to the patient and to allow for removal of the arm boards from the OR table (**FIG 3**).
- If a parathyroid transplant is planned to the patient's forearm, this arm can be extended from the patient and reprepped and draped at the time of that portion of the procedure (after the parathyroid tissue has been removed from the neck).
- A towel roll or other small bump is placed behind the patient's shoulder to aid in extension of the neck.
- The bed is positioned with the head up, the feet down, and in some slight Trendelenburg. This is known as the semi-Fowler's position or the beach chair position.
- Some surgeons will rotate the OR table 90 degrees to have the head of the patient away from the anesthesia providers and thus more accessible to the surgical team.

FIG 3 ● The patient is positioned on the OR table with the arms tucked, a roll behind the shoulders, and the head elevated.

PLACEMENT OF INCISION

- A transverse incision is made in the line of a skin crease roughly 1 cm caudal to the cricoid cartilage or two fingerbreadths cephalad to the suprasternal notch. The incision may be between 3 and 5 cm in length and is centered on the midline of the neck (**FIG 4**). Some surgeons will infiltrate the region of the incision with a local anesthetic combined with epinephrine. Placement of the incision within a natural skin line or crease of the neck is more important for postoperative cosmesis than the length of the incision (**FIG 5**).

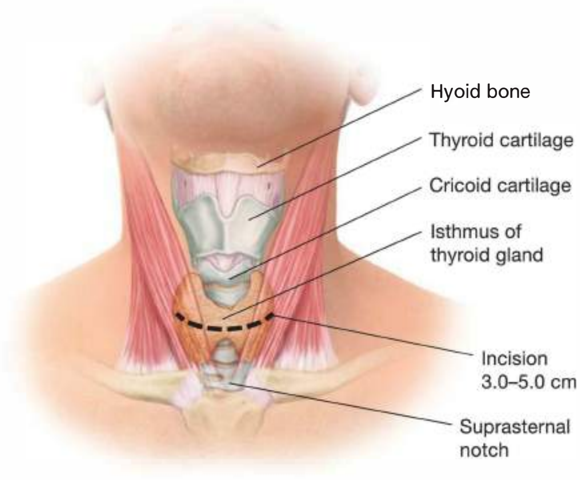


FIG 4 ● Surface anatomy and relationships for parathyroid incision placement.

FIG 5 ● Diagram of planned parathyroidectomy incision, with clavicular heads and sternal notch marked for reference.

CREATION OF FLAPS

- Dissection is deepened through the subcutaneous tissues and through the platysma muscle with electrocautery. Subplatysmal flaps are created superiorly, inferiorly, and laterally with a combination of electrocautery and blunt dissection (**FIG 6**).
- Care must be taken to avoid injury to the paired anterior jugular veins. Should a rent be made in one of these veins, it is best to ligate the vein rather than attempt to cauterize the vein.
- The superior flap should extend to the level of the thyroid cartilage and the inferior flap down to the sternal notch.

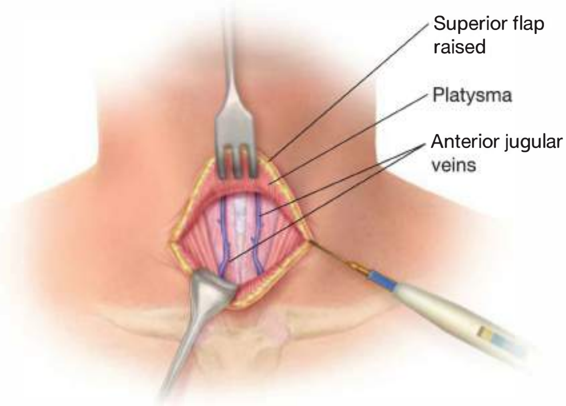


FIG 6 ● Myocutaneous flaps are raised superiorly, inferiorly, and laterally to facilitate skin retraction and to expose the various sites to be explored.

ENTRY INTO THE DEEP CENTRAL NECK SPACE

- The avascular, midline raphe between the sternohyoid and sternothyroid muscles on each side is entered with electrocautery. This midline is best identified by digital palpation of the midline of the underlying trachea. These strap muscles should be separated to expose the underlying thyroid isthmus (**FIG 7**).
- The layers of the strap muscles are separated into two by dividing the connective tissue in the layer between the sternohyoid and the sternothyroid muscles. The lateral extent of this dissection is the lateral borders of these muscles and the carotid sheath. This exposes the internal jugular vein, a site from which to draw a baseline blood sample for intraoperative PTH monitoring[6] (**FIG 8**).
- An alternate site for PTH sampling is a peripheral venipuncture (often in the lower extremity) performed by the anesthesiologist. If an arterial catheter is present for anesthetic monitoring, it is acceptable to use an arterial blood sample for PTH monitoring.

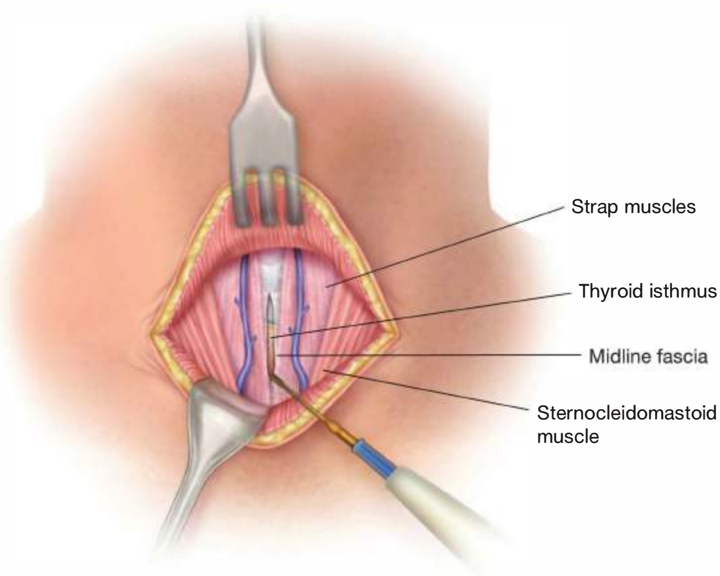


FIG 7 ● The strap muscles (sternohyoid and sternothyroid) are separated in the midline with electrocautery to expose the underlying thyroid isthmus.

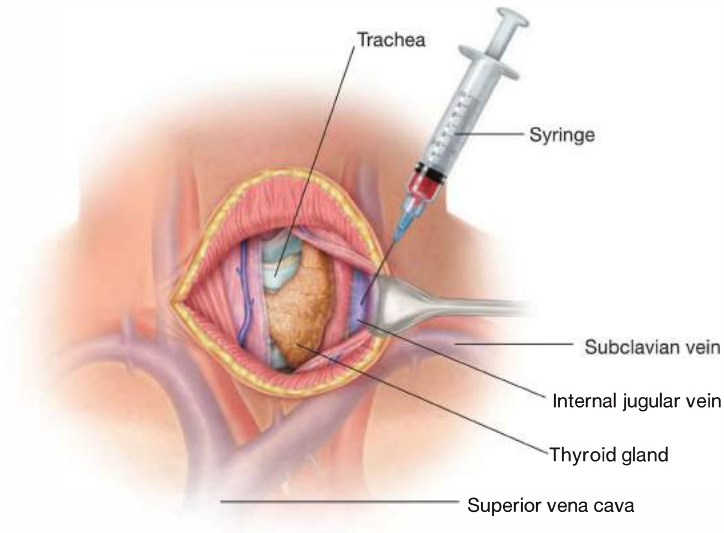


FIG 8 ● Blood is drawn from the internal jugular vein to test for PTH levels.

- The space between the sternothyroid muscle and the thyroid lobe is developed with a combination of blunt dissection and electrocautery. The operation must necessarily begin on one side of the neck, but an identical procedure will be done on the contralateral side of the neck to identify all four parathyroid glands. This space lateral to the thyroid lobe and medial to the carotid artery is developed back to the level of the prevertebral fascia. The crossing middle thyroid vein may need to be divided. This may be accomplished with metallic clips, suture, or through any of the available powered surgical devices (**FIG 9**). Caution must be taken to avoid searching for parathyroid tissue too soon, as it is possible for the tumor to be more posterior than one has opened, or remaining with either the thyroid or the carotid sheath.
- The recurrent laryngeal nerve may be identified at this point, coursing superiorly in the tracheoesophageal groove (**FIG 10**).

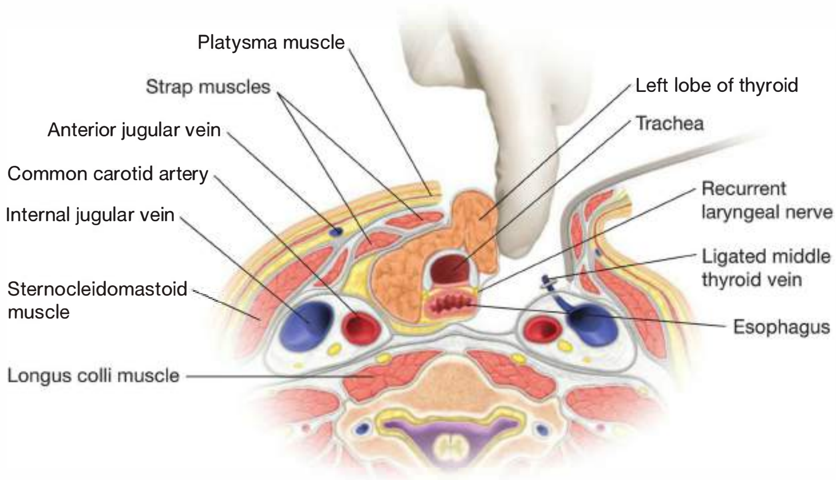


FIG 9 ● Initial dissection for a parathyroidectomy includes separating the strap muscles off the underlying thyroid lobe. The plane just medial to the carotid sheath is followed posteriorly to the level of the spine. The only transversely crossing structure is the middle thyroid vein, which can be ligated. All soft tissue, along with the thyroid lobe, is kept under the surgeon's finger.

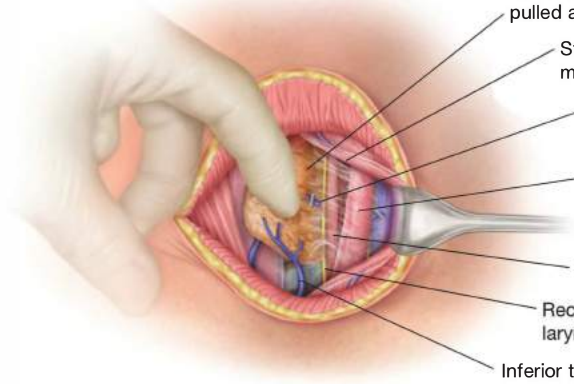


FIG 10 ● The recurrent laryngeal nerve courses superiorly in the tracheoesophageal groove and can often be identified most easily at the level of the inferior pole of the thyroid gland.

IDENTIFICATION OF SUPERIOR PARATHYROID GLANDS

- The superior parathyroid glands lie posterior to the upper pole of the thyroid lobe. To explore this space, the thyroid lobe is rolled anteromedially using one's finger or a Kittner dissector. The superior parathyroid glands are posterior to the recurrent laryngeal nerve as it passes underneath the tubercle of Zuckerkandl and just posterolateral to the ligament of Berry (**FIG 11**). Their position is more constant than that of the inferior parathyroid glands. There is often symmetry between sides of the neck, and if one cannot locate a superior parathyroid gland on one side, it is often advisable to locate it on the contralateral side.

FIG 11 ● Right superior parathyroid adenoma lying posterior to the right thyroid lobe (rolled anteriorly with Kittner dissector). The right strap musculature is seen retracted laterally.

- Due to limited space for enlargement, superior parathyroid adenomas often grow caudad and ultimately lie in a pseudoectopic position in the tracheoesophageal groove, low in the neck. The blood supply, however, remains in the eutopic position near the upper pole of the thyroid lobe. Caution must be taken elevating these low-lying superior parathyroid adenomas out of the tracheoesophageal groove as they often lie with the recurrent laryngeal nerve draped over them.
- Ectopic positions for the superior parathyroid glands include low in the tracheoesophageal groove, retroesophageal, retrotracheal, within the carotid sheath, and within the thyroid gland.
- Exploration of the carotid sheath begins with retraction of the sternothyroid muscle laterally to expose the carotid artery. Gentle blunt dissection anterior to the carotid artery allows separation of the carotid artery from the internal jugular vein just lateral to it. Posterior in the carotid sheath is the vagus nerve. Exposure of the carotid sheath for about 5 to 6 cm in a cephalocaudal direction allows one to search for a soft, brown nodule consistent with a parathyroid adenoma (**FIG 12**). Care must be taken not to mistake nodules posterior to the carotid sheath for parathyroid adenomas as these may in fact be ganglia of the sympathetic chain.
- Once identified, the parathyroid tumor should be dissected back to its single vascular pedicle. Great care should be taken to avoid entry into the parathyroid capsule and the potential for spilling and seeding parathyroid tumor cells in the central neck space (known as parathyromatosis).
- Any uncertainty in the visual identification of parathyroid tissue should prompt a biopsy sent for frozen section analysis. A small fragment of tumor can be taken with a pair of scissors. Gentle pressure can control any slight ooze from the biopsied gland.
- Once the superior gland has been identified, it should remain in place until the inferior gland has been identified.
- This same procedure will be used to identify the superior parathyroid glands on each side of the neck.

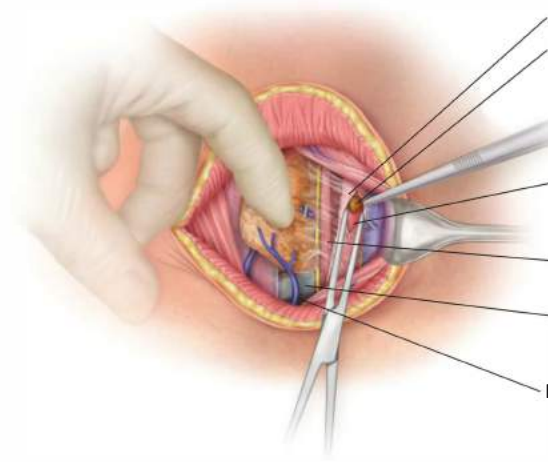


FIG 12 ● Exploration of the carotid sheath for a missing or ectopic superior parathyroid gland. The soft tissue covering the carotid artery is opened, and this space can be explored from the retropharyngeal region into the posterior superior mediastinum.

IDENTIFICATION OF INFERIOR PARATHYROID GLANDS

- The inferior parathyroid glands have a slightly more variable location than the superior parathyroid glands related to the greater distance of migration during embryologic development. The typical location for these glands is just caudal and slightly posterior to the inferior tip of the lower pole of the thyroid lobe. The inferior parathyroid glands often lie in a plane equal to the trachea. They are uniformly anterior to the recurrent laryngeal nerve (**FIG 13**).

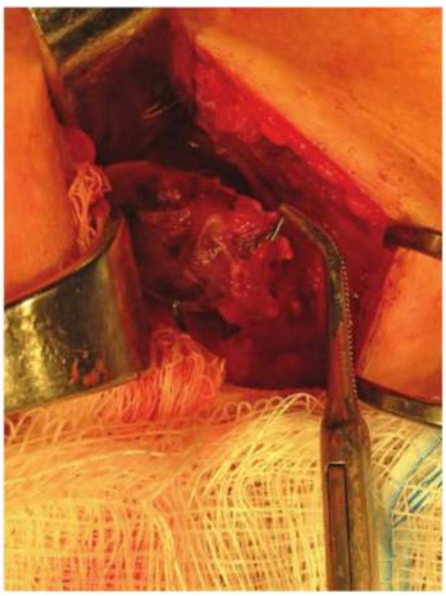


FIG 13 ● Left inferior parathyroid adenoma retracted away from the inferior pole of the thyroid gland.

- As the inferior parathyroid gland enlarges, it may descend with gravity into the fatty tissue caudal to the thyroid lobe and into the anterior superior mediastinum. Gentle dissection in this region can allow for identification of a parathyroid adenoma without causing bleeding.
- The inferior parathyroid glands may lie in the connective tissue ligament that attaches the lower pole of the thyroid to the cervical horn of the thymus (the so-called thyrothymic ligament).
- Ectopic positions for the inferior parathyroid glands include the thyrothymic ligament, the cervical portions of the thymus, the intrathoracic thymus, undescended within the neck, and with the thyroid gland itself. Each of these spaces needs to be examined for a missing parathyroid gland. There is often symmetry of location of the inferior parathyroid glands, and inability to find one inferior parathyroid gland should prompt attempts at identification of the contralateral inferior parathyroid gland as a guide.
- A transcervical thymectomy may be done to identify missing or ectopically located inferior parathyroid glands. This procedure is begun by dissecting the fatty tissue in the anterior superior mediastinum just posterior to the clavicular head and just lateral to the trachea. A search is undertaken for the canary yellow color of the remnant thymus. Gentle traction in a cephalad direction will allow one to extract the thymus from the mediastinum. An encasing membrane will often need to be opened to fully allow the thymus to be removed. The cervical thymic remnant will thin out to a small attachment often containing a blood vessel that should be clipped or suture ligated (**FIG 14**).
- Once the inferior parathyroid adenoma is identified, it should be dissected back to its vascular pedicle. Any question as to its identity should prompt a small sample to be taken with scissors for frozen section biopsy.
- An identical procedure will be followed to identify the inferior parathyroid tumor on the contralateral side.

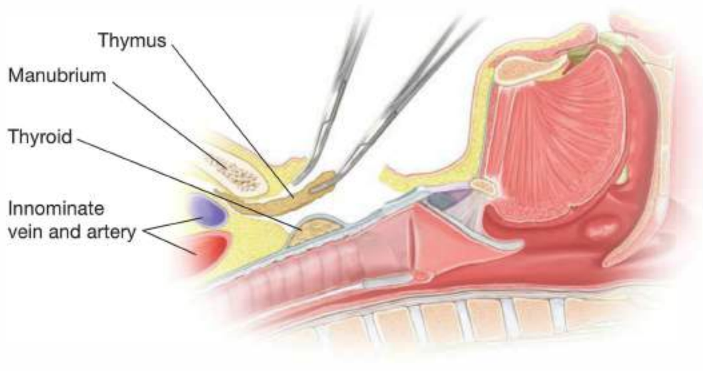


FIG 14 ● A transcervical thymectomy can be accomplished to identify ectopic inferior parathyroid glands that lie caudal to the sternal notch. The thymic tissue is grasped and gently pulled up from the mediastinum and into the cervical incision.

FROZEN SECTION PATHOLOGIC ANALYSIS

- It is often advisable to confirm the identity of the four parathyroid glands identified with frozen section.
- Frozen section is used to confirm identification as parathyroid tissue more so than to quantify cellularity of the parathyroid gland. It is nearly impossible to reliably determine parathyroid hyperplasia from a parathyroid adenoma on frozen section (**FIG 15A,B**).

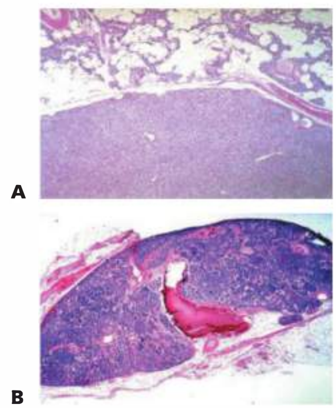


FIG 15 ● Low-power photomicrographs of **(A)** a parathyroid adenoma and **(B)** a hyperplastic parathyroid gland. The adenoma has a characteristic compressed rim of normal parathyroid tissue, with admixed adipocytes and parathyroid chief cells.

SUBTOTAL RESECTION OF PARATHYROIDS

- If a subtotal resection of the parathyroid glands is to be done, one plans to resect three and a half of the four glands. This is best done by dividing one of the glands first and continually checking on its viability as the resection of the second through fourth glands ensues to avoid an inadvertent total parathyroidectomy.
- In general, the remnant of parathyroid gland to remain on its native blood supply in the neck should be a portion of the most normal-appearing gland of the four identified.
- If possible, a remnant inferior gland should be left, as this remnant will sit more anterior, and anterior to the recurrent laryngeal nerve, making it easier to reoperate upon if necessary.
- A sufficient parathyroid remnant is about 30 to 50 mg of tissue or the size of a normal parathyroid gland.
- The parathyroid remnant is created by placing a metallic clip or clips across the gland and sharply dividing the distal segment of the gland away from the remnant (**FIG 16**).
- The remnant may also be tagged with a Prolene suture to aid in future identification if a reoperation becomes necessary. Great care should be taken when placing this marking stitch to avoid injury to the end arteriole feeding the parathyroid gland.
- The second through fourth glands are removed by dividing the vascular pedicle of the gland. The vascular pedicle can be clipped or tied as per surgeon preference.

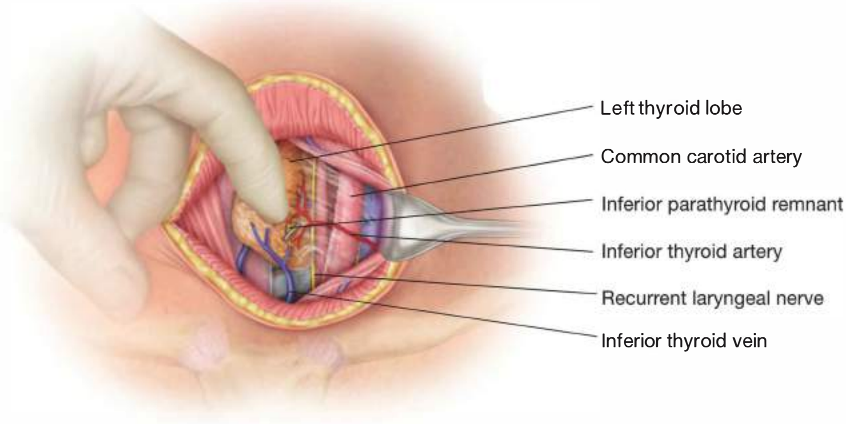


FIG 16 ● A remnant of a left lower parathyroid gland is left on its native blood supply. A metallic surgical clip is placed to divide the gland and to mark in the case that a future reoperative parathyroid surgery becomes necessary. Great care must be taken to ensure that the clip is not placed across the blood supply to the parathyroid remnant.

TOTAL PARATHYROIDECTOMY

- A total parathyroidectomy involves the removal of all parathyroid tissue (usually four glands) from the neck.
- Each gland is fully dissected back to its vascular pedicle, which is clipped or ligated and then divided.
- The parathyroid tissue to be transplanted is identified and kept moist. Great care should be taken to avoid this tissue from mistakenly being handed off the sterile field (**FIG 17**).

FIG 17 ● Ex vivo right superior parathyroid adenoma.

INTRAOPERATIVE PARATHYROID HORMONE MONITORING

- If intraoperative PTH monitoring is being used, a postresection PTH value should be drawn and sent at 5, 10, or 15 minutes postresection of all parathyroid tissue. Timing is per the surgeon's protocol. Longer time points (15 minutes) are usually used if the PTH specimen is being drawn from a central vein (internal jugular). Shorter time points may be used if the specimen is from a peripheral venipuncture or a radial arterial line.[6]
- Resolution of hyperparathyroidism and long-term eucalcemia is well predicted by postresection PTH values that are at least 50% of the baseline value and into the normal range (<40 pg/mL).[7]

HEMOSTASIS

- Careful attention to hemostasis is of paramount importance throughout the entire parathyroidectomy to ease in parathyroid identification.
- Postoperative neck hematomas are a rare but potentially disastrous complication following parathyroidectomy.
- Prior to wound closure, a Valsalva maneuver is requested to decrease venous return and to identify any slight bleeding in the operative bed.
- Topical hemostatic agents may be placed in the tracheoesophageal groove and inferior to the thyroid lobes.
- Routine placement of closed suction drains is not required.

WOUND CLOSURE

- The two layers of strap musculature are closed in the midline in either one layer or two separate layers. Three to four interrupted, absorbable stitches are sufficient to reapproximate these muscles.
- The platysma muscle layer is reapproximated with interrupted, buried, absorbable sutures.
- The skin edges are brought together with a 3-0 Prolene suture in a subcuticular stitch.
- Skin glue is applied to the wound, and once dry, the Prolene suture may be removed immediately. No further dressings are required.

IMMEDIATE PARATHYROID AUTOTRANSPLANTATION

- If a total parathyroidectomy has been performed, one must reimplant autologous parathyroid tissue to avoid permanent hypoparathyroidism.
- Roughly 30 to 50 mg of parathyroid tissue should be transplanted.
- The upper extremity in which the parathyroid graft is to be placed is extended out from the patient and supported on an arm board (**FIG 18**).
- The transplant site is into the brachioradialis muscle on the dorsal aspect of the forearm (usually the nondominant forearm). Again, thought must be given to the location of a current or future hemodialysis access in those patients on chronic renal replacement therapy.
- The dorsal forearm is prepped and draped in the usual fashion.
- A 3- to 4-cm longitudinal incision is made, and dissection is deepened through the subcutaneous tissue to the fascia overlying the brachioradialis muscle (**FIG 19A,B**).
- The fragment of parathyroid tissue to be transplanted is then cut into 1-mm^3 fragments, totaling about 15 fragments (**FIG 20**).
- A small muscle pocket is made in the brachioradialis muscle with the tip of a dissecting instrument, and a single

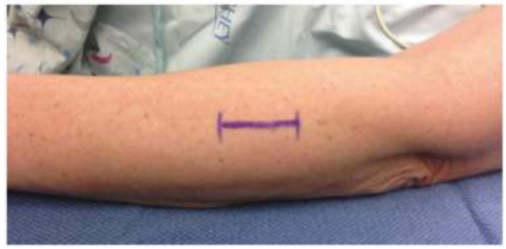
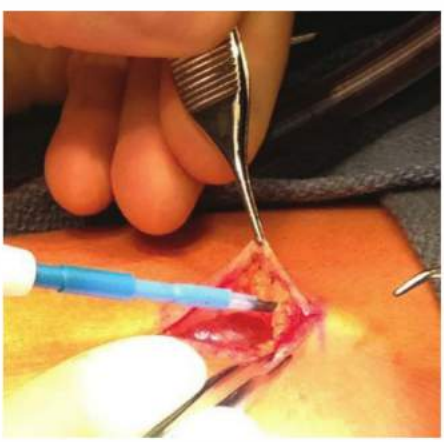
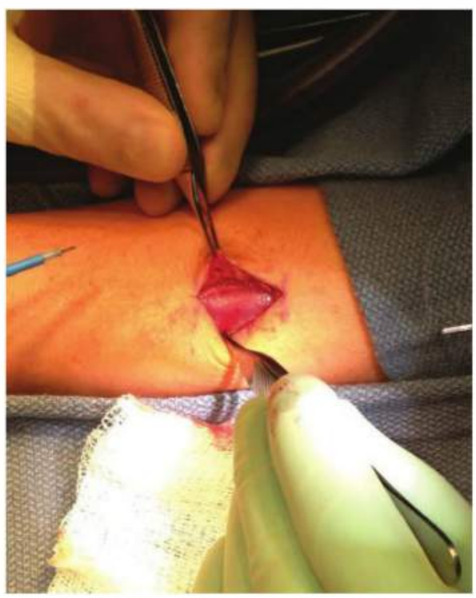


FIG 18 ● The heterotopic transplant site is marked prior to surgical prepping and draping. The transplant site is the brachioradialis muscle of the nondominant forearm.



A



B

FIG 19 ● Preparing the recipient site for parathyroid tissue. **A.** Dissection through subcutaneous tissue to the level of the brachioradialis muscle. **B.** Exposed brachioradialis muscle.

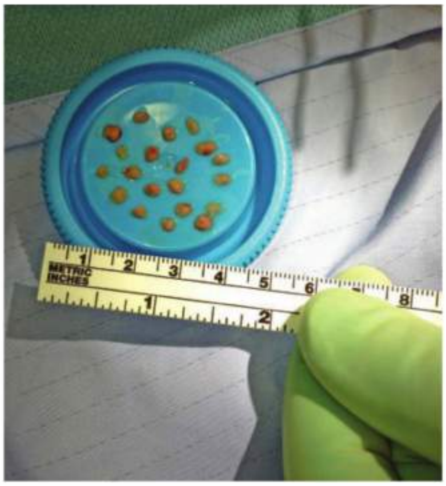


FIG 20 ● Minced parathyroid to be transplanted. Numerous 1-mm^3 fragments of parathyroid tissue await placement into individual muscle pockets.

fragment of parathyroid tissue is placed into this pocket. The edges of the pocket are loosely approximated with an absorbable suture or a metallic clip.

- This procedure is repeated until each fragment of parathyroid tissue has been placed into a separate muscle pocket (**FIG 21**).
- Great care needs to be taken to avoid any bleeding in these muscle pockets as the initial nutrient supply of the parathyroid graft requires contact with the vascularized muscle.
- The wound is then closed in layers, using interrupted, absorbable sutures to close the deep dermal layers and tissue adhesive to reapproximate the skin edges (**FIG 22**).

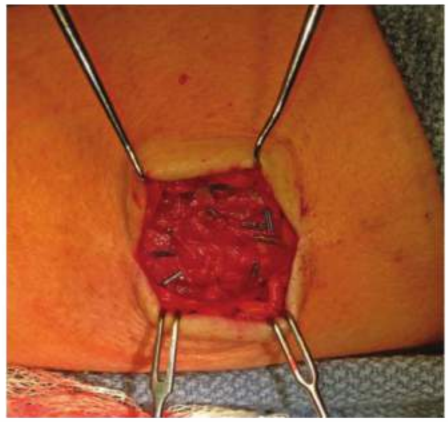


FIG 21 ● Parathyroid autotransplantation completed, with muscle pockets loosely approximated with metallic clips.

FIG 22 ● The transplant incision is closed with skin glue.

PEARLS AND PITFALLS

Indications	■ Hyperparathyroidism is a biochemical diagnosis, and this needs to be secured prior to cervical imaging or planning an operation.
Identification of parathyroids	■ Dissection in the central neck space should free the carotid sheath medially and include all the tissue down to the prevertebral fascia.
Excision of parathyroid adenomas	■ Parathyroid glands have a singular blood supply and should be dissected back to this vessel prior to ligation and division to avoid injury to critical adjacent structures such as the recurrent laryngeal nerve.
Hemostasis	■ A bloodless field greatly aids in the identification of parathyroid glands from their surrounding tissue. ■ A hematoma at the site of a parathyroid transplant greatly jeopardizes the viability of the autologous graft.
Placement of autologous graft	■ The parathyroid autotransplant may be placed in either the dorsal forearm or the presternal area.
Postoperative hypocalcemia	■ Anticipate and aggressively treat the hypocalcemia that accompanies either a subtotal parathyroidectomy or certainly a total parathyroidectomy with autologous graft.

POSTOPERATIVE CARE

- Patients undergoing subtotal parathyroidectomy or total parathyroidectomy with autologous graft should be admitted for at least 1 day to monitor postoperative calcium and PTH levels.
- Patients having undergone a forearm parathyroid transplant should have a limb alert placed, and blood pressures, IV sites, and venipunctures should be avoided in the transplant arm.
- Acetaminophen or ibuprofen is often sufficient for the pain related to the procedure. Occasionally, opioid agents are needed for a short time postoperatively.
- Endocrinology consultation can be sought as needed by the surgical team.
- Oral calcium and possibly vitamin D (in the form of calcitriol) should be started immediately and titrated if hypocalcemia occurs.
- Patients having undergone a total parathyroidectomy will have an obligate period of hypoparathyroidism until their autograft begins to function.
- Parenteral calcium should be restricted to severely low serum calcium levels and/or patients with symptomatic hypocalcemia.
- Symptoms of hypocalcemia include perioral and digital numbness or tingling, muscle aches/spasms, carpopedal spasms, facial nerve hyperactivity (Chvostek's sign), respiratory muscle insufficiency, and tetany.

OUTCOMES

- The long-term outcome as measured by eucalcemia from a subtotal parathyroidectomy and a total parathyroidectomy with immediate parathyroid autotransplantation are very similar. Both have a small rate of recurrent hyperparathyroidism (as a result of the natural history of the parathyroid disease). This recurrence may occur 10 to 20 years after the index operation.[8]
- Immediate transplantation of autologous parathyroid tissue has successful engraftment approximately 95% of the time. Most parathyroid grafts will gain function in about 8 weeks.[9]

COMPLICATIONS

- Compressive cervical hematoma
- Laryngeal nerve injuries (external branch of the superior laryngeal nerve or recurrent laryngeal nerve)
- Sympathetic chain/stellate ganglion injury
- Prolonged or permanent hypoparathyroidism
- Inability to extirpate all hyperactive tissue with resultant persistent hyperparathyroidism
- Tracheal injury
- Esophageal injury
- Lymph or chylous leak
- Wound infection
- Unsightly neck or arm scarring

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Chapter 43

Minimally Invasive Parathyroidectomy

Peter Angelos Raymon H. Grogan

DEFINITION

- Although there is no uniformly agreed upon definition of a "minimally invasive parathyroidectomy" (MIP), most surgeons accept that this term refers to an operation to remove the parathyroid gland that is a focused or unilateral exploration done through a small incision.[1] Some surgeons stress that MIP should also refer to an operation done without general anesthesia in an outpatient setting. However, we believe that because the choice of anesthesia and determination of whether a patient is discharged on the day of surgery is dependent on the patient (and not always the operation), we do not limit MIP to outpatient procedures without general anesthetic. We believe that MIP is the treatment of choice for primary hyperparathyroidism (HPT) when the location of the abnormal parathyroid gland has been well localized preoperatively.[2,3]
- MIP is effective and recommended for the treatment of sporadic primary HPT but not in cases of familial HPT (e.g., multiple endocrine neoplasia type 1 or 2), secondary HPT, or tertiary HPT. In all of the latter categories, the high likelihood of multigland disease necessitates the exploration of all four glands.
- Although MIP is effective in both primary operations as well as in reoperative cases, we will focus on primary operations in the following description. The decision making for reoperative parathyroidectomy is complicated by the scarring that will be present in the neck and the potential difficulty with performing a four-gland exploration. For this reason, preoperative localization becomes much more important in reoperative cases and is beyond the scope of this chapter.

DIAGNOSIS AND INDICATIONS FOR SURGERY

- The diagnosis of HPT is made by the finding of an elevated calcium level with an elevated intact parathyroid hormone (iPTH) level. It is possible to have normocalcemic HPT if the calcium level is at the upper range of normal but the iPTH is elevated. Alternatively, patients sometimes have elevated calcium levels with the iPTH level being inappropriately in the high normal range. It is important when making the diagnosis of HPT to assess both calcium and iPTH levels so that the relative values of these tests can be compared. In a patient with normally functioning parathyroid glands, a high calcium should be associated with a low iPTH level.
- In order to confirm the diagnosis of HPT and rule out familial benign hypocalciuric hypercalcemia (FBHH), a 24-hour urine calcium should be obtained. In FBHH, the urinary calcium is expected to be very low. A normal or elevated 24-hour urine calcium level effectively rules out FBHH. An elevated 24-hour urine calcium increases the risk of kidney stones.
- The indications for surgery in HPT are well described in several National Institutes of Health (NIH) consensus conferences over the last few decades.[4] Most surgeons and endocrinologists currently agree that patients with HPT who are symptomatic or have marked elevations in serum calcium should have surgery. A history of kidney stones and the presence of osteoporosis are widely accepted as indications for surgery. It is common for patients with HPT to have additional symptoms that may be associated with the disease, including low energy, bone pain, decreased proximal extremity muscle strength, decreased ability to concentrate, and reductions in short-term memory. Although all of these symptoms may be caused by conditions other than HPT, they are very common in patients with HPT and may influence the decision to recommend surgery.
- The diagnosis of HPT in a young patient (<50 years old) also is a relative indication for parathyroidectomy because such patients will have more years to develop osteoporosis and other problems associated with HPT. In addition, for women of childbearing age, HPT also appears to increase the risks of spontaneous abortion.
- There is currently no approved medical treatment for primary HPT. For this reason, the choice for patients and physicians is between parathyroidectomy and continued observation.

IMAGING AND OTHER DIAGNOSTIC STUDIES

- Once the decision is made to proceed to surgical treatment, localization studies to attempt to identify the location of the abnormal parathyroid gland are indicated. We recommend the routine use of technetium-99m (Tc-99m) sestamibi scan and ultrasound evaluation of the thyroid gland.[5]
- Sestamibi scanning has high rates of sensitivity and specificity and is effective in localizing not only parathyroid adenomas in the neck but also in ectopic locations such as undescended glands in the neck or intrathoracic glands. Unfortunately, in cases of multigland disease, sestamibi scanning is least likely to identify the location of abnormal glands. Sestamibi is taken up by both thyroid and parathyroid cells. It is more rapidly cleared from thyroid cells than from abnormal parathyroid cells. For this reason, a comparison of early and delayed scans often reveals the presence of a persistent focus of increased activity in the abnormal parathyroid gland. With the use of fused sestamibi–computed tomography (CT) scanning or three-dimensional single photon emission computed tomography (SPECT) reconstructions, it is often possible to determine

whether the focus of uptake is anterior in the neck (at or near the level of the thyroid lobe) or more posterior. Because the superior parathyroid gland is located posterior to the recurrent laryngeal, posterior parathyroid glands on scans are most likely superior glands, whereas anterior glands are more likely to be inferior glands.

- Ultrasonography is an effective noninvasive means of identifying abnormal parathyroid glands. The study can be performed in the radiology department or by surgeons in the clinic or operating room. Ultrasonography is effective in identifying enlarged parathyroid glands that are close to the thyroid gland. Abnormal parathyroid glands usually appear as hypoechoic lesions either posterior or inferior to the thyroid gland. Parathyroid glands that are located posterior to the esophagus and those in the mediastinum are less likely to be visualized on ultrasound.
- Ultrasound is very effective at identifying thyroid nodules, which may be a source of increased uptake on sestamibi scans. We believe that thyroid nodules greater than 1 cm or with suspicious characteristics should be evaluated with fine needle aspiration cytology prior to planned parathyroidectomy. This strategy limits the chances of missing a nonpalpable thyroid malignancy and thus reduces the likelihood for reoperative neck surgery.
- In cases of primary HPT when patients have negative preoperative localization studies, we recommend proceeding with surgery and planning on a four-gland exploration (see Part 5, Chapter 41). Some surgeons would obtain a four-dimensional CT scan of neck and chest prior to exploring the patient. However, we believe that additional evidence is required before this approach should be routinely adopted.

SURGICAL MANAGEMENT

- MIP can be performed either with local anesthesia and sedation or with general anesthesia, depending on surgeon and patient preference. We have found that because inferior parathyroid adenomas are located more anteriorly in the neck, these glands are more amenable to resection without using general anesthesia. Large posteriorly located superior parathyroid adenomas often are more challenging to remove without general anesthetic because of the need to rotate the thyroid lobe medially to gain access to the space posterior to the esophagus. Although it is possible to access these glands even when the patient is not asleep, surgeons should be cognizant of the challenge and choose the appropriate patient for such an approach.
- Identification of the optimal skin crease for a cosmetic incision is best done with the patient sitting up while awake. Although extending the neck in the operating room may change the location of skin creases, marking them prior to entering the operating room increases the likelihood of a good cosmetic result.
- After the patient has been either intubated or appropriately sedated, the use of superficial cervical plexus block may be used to facilitate local anesthesia if the patient has not received a general anesthetic or to improve postoperative pain control if a general anesthetic is used.
- The superficial cervical plexus block is a safe, effective technique to provide cutaneous anesthesia to the C2, C3, and C4 dermatomes. We perform a two-point (transverse and inferior), bilateral superficial blockade to allow complete local anesthesia of the midline Kocher incision, which, if done correctly, will last for several hours after the procedure. Anecdotally, this should also allow for reduced general anesthesia intraoperatively, particularly for superficial lower parathyroidectomies. We use 10 mL of 0.25% bupivacaine without epinephrine for each side of the neck.
- After induction of general anesthesia, the patient's neck is extended with a beanbag or shoulder roll. The midpoint of the posterior border of the sternocleidomastoid muscle is identified, and a 22-gauge needle is inserted subcutaneously (no more than 1 cm) at this anatomic landmark (**FIG 1**). Check to be sure the needle is not inserted into a vein by pulling back on the plunger of the syringe. First, 5 mL of anesthetic are injected straight toward the midline of the neck (transverse injection) just posterior to the muscle. The needle is then repositioned without removing it from the skin so that it is now pointing at the sternal notch. The remaining 5 mL of anesthetic is then injected inferiorly along the posterior border of the muscle (inferior injection). The other side of the neck is then injected in a similar manner.
- If done correctly, there is minimal risk associated with this technique. The main risk of this procedure occurs if the injection is done too deep. If injected too deep into the neck, branches of the brachial plexus can be anesthetized, and the patient may have a temporary paralysis of the ipsilateral upper extremity. A deep injection can also anesthetize the phrenic nerve and lead to temporary diaphragmatic paralysis. For this reason, if the injection is being done without general anesthetic while the patient is awake, it is important that bilateral blockade is not performed simultaneously on both sides of the neck. Finally, if the injection infiltrates superiorly, the greater auricular branch of the plexus will be blocked, and the patient will have numbness of the skin overlying the parotid and the earlobe. This is a common side effect that the patient should be told to be aware of in the immediate postoperative period.

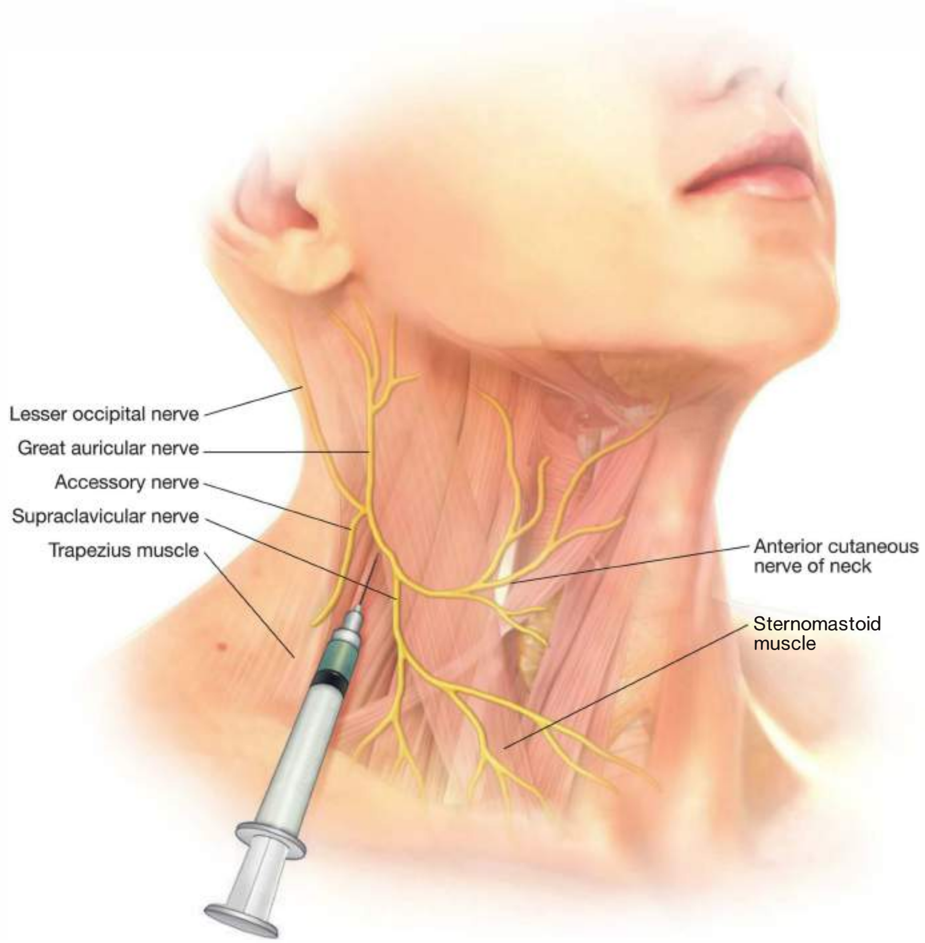

FIG 1 ● A 22-gauge needle is inserted no more than 1 cm subcutaneously at the midpoint of the posterior border of the sternocleidomastoid muscle. After assuring the needle is not in a vein, 5 mL of anesthetic is injected toward the midline of the neck (transverse injection). The needle is repositioned without removing it toward the sternal notch. The remaining 5 mL of anesthetic is then injected inferiorly along the posterior border of the muscle (inferior injection).

- Optimal positioning for parathyroidectomy is with the patient's neck gently extended but well supported. Prior to prepping the skin, we routinely perform an intraoperative ultrasound of the neck to ensure the choice of the optimal location for the skin incision (**FIG 2**). In addition, intraoperative ultrasound often allows the surgeon to confirm the location of the adenoma and focuses the subsequent surgical exploration.
- After prepping the skin, it is critical that if the patient has not received a general anesthetic, care must be taken when placing drapes to ensure that the operative field is fully separated from the space below the drapes. Patients who are receiving sedation and local anesthesia usually are also given supplemental oxygen by the anesthesiologist during the operation. This is commonly done with nasal cannula and results in relatively high oxygen concentrations below the drapes. If that oxygen comes in contact with a spark from electrocautery used during the performance of the parathyroidectomy, the risk of fire is increased. For this reason, when draping the patient, an occlusive dressing or adherent drapes are important to separate the operative field from the space below the drapes (**FIG 3**).
- A small (2 to 3 cm) incision in the midline is made in a skin crease. Although some surgeons prefer an incision shifted toward the side of the parathyroid adenoma, we prefer using a midline incision so that if it becomes necessary to explore both sides, the same incision can often be used. If it is necessary to lengthen the incision, this is usually only a minimal increase in incision size.

FIG 2 ● Ultrasound of the neck is performed prior to prepping the patient's neck. The ultrasound is particularly useful in determining the optimal location for the small neck incision. Note that the mark on the neck is of the skin crease but not the actual length of the incision.

FIG 3 ● Occlusive barrier dressing being placed. This is very important if the patient is not intubated and supplemental oxygen is used. The barrier dressing separates the space under the drapes from the operative field and reduces the risk of fire.

- Small subplatysmal flaps are created with electrocautery to allow the skin incision to be moved up or down depending on where the abnormal gland is located. The midline strap muscles are then separated in the midline so that the thyroid lobe on the involved side can be rotated medially (**FIG 4**). If, based on preoperative imaging, the abnormal parathyroid appears to be the inferior parathyroid, then the dissection is focused on the area near the inferior pole of the thyroid or in the thyrothymic tract where inferior parathyroid glands are most commonly located. If the abnormal parathyroid gland appears to be a superior gland, then dissection is focused on the more posterior tissue. The entire thyroid lobe is mobilized medially such that the space posterior to the esophagus can be adequately explored.
- Once an abnormal parathyroid gland is identified, the vascular pedicle should be carefully identified, ligated, and divided (**FIG 5**). Once adequate hemostasis is achieved, the incision is closed.

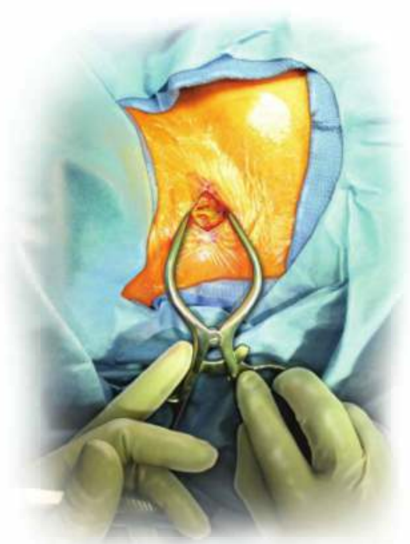

FIG 4 ● Small skin incision after the subplatysmal flaps have been created and the midline strap muscles have been separated to expose the thyroid gland below.

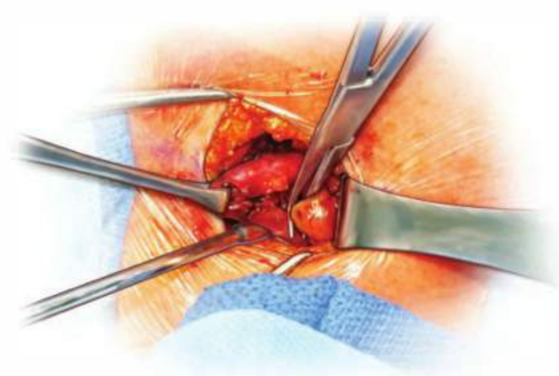

FIG 5 ● Parathyroid adenoma is identified in proximity to the thyroid gland. The parathyroid adenoma is separated from the surrounding tissue, taking care not to enter the capsule of the gland. The vascular pedicle is identified, ligated, and divided.

INTRAOPERATIVE DECISION MAKING WITH INTRAOPERATIVE PARATHYROID HORMONE

- We believe that intraoperative PTH assay is an important component of any MIP. iPTH has such a short half-life that if the abnormal parathyroid gland is removed and the other glands are normal, the PTH levels will drop by more than 50% in 5 to 10 minutes for the vast majority of patients. In most circumstances, a second peripheral intravenous catheter is placed prior to positioning the patient. Blood samples are then drawn through this intravenous catheter, taking care to ensure adequate blood is drawn to avoid a dilute sample from the intravenous fluid. We routinely draw four samples. The first is drawn after the skin preparation prior to making an incision ("preincision"). The second is drawn after finding the parathyroid adenoma prior to dividing its blood supply ("preexcision"). Postexcision levels are then drawn at 5 and 10 minutes after removing the parathyroid adenoma.
- Although many papers have been written on identifying the optimal criteria for intraoperative drop in PTH, we believe that a drop of 50% from the first baseline level at 5 or 10 minutes postexcision, as long as the value is within normal range, is strongly predictive of a successful operation.[6] If the preincision PTH level is very high and the preexcision level is even higher, it is sometimes necessary to draw levels beyond 10 minutes postexcision in order to see an adequate drop in PTH levels. We believe that with positive preoperative localization studies and a dramatic drop in PTH after excising the adenoma, the likelihood of a second abnormal parathyroid gland is exceedingly low and a four-gland exploration is not indicated.

CLOSURE

- As long as the skin incision is located in a skin crease or at least in line with skin creases, the likelihood of a cosmetically appealing scar is very high. We routinely close the skin with an absorbable suture in the platysma and subdermal level to take tension off the skin edges. The skin is closed with a 5-0 monofilament subcuticular suture with no knots. If an absorbable suture is used, Steri-Strips are applied and the suture is then cut flush with the skin. If a nonabsorbable suture is used, skin glue is placed over the incision prior to pulling the subcuticular stitch out in the operating room. Most patients have excellent cosmetic results.

POSTOPERATIVE CARE

- Assuming no other medical issues, many patients can be discharged after a successful MIP. Because a focused exploration has been undertaken, only one side of the neck has been dissected. Patients are generally given extra oral calcium for several days to prevent transient symptomatic hypocalcemia while the remaining parathyroid glands recover from having been suppressed. The extra calcium can be rapidly weaned. Patients are allowed to shower the day after surgery and the only restriction in activity is to avoid driving a car until there is no neck pain in turning and the patient is off pain medication.

OUTCOMES

- The outcomes after MIP have been shown to be excellent in several large series.[7,8] Patients recover rapidly and many have improvements in energy level with decreased bone pain in the weeks to months after surgery. The long-term risks of recurrent HPT are not different in many large series when comparing MIP with four-gland exploration.

COMPLICATIONS

- The primary risk of MIP is the small possibility of recurrent laryngeal nerve injury resulting in hoarseness. The risk of permanent hoarseness is in the 1% to 2% range in most large series of parathyroidectomies. Use of MIP in comparison to four-gland exploration does not seem to affect risk of recurrent laryngeal nerve injury. By contrast, the risk of permanent hypoparathyroidism, which is approximately 1% with a four-gland exploration, is eliminated with an MIP approach.
- Other potential complications of MIP include bleeding and infection. Both of these risks are extremely low with a parathyroidectomy and are not increased by use of MIP.

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Chapter 44

Endoscopic Parathyroidectomy by Lateral Approach

Jean-François Henry

DEFINITION

- A minimally invasive parathyroidectomy (MIP) may be defined as an operation requiring a small and discrete incision for a very direct access to the parathyroid glands, resulting in a focused dissection. MIP may be divided in two groups: open MIP performed under direct vision via a small cervical incision[1] and various endoscopic MIP performed partially or totally with the help of an endoscope. Today, three different types of endoscopic parathyroidectomies can be considered to be an option for surgeons: (1) Video-assisted parathyroidectomy,[2] which is a mini-open procedure performed partially with the help of the endoscope. (2) Endoscopic techniques using an extracervical approach. These techniques have the advantage of leaving no scar in the neck area but cannot reasonably be described as minimally invasive as they require more dissection than conventional open surgery. (3) Pure endoscopic techniques using a cervical access. These operations are performed totally with the help of the endoscope and include constant gas insufflations. Two pure endoscopic techniques have been described: the endoscopic parathyroidectomy by midline approach[3] and the endoscopic parathyroidectomy by lateral approach (EPLA).[4] EPLA develops the plane between the carotid sheath laterally and the strap muscles medially. This "back-door route" does not require complete dissection of the thyroid lobe from the strap muscles. It allows direct access to the posterior aspect of the thyroid lobe and it does not require anterior and medial retraction of the thyroid lobe during the entire procedure.

DIFFERENTIAL DIAGNOSIS

- Today, the diagnosis of primary hyperparathyroidism (PHPT) can be made with near certainty by documenting an increased serum intact parathormone (iPTH) level in a patient with increased ionized or total calcium. It is therefore necessary to eliminate all other causes of hypercalcemia and iPTH elevation. As for iPTH elevation, renal dysfunction and vitamin D deficiency are well known. Among causes of hypercalcemia, thought should be given to the syndrome of benign familial hypocalciuric hypercalcemia (BFHH), where the hypercalcemia is associated with normal or slightly raised levels of iPTH coexisting with hypocalciuria.

PATIENT HISTORY AND PHYSICAL FINDINGS

- The patient must be carefully selected. Not all patients presenting with HPT are candidates for an EPLA, as EPLA does not allow for a bilateral exploration.[5] Patients who are suspected to have multiglandular disease (MGD), including patients with secondary hyperparathyroidism (HPT) or patients with familial primary HPT, are not eligible for this procedure. Suspicion of parathyroid carcinoma is also an absolute contraindication. A history of neck irradiation, the presence of a large goiter and previous surgery in the thyroid vicinity are relative contraindications. EPLA can be performed in patients who have previously undergone a contralateral neck operation (Table 1).
- When considering EPLA, the adenoma must be solitary and clearly localized by preoperative imaging studies. Whether preoperative localizations techniques can rule out MGD with sufficient accuracy is questionable. Therefore, as with other minimally invasive techniques, the risk of missing MGD justifies the use of a quick intraoperative parathormone assay (QPTH).[6] The less definitive the localizations studies, the more imperative the need for QPTH.
- When patients are selected on the basis of the abovementioned criteria, no more than 50% of patients are eligible for this procedure (**FIG 1**).
- EPLA is technically more challenging than standard cervical exploration and its performance should be confined to tertiary centers. The surgeon must be experienced in conventional parathyroid surgery. Mentoring by a surgeon who has experience with endoscopic neck procedures is also recommended.

IMAGING AND OTHER DIAGNOSTIC STUDIES

- Only noninvasive tests should be considered. When these tests are negative, EPLA is not indicated and the traditional open cervicotomy is preferable. The topographic diagnosis should ideally be established by convergence of the results of two different investigations, one providing good anatomic information and the other providing functional information.
- High-resolution ultrasonography (US) and technetium-99m (Tc-99m) sestamibi scan are used most commonly in combination.[7] US can only assess the cervical region but gives good anatomic information, including useful information about the thyroid gland. The patient should be examined in the supine position with the neck in hyperextension. A pillow can be placed under the shoulders if the patient has a short neck. A high-frequency linear transducer

Table 1: Absolute and Relative Contraindications for Endoscopic Parathyroidectomy by Lateral Approach

Absolute contraindications
Suspicion of parathyroid carcinoma
Large goiter
Secondary or tertiary HPT
Familial HPT
Suspicion of MGD
No localization
Relative contraindications
Previous surgery
History of neck irradiation
Large tumor (>3 cm)
Inferior adenoma located anteriorly

HPT, hyperparathyroidism; MGD, multiglandular disease.

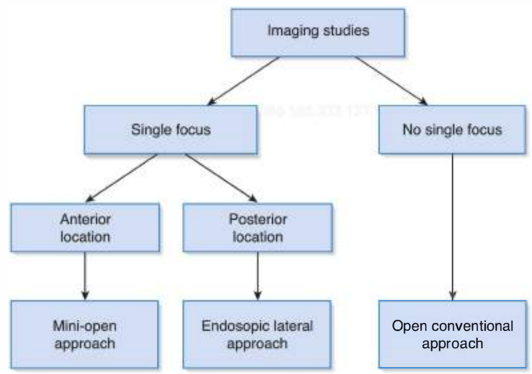

FIG 1 ● Algorithm for the surgical management of patients eligible for an endoscopic parathyroidectomy by lateral approach.

(7.5 to 10 MHz) is used to obtain optimal depth penetration of 3 to 4 cm. A bilateral and comparative scan should be performed in transverse section, then in longitudinal section. In transverse section, the examination concentrates on an area defined by the longus colli muscles posteriorly, the thyroid gland anteriorly, the trachea medially, and the carotid artery laterally. The scan is then performed in cranial and caudal directions. An additional scan can be performed with the head of the patient turned away to the side and during deglutition to optimize the lateroesophageal images. The anterosuperior mediastinum is examined by inclining the transducer deeply in a retrosternal direction. The examiner should note the precise location with respect to surrounding structures, particularly to the thyroid gland, and the depth from the skin. Finally, a color flow Doppler or a power flow Doppler will be performed to test the vascularization of the area and define the artery branches involved.

- Two protocols for sestamibi scanning can be used: the single isotope dual phase protocol and the substraction protocol. The dual protocol requires early (15 minutes postinjection) and delayed images (at 1 and 2 to 3 hours, depending on thyroid washout). In cases of multinodular thyroid disease, additional further delayed images are sometimes needed. When a subtraction protocol is used, Tc-99m sestamibi is used in conjunction with another radionuclide specific to the thyroid. Tc-99m pertechnetate and ^{123}I are the most widely used radioisotopes for thyroid scintigraphy. The main advantage of using ^{123}I is that thyroid and parathyroid images can be acquired simultaneously in a dual energy window setup. The disadvantage is the cost of the protocol related to ^{123}I. Parathyroid scintigraphy should include views of the neck and the mediastinum. Single-photon emission computed tomography (SPECT) can be helpful for more precise localization of adenomas, as it provides simultaneous three-dimensional (3-D) information on both neck and superior mediastinum.
- Instead of US and Tc-99m sestamibi scan, four-dimensional computed tomography (4D-CT)[8] or the use of computed axial tomography-methoxyisobutyl isonitrile (MIBI) image fusion,[9] when available, may be preferable.
- Consideration for EPLA depends on the results of preoperative imaging. EPLA should be strongly considered when the parathyroid adenoma is in close proximity to the recurrent laryngeal nerve, as the nerve is at risk during MIP. Therefore, EPLA is the procedure of choice in all cases where the parathyroid adenomas are deeply located in the neck.
- Three locations of parathyroid adenomas with regard to the recurrent laryngeal nerve can be described (**FIG 2**).[4] Location 1 is posterior to the two superior thirds of the thyroid lobe (**FIGS 3** and **4**). These adenomas are superior glands. Location 2 is at the level of or below the inferior pole of the thyroid lobe but in a plane posterior to it (**FIGS 5** and **6**). These adenomas may be either a superior gland that has migrated posteriorly and in a downward direction or an inferior gland that has fallen posteriorly. These glands can also migrate into the superior and posterior mediastinum. Location 3 is at the level of or below the inferior pole of the thyroid lobe but in a superficial plane (**FIGS 7** and **8**). These adenomas are always inferior glands and can be found in close contact with the tip of the inferior pole of the thyroid lobe but also along the thyrothymic ligament or into the superior pole of the thymus.

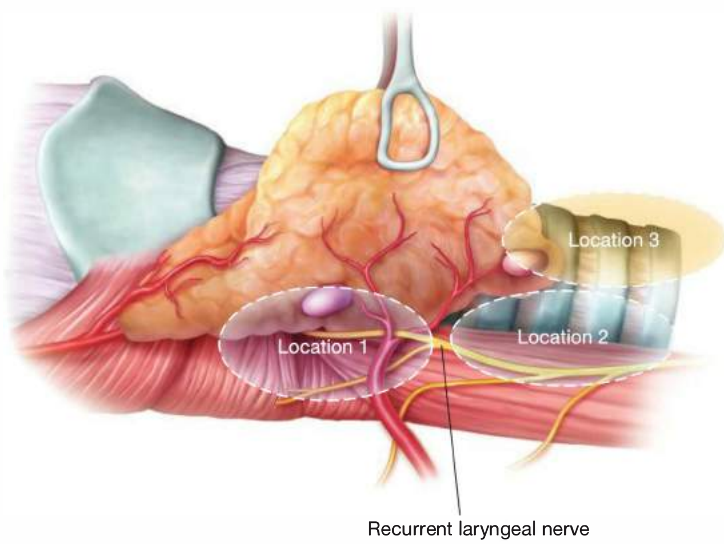

FIG 2 ● The three different locations of parathyroid adenomas with regard to the recurrent laryngeal nerve. Location 1, posterior to the two superior thirds of the thyroid lobe; location 2, at the level of or below the inferior pole of the thyroid lobe but in a plane posterior to it; location 3, at the level of or below the inferior pole of the thyroid lobe but in a superficial plane.

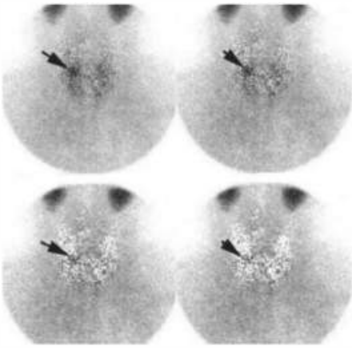

FIG 3 ● Parathyroid Tc-99m sestamibi scintigraphy; subtraction protocol. The subtraction image demonstrates a right parathyroid adenoma at the level of the middle third of the right thyroid lobe *(arrow)*.

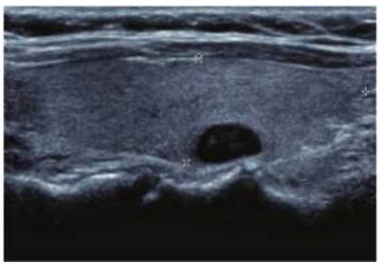

FIG 4 ● Ultrasound (same patient in **FIG 3**). Right parathyroid adenoma posterior to the middle third of the thyroid lobe: right superior parathyroid adenoma in location 1. EPLA is indicated.

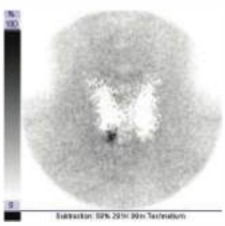

FIG 5 ● Parathyroid Tc-99m sestamibi scintigraphy; subtraction protocol. The subtraction image demonstrates a right parathyroid adenoma at the level of the inferior third of the right thyroid lobe.

FIG 6 ● Ultrasound (same patient in **FIG 5**). Right parathyroid adenoma posterior to the inferior third of the thyroid lobe: right, more probably inferior, parathyroid adenoma in location 2. EPLA is indicated.

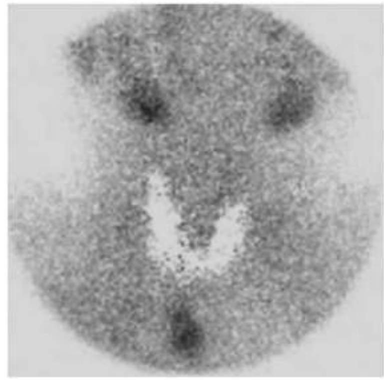

FIG 7 ● Parathyroid Tc-99m sestamibi scintigraphy; subtraction protocol. The subtraction image demonstrates a right parathyroid adenoma below the inferior pole of the thyroid lobe.

- Adenomas in locations 1 and 2 are deeply located and are in the vicinity of the recurrent laryngeal nerve. The nerve is at risk and its clear identification during the procedure is recommended. The lateral view, provided by EPLA, permits its easy identification and allows a secure dissection. On the other hand, adenomas in location 3 are at distance from the nerve, which runs more deeply. Its identification is not essential. An anterior mini-open approach without the help of the endoscope is indicated.
- In conclusion, the need to know preoperatively when the nerve is at risk reinforces the role of preoperative imaging studies. Depending on whether the patient has a deep-seated adenoma or a superficial-seated adenoma, the surgeon can choose between EPLA and an anterior mini-open approach.
- The main interest of using an endoscope is not that one can perform a parathyroidectomy through a small incision but that one can perform a safe parathyroidectomy through a small incision.

SURGICAL MANAGEMENT

Preoperative Planning

- Prior to surgery, the patient undergoes a vocal cord check.
- The procedure is performed under general anesthesia with endotracheal intubation. Trocars are poorly tolerated by

FIG 8 ● Ultrasound (same patient in **FIG 7**). The adenoma *(2)* is in the superficial plane, below the inferior pole of the thyroid lobe *(1)*, along the thyrothymic tract: right inferior parathyroid adenoma in location 3. There is no need for the endoscope. A mini-open procedure is indicated.

FIG 9 ● Instruments of 3-mm trocars (Medtronic Xomed, MicroFrance, Saint Aubin Le Monial, France).

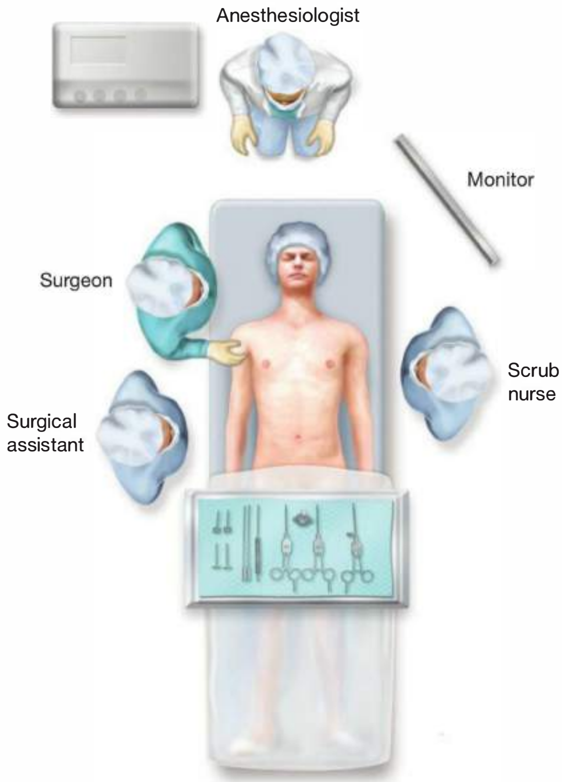

FIG 10 ● Operating room organization.

patients under local or regional anesthesia. In addition, swallowing and spontaneous breathing present impediments when dissecting in a small operative space.

- The surgical instruments required include a 10-mm trocar, which will accommodate a 0-degree fiberoptic endoscope, and two 3-mm trocars, which will receive a series of purpose-made instruments (Medtronic Xomed, MicroFrance) including blunt-tipped dissectors, graspers, scissors, a diathermy hook, and an aspiration canula. These instruments measure 25 cm in length (**FIG 9**).
- In patients presenting with small parathyroid adenomas less than 2 cm in diameter, a 5-mm trocar and a 5-mm 0-degree endoscope can be used.
- QPTH assays are performed before and at the time of incision, directly before parathyroid excision and, subsequently, 5 and 15 minutes after parathyroid excision. Parathyroidectomy is considered successful when QPTH value falls by greater than 50% with respect to the highest preexcision level and into normal range (10 to 65 pg/mL).[5]
- The surgical team consists of the operator, first assistant, and a scrub nurse. The surgeon and first assistant stand on the side of the diseased gland, with the scrub nurse facing them. The monitor is placed next to the scrub nurse and directly in front of the surgeon (**FIG 10**).

Positioning

- The patient is positioned in the supine position. The head is placed in a neutral position without hyperextension to avoid tensing the sternocleidomastoid muscle (SCM) and the strap muscles. Complete relaxation and suppleness of these muscles are essential to prevent narrowing down the operative space given that this is maintained with low-pressure gas insufflation. The patient is prepped and draped as for standard parathyroid surgery.

THE BACK-DOOR APPROACH

- An initial 12- to 15-mm transverse skin incision (optic trocar incision) is made on the anterior border of the SCM, at the level of the thyroid isthmus (**FIG 11**). It will permit the creation of a space through which the 10-mm trocar will be introduced. This incision is placed such that in the event of conversion, it can be extended medially to result in a symmetric collar incision.
- After division of the platysma, the anterior border of the SCM is identified and the investing layer of cervical fascia is incised. This allows access to the plane of dissection between the SCM laterally and the strap muscles medially, just inferior to the omohyoid muscle (**FIG 12**).
- The fascia connecting the posterior aspect of the thyroid lobe medially to the carotid sheath laterally is gently divided with scissors (**FIG 13**). A middle thyroid vein may be encountered. It is ligated without any difficulty through the incision.
- A small moist gauze is then inserted through the incision and packed deeply in an upward and downward direction into the initially created space (**FIG 14**). This blind maneuver enlarges the cavity and permits a surprisingly quick, efficient, and bloodless exposure of the operative field.

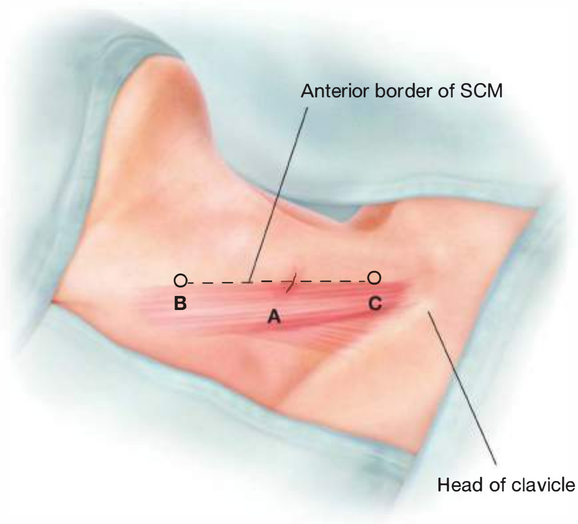

FIG 11 ● Trocar sites. All three trocars are positioned on the line of the anterior border of the SCM. Main trocar *(A)* is placed at the level of the thyroid isthmus. Trocars *B* and *C* should be 3 to 4 cm apart and will be used for the 2-mm instruments. SCM, sternocleidomastoid muscle.

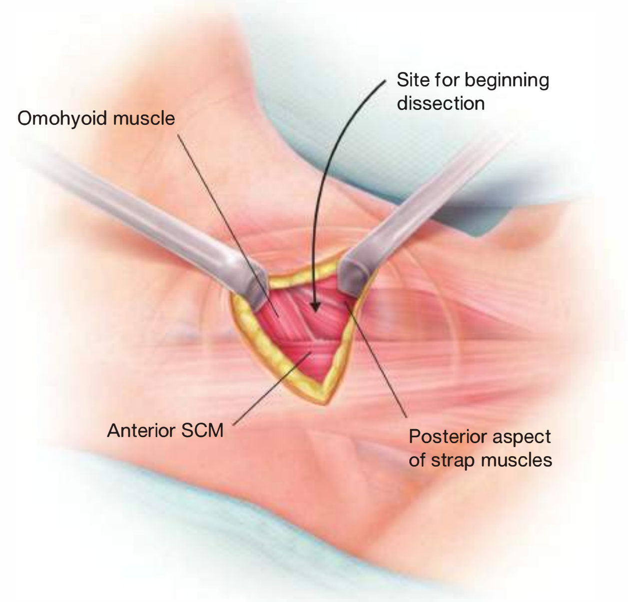

FIG 12 ● The access to the plane of dissection between the SCM laterally and the strap muscles medially is just inferior to the omohyoid muscle. SCM, sternocleidomastoid muscle.

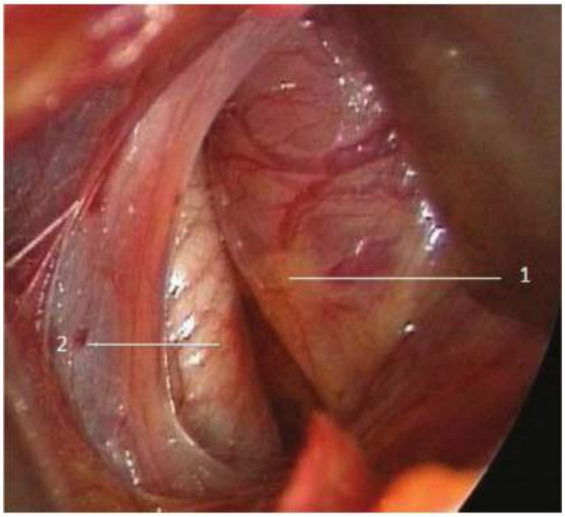

FIG 13 ● The back-door approach uses the plane between the posterior aspect of the thyroid lobe medially *(1)* to the carotid sheath laterally *(2)*.

FIG 14 ● Creating space for endoscopic exploration. A small moist gauze roll is inserted through the incision and packed deeply into the initially created space.

INSTALLATION OF THE TWO 3-MM WORKING TROCARS

- The two 3-mm trocars are placed on the line situated along the anterior border of the SCM, in their respective positions, above (5 to 6 cm) and below (3 to 4 cm) the main optic trocar incision. Safe trocar placement is achieved by tunnelling a 2.5-mm drain introducer needle inserted from within the main incision through to the skin. The direction this guide takes must follow the anterior border of the SCM. During this maneuver, one must constantly be aware of the internal jugular vein situated posteriorly, the external jugular vein situated cranially, and the anterior jugular vein situated caudally. The 3-mm trocar is placed over the tip of the introducer needle, which has pierced the skin from inside out and railroaded into the operative space (**FIG 15**). Each appropriately positioned 3-mm trocar is then loosely fixed to the skin with a nonabsorbable monofilament stitch to prevent involuntary removal.

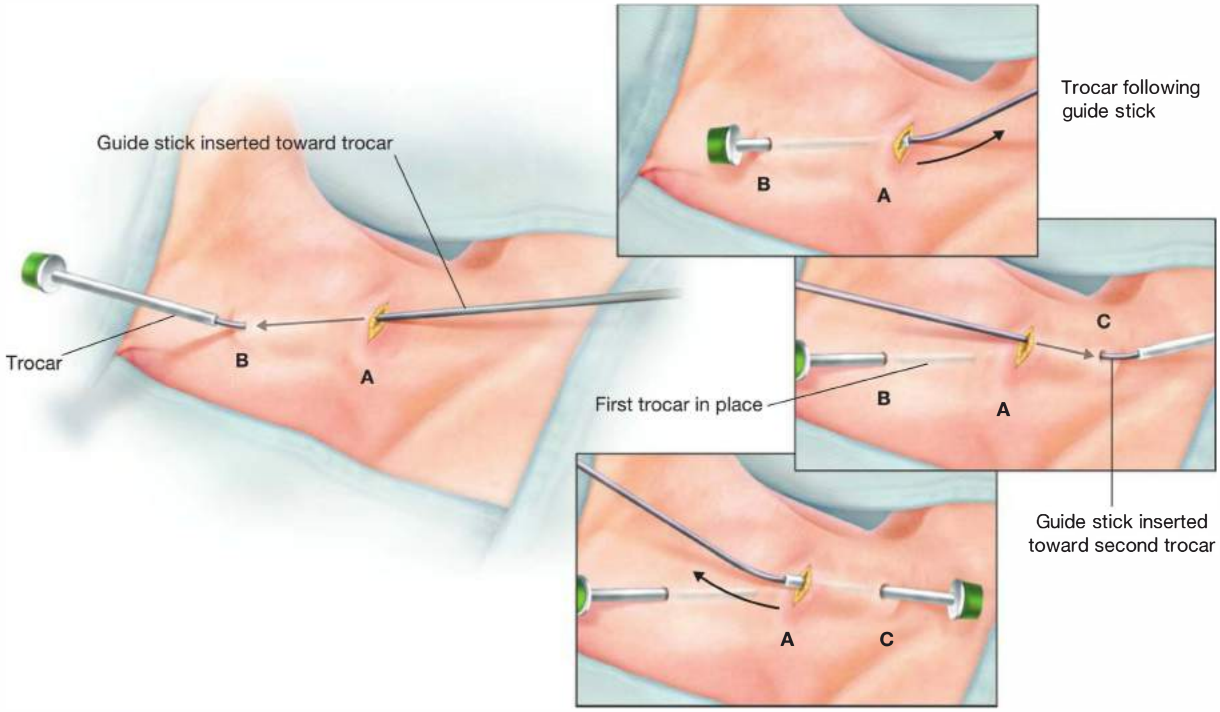

FIG 15 ● Installation of the 3-mm trocars. The transparietal path of both trocars is made through the incision *(A)*, from the inside to the outside, using a guide stick. The pathway of the guide stick must follow the anterior border of the SCM. Then, the 3-mm trocar is placed over the tip of the guide stick and railroaded into the operative space.

INSTALLATION OF THE 10-MM OPTIC TROCAR

- A purse-string stitch is placed around the main wound. It incorporates not only the skin but also the anterior border of the SCM laterally and the posterior border of the sternothyroid muscle medially. At this stage, the gauze roll is removed, the 10-mm trocar inserted and held in position with the purse-string suture.
- The purse string is subsequently threaded through an eyelet mounted on a specifically designed device encircling the trocar and secured to this (**FIG 16**). This arrangement guarantees air tightness, allows the amplification of the operative space, and prevents the trocar from slipping out of the wound.
- The three trocars are now positioned. The assistant takes care of the endoscope and the surgeon works through the other two trocars (**FIG 17**).

FIG 16 ● Installation of the main trocar. A purse-string stitch is placed around the main wound and is tied on a specifically designed device encircling the main trocar.

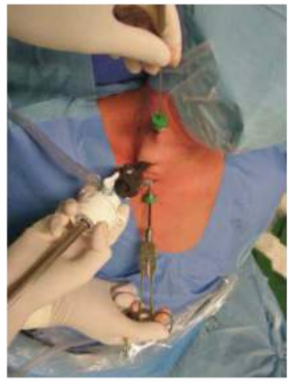

FIG 17 ● The three trocars are positioned. Insufflation (8 mmHg) is installed. The assistant holds the camera and the operator works through the other two 3-mm trocars. Endoscopic exploration can start.

ENDOSCOPIC PARATHYROID EXPLORATION

- A pneumocervicotomy is established using insufflation with carbon dioxide (CO_2) at low pressure (8 mmHg). The gas not only maintains the working operative space but also may tamponade off minor bleeders. First, the carotid must be identified. Then, the space between the carotid laterally and the posterolateral aspect of the thyroid lobe medially is developed. The dissection is performed with the help of two blunt-tipped metallic dissectors. Ligatures or clip applications are not necessary. The combination of blunt dissection and gas insufflation allows easy separation of structures, minimizing the need for sharp dissection. This facilitates identification of the key structures and landmarks that will permit a safe dissection. The inferior thyroid artery and, of course, the recurrent laryngeal nerve must be identified first. The inferior thyroid artery is a useful landmark for locating the recurrent laryngeal nerve. The easiest site to identify the nerve is at the level of the lower pole of the thyroid gland, just caudally to the trunk of the artery. On the left side, the nerve ascends at the depth of the tracheoesophageal groove. On the right side, the nerve courses more obliquely. The magnification allowed by the endoscope provides improved visualization of the vasa nervorum running along the nerve and help its identification.
- Very often one can observe that the nerve branches far below its laryngeal entry point (**FIG 18**). Also, small extralaryngeal branches extending to the adjacent trachea and esophagus are easily seen.

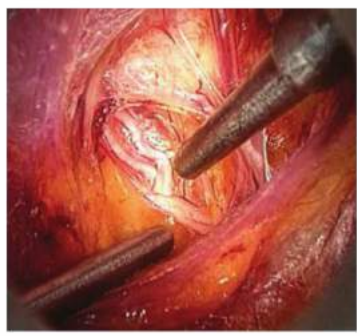

FIG 18 ● Endoscopic exploration on the right side: identification of the right recurrent laryngeal nerve. In this case, the nerve branches far below its laryngeal entry point.

IDENTIFICATION OF THE PARATHYROID ADENOMA

- Based on the results of the preoperative imaging studies, the surgeon may suspect an adenoma in location 1 or 2.
- All glands in location 1 are superior parathyroid adenomas. The search for them requires the dissection of the upper two-thirds of posterior aspect of the thyroid lobe (**FIG 19**). Small superior adenomas usually remain located in their orthotopic site, floating in a loose, fatty setting immediately adjacent to the inferior thyroid artery. Large superior adenomas tend to migrate posteriorly and downward. Therefore, if they are not found in immediate contact with the thyroid capsule, they should be sought beside or behind the esophagus.
- Glands in location 2 may be also superior parathyroid adenomas. Their migration may drag them down very low, well below the inferior thyroid artery, behind whose

FIG 19 ● Endoscopic exploration on the right side: inferior thyroid artery *(1)*, superior parathyroid adenoma *(2)* posterior to the middle third of the thyroid lobe *(3)*. The adenoma is located in location 1.

trunk they cross during their descent. Endoscopic exploration behind the inferior thyroid artery, along the esophagus, and down into the posterior mediastinum can be easily accomplished by this back-door approach. These adenomas are revealed by their vascular pedicle, which is easily dissected at the level of the inferior thyroid artery. They emerge with simple traction on it and their elongated shape is amenable to expeditious extraction.

- The search of inferior parathyroid adenomas in location 2 requires the exploration of the lower third of the posterior aspect of the thyroid lobe. Sometimes, they are identified immediately after introducing the endoscope. They tend to descend posteriorly and in a downward direction to acquire a paratracheal or a paraesophageal position. It is in these cases that they become intimate with the recurrent laryngeal nerve. Their posterior surface may adhere to the nerve. In these cases, the lateral view allows a secure dissection of the nerve.
- Although searching for the ipsilateral gland is not mandatory, it can often be identified when it is in location 1 or 2 (**FIG 20**).

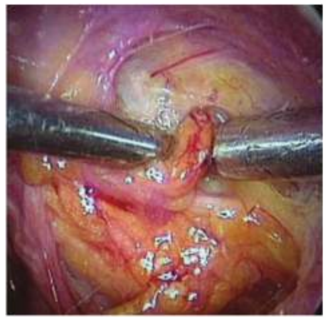

FIG 20 ● Identification of the ipsilateral inferior parathyroid gland. The gland is normal.

DISSECTION OF THE PARATHYROID ADENOMA

- The adenoma must never be grasped to avoid parathyroid fracture and potential risk of parathyromatosis. The adenoma is progressively freed from adjacent structures by blunt dissection with the help of two blunt-tipped metallic dissectors (**FIG 21**). One dissector retracts the adenoma, providing tension, while the other instrument is used to dissect the gland away from surrounding structures and loose areolar tissue until complete mobilization is achieved. When the pedicle is isolated (**FIG 22**), the terminal vascular branches are grasped, skeletonized, and electrocoagulated with the 3-mm diathermy hook (**FIG 23**).

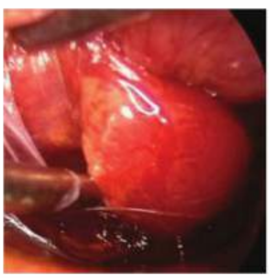

FIG 21 ● Endoscopic dissection of the superior parathyroid adenoma with the help of two blunt-tipped dissectors. The gland should not be grasped to avoid capsular disruption.

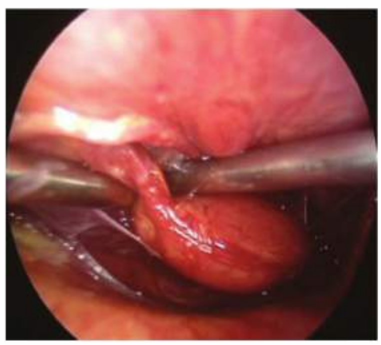

FIG 22 ● Dissection of the vascular pedicle of the superior parathyroid adenoma.

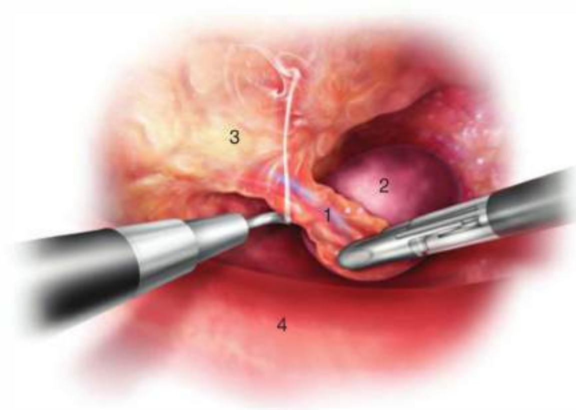

FIG 23 ● Electrocoagulation of the terminal vascular branches *(1)* of the superior parathyroid adenoma *(2)* with the 3-mm diathermy hook. *3*, thyroid lobe; *4*, carotid artery.

EXTRACTION OF THE PARATHYROID ADENOMA

- Most parathyroid adenomas can be extracted through the 10-mm trocar. In performing this step, after removing the 10-mm endoscope, a grasper and a 5-mm lens are simultaneously introduced into the 10-mm trocar. The pedicle of the adenoma is grasped and the adenoma is drawn into the trocar (**FIG 24**), the trocar containing the specimen is then removed.
- Larger adenomas that cannot be drawn into the 10-mm trocar are extracted directly through the trocar site under direct vision. There is no need to place them in a sterile plastic bag during this maneuver. After checking hemostasis, the two 3-mm trocars are removed.

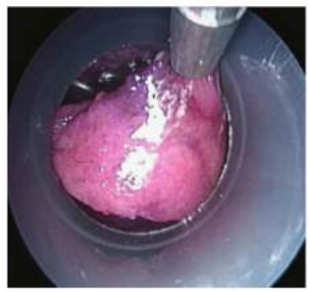

FIG 24 ● Extraction of the parathyroid adenoma. The pedicle of the adenoma is grasped and the adenoma is drawn into the trocar.

CLOSURE

- A surgical drain is not necessary. The platysma is sutured. The skin incision and the two 3-mm trocars sites are closed with fibrin glue (**FIG 25**). No dressing is required.

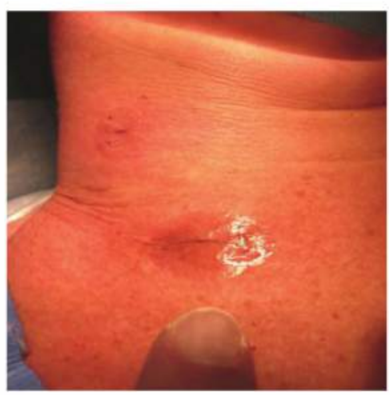

FIG 25 ● Fibrin glue is used to close the skin.

PEARLS AND PITFALLS

Indications	■ Only patients with sporadic primary HPT, in whom a single adenoma has been clearly localized by preoperative imaging studies, are potential candidates for EPLA. ■ Based on the results of preoperative imaging studies, EPLA should be reserved for patients presenting with parathyroid adenomas deeply located in the neck.
QPTH assay	■ The availability of the QPTH assay is of utmost importance. This test is especially useful when localization studies are less certain.
Installation of trocars	■ Place all three trocars on the line of the anterior border of the SCM and fix them to the skin to prevent involuntary removal. ■ Optic trocar incision should be created such that in the event of conversion, it can be extended medially to result in a traditional cervicotomy. ■ The transparietal path of the working trocars should be made through the optic trocar incision, from the inside to the outside.
Working space	■ Place the head in a neutral position to avoid tensing the SCM and the strap muscles. ■ In order to enlarge the working area, before introducing the optic trocar, stuff a small moist gauze, upward and downward, deeply into the initially created space, and then remove it.
Endoscopic exploration	■ Bear in mind that because the working space is very small, the endoscope is very close to the anatomic structures, which will therefore appear highly magnified. There is a definite risk of removing a normal gland that appears enlarged under endoscopic vision.
Endoscopic dissection	■ Never grasp the adenoma to avoid parathyroid fracture. The dissection can be performed entirely with the two blunt-tipped palpators.

POSTOPERATIVE CARE

- The patient may remain in the operating room or, in case of long processing for the QPTH assay, may be transferred to the postanesthesia care unit after extubation. In this latter case, if the results of QPTH are not consistent with successful removal of parathyroid adenoma, the patient must be returned to the operating room. In both cases, conversion to bilateral neck exploration is performed if the QPTH value does not fall by greater than 50% and into normal range (10 to 65 pg/mL).
- Patients have determination of serum parathyroid hormone (PTH) 4 hours after excision of the adenoma, then on day 1 and day 8 after surgery. Calcemia and phosphoremia are also systematically evaluated on day 1 and day 8.
- The serum PTH level reaches its nadir 4 hours after excision of the adenoma and, in most patients, the serum calcium reaches its lowest level within 48 to 72 hours after surgery. Because the parathyroid exploration is unilateral, postoperative hypoparathyroidism is not observed. However, postoperative hypocalcemia can be observed in patients with severe skeletal depletion of calcium, resulting in "bone hunger." If symptoms appear, calcium and vitamin D derivatives should be administrated.
- Usually, patients are discharged the day after surgery.
- Postoperative vocal cord evaluation must be performed systematically.

OUTCOMES

- After EPLA, more than 95% of patients are normocalcemic. However, it should be kept in mind that these excellent results are obtained in a group of carefully selected patients.[4]
- EPLA does not appear to be clearly superior to other MIP technique in terms of recurrent disease or postoperative complications.[10]
- As with other techniques of single-gland excision through a limited neck exploration, EPLA does not lead to an increased incidence of persistent/recurrent HPT[10]; it is associated with a better postoperative course in terms of pain and it produces better cosmetic results compared to bilateral neck exploration[11] (**FIG 26**). Prevalence and severity of postoperative hypocalcemia are lowered.[12]

FIG 26 ● Cervical scar 1 month after surgery.

COMPLICATIONS

- Hematoma
- Inferior laryngeal nerve injury
- Parathyroid adenoma not found: conversion
- Capsular rupture of adenoma
- False-positive result of preoperative imaging studies
- False-negative result of QPTH assay

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Chapter 45 Reoperative Parathyroidectomy

Barnard J. A. Palmer   William B. Inabnet, III

DEFINITIONS

- Reoperative parathyroid surgery occurs in multiple clinical settings but is most frequently performed as the result of failed exploration, recurrent, or persistent hyperparathyroidism.
- Persistent hyperparathyroidism is defined as hypercalcemia that remains or recurs within 6 months of an initial parathyroid operation.
- Recurrent hyperparathyroidism is the reappearance of hypercalcemia after a period of 6 months of postoperative normocalcemia following successful surgery.

PATIENT HISTORY AND PHYSICAL FINDINGS

- A detailed history of the patient's disease should be performed, focusing on the management to date.
- Biochemical confirmation of persistent or recurrent hyperparathyroidism is the initial step in management. A 24-hour collection for calcium is recommended.[1,2]
- The benefits of reoperation must be weighed against the risks of continued hyperparathyroidism and the surgical complications for each individual patient. Nonsurgical management can be considered if the sequela of continued parathyroid disease is relatively low risk or the risk of operation is high.
- Surgical history is an essential component of reoperative parathyroid surgery. The surgeon must understand reasons for initial operative failure.[3]
- Operative and pathology reports should be carefully reviewed, focusing on the extent of exploration, glands identified and removed, whether confirmed by biopsy, if marked, and if reimplanted.

IMAGING AND OTHER DIAGNOSTIC STUDIES

- Extensive preoperative planning is key to successful reoperative surgery.
- Previous operative reports, imaging, and pathology results should be obtained and reviewed to understand the cause of failure.[2]
- Localization studies are an essential portion of preoperative planning and should be performed in all reoperative parathyroid patients. Ultrasound, sestamibi, computed tomography (CT) (parathyroid protocol, 4-D) (**FIG 1**), single-photon emission computed tomography–computed tomography (SPECT/CT), and fluorodeoxyglucose-positron emission tomography (FDG-PET) can be used for localization and to rule out multigland disease. Preoperative location of abnormal glands can significantly alter the operative approach particularly if aberrant glands lie in the mediastinum.
- Fine needle aspiration (FNA) with measurement of parathyroid hormone (PTH) can confirm parathyroid tissue in questionable lesions or parathyroid adenomatosis identified by ultrasound.
- Invasive localization studies such as selective venous sampling (**FIG 2**) or arteriography should be reserved for when noninvasive studies fail to localize pathology.

SURGICAL MANAGEMENT

Preoperative Planning

- The imaging must be thoroughly reviewed to plan the operative approach.
- Prior operative notes are reviewed and operative steps clearly determined prior to reexploration.
- Positively localized lesions lend themselves to focused reexplorations, whereas more extensive exploration is required for multigland or nonlocalized diseases.
- Preoperative flexible laryngoscopy is recommended prior to reoperative surgery to document vocal cord function and guide the extent of surgery.
- Frozen section and intraoperative PTH assays are useful adjuncts to confirm parathyroid identification and biochemical cure.

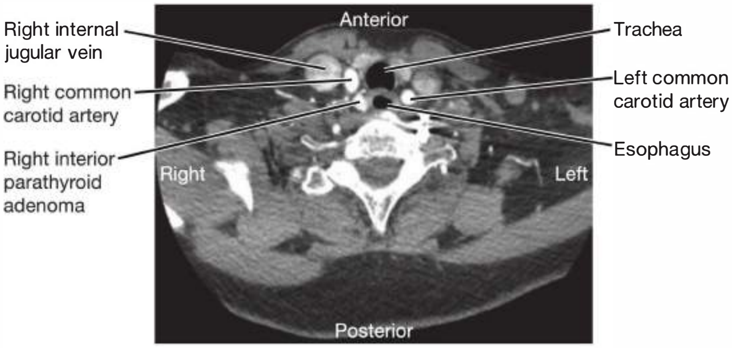

FIG 1 ● Parathyroid CT demonstrates a contrast-enhancing lesion posterior to the right common carotid artery, posterolateral to the trachea, and lateral to the esophagus, representing a right inferior parathyroid adenoma.

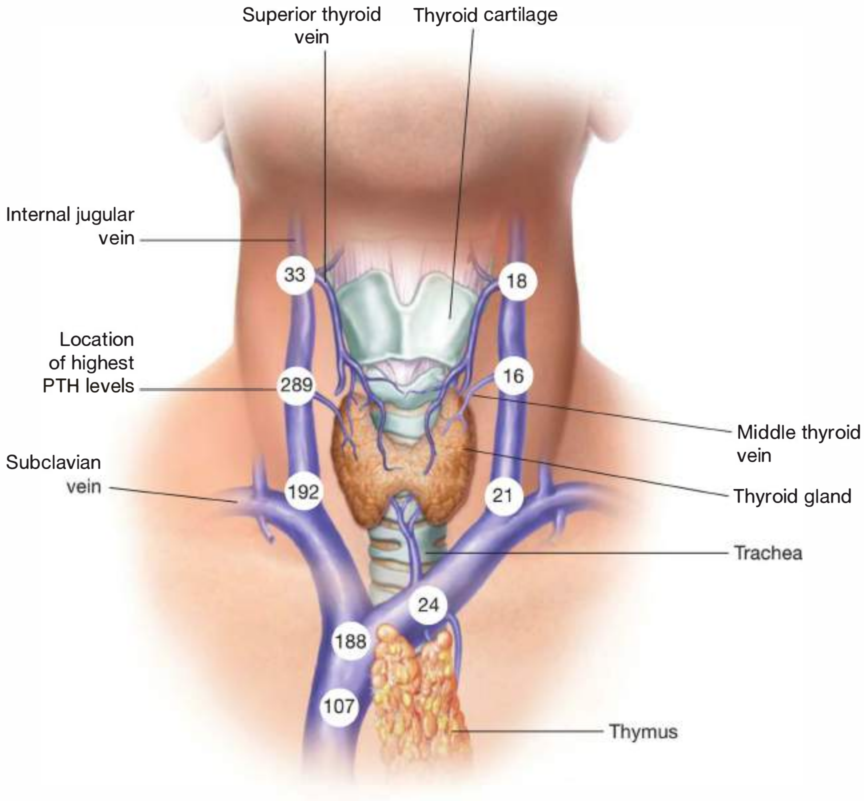

FIG 2 ● Selective venous sampling schematic lists PTH levels at different anatomic locations and is consistent with a right midlobe parathyroid adenoma.

Positioning

- The patient is positioned either supine or in the semi-Fowler position. Both arms are tucked and neck extension is achieved with a shoulder roll (**FIG 3**).
- Surgical prep must be wide enough to allow access superiorly to angle of mandible and inferiorly to xiphoid in the instance that sternotomy is necessary.
- General endotracheal anesthesia permits the use of intraoperative nerve monitoring.

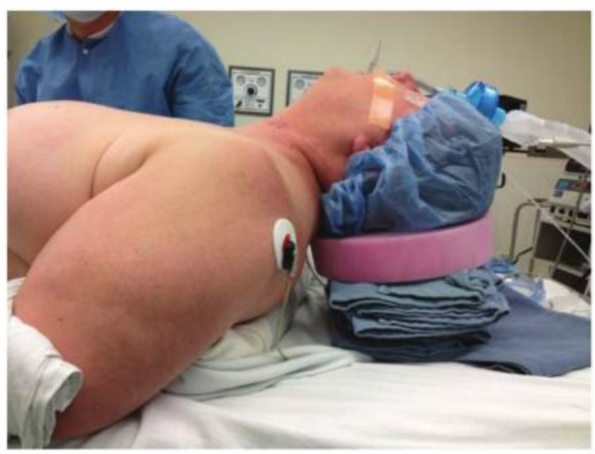

FIG 3 ● The patient is placed supine with both arms tucked. A shoulder roll provides additional neck extension, which elevates the trachea anteriorly and superior mediastinal structures cephalad.

CERVICAL REEXPLORATION

Incision and Flap Elevation

- Skin incisions are placed as indicated by the preoperative localizing studies, preferably in a natural cervical skin crease or the old incision (unless the scar is too low or high). Width of incision is dependent on depth of neck but is large enough to allow access superiorly to the level of the hyoid bone and inferiorly to the anterior mediastinum (**FIG 4**).
- Incisions may be placed over the site of pathology for a directed approach if preoperatively localized.
- Skin and platysma are divided and subplatysmal flaps superficial to the anterior jugular veins are elevated superiorly to the thyroid notch, inferiorly to the sternal notch, and laterally to anterior borders of the sternocleidomastoid muscles (SCM).

Cervical Approach[3]

- Surgical approach to the reoperative neck is done via focused exploration or by classic midline, posterolateral, or thyrothymic ligament approaches.
- Focused explorations for preoperatively localized ectopic glands not accessible via prior cervicotomy should be adjusted to location and surgeon experience with incisions placed according to imaging.
- Revision cervicotomy is indicated when multigland disease is suspected or when abnormal glands are not localized preoperatively. The previous incision is used and the cervical scar revised prior to opening the midline raphe by vertical separation of strap muscles (see Part 5, Chapters 45 and 48).

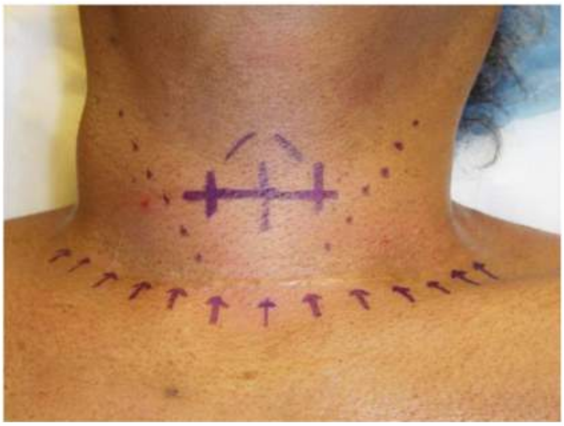

FIG 4 ● Skin incisions are placed in a natural skin crease and is adjusted according to preoperative localization and planned approach. Classic, large, inferior incisions have been substituted by more superior smaller incisions or incisions directly over parathyroid lesions. Lateral incisions can be made for a posterolateral approach with entry between the anterior border of the sternocleidomastoid and lateral border of the strap muscles. *Upward arrows* on the pictures show a classic incision versus a small superior incision as indicated by the *solid transverse line markings*.

- The back door or ***posterolateral*** approach should be considered when there is extensive scar tissue or when seeking a posteriorly localized gland. The lateral portion of a prior wound is used and entry to the neck is achieved between the lateral border of the straps and anterior portion of the SCM (**FIG 5**).

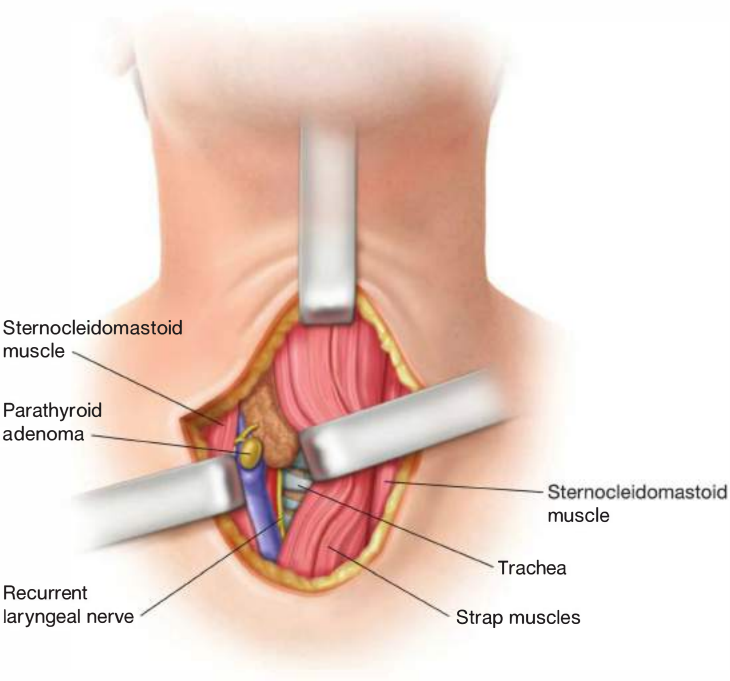

FIG 5 ● The posterolateral approach to the neck is similar to the classic approach except that subsequent access is achieved along the medial border of the SCM and lateral to the sternohyoid-sternothyroid, minimizing dissection through midline scar. The omohyoid muscle is divided as necessary.

- The front door or ***thyrothymic*** ligament approach should be considered when adenomas are localized anteriorly along the inferior thyroid pole or thyrothymic ligament. Infrahyoid muscles may be divided as inferiorly as possible to allow direct access to the thyrothymic ligaments, avoiding dissection between the strap muscles and thyroid capsule.
- Once deep to the strap muscles, retraction of the thyroid involves elevation of the strap muscles off the gland and medial thyroid rotation. A Kittner, thyroid clamp, or figure-of-eight suture assists thyroid retraction.
- The recurrent laryngeal nerve (RLN) is then identified and preserved.

Exploration

- Steps are systematically planned and based on preoperative imaging.
- If an abnormal gland is localized preoperatively, commence with focused exploration.
- Start by exploring the normal locations of the missing glands. The superior glands are generally at the mid to upper one-third of the thyroid in the expected position 85% of the time, at the inferior border of the thyroid cartilage posterior to the RLN and the superior portion of the inferior thyroid artery.
- The inferior glands are classically located near the posterior aspect of the thyroid pole, anterior to the RLN from the inferior thyroid artery to the inferior thyroid pole or along thyrothymic ligament (see Part 5, Chapter 41, **FIG 11**).
- If unable to locate in normal positions, search expected aberrant positions.
- Ectopic superior glands are generally displaced posteriorly or inferiorly, becoming more posterior as they travel inferiorly.
- Search circumferentially around the superior thyroid pedicle and visceral sheath of the thyroid capsule with thyroid palpation.
- Follow the tracheoesophageal groove inferiorly down to the posterior mediastinum (**FIG 6**).
- Inferior glands have a greater range of position but nearly 25% are along the thyrothymic ligament or upper pole of the thymus. They are rarely posterior and become more anterior the lower they are.
- Search and digitally explore the posterior and inferior thyroid gland.
- Inspect the thyrothymic ligament, incise the thymic sheath, and pull the thymic lobe cephalad to inspect the thymus (see **FIG 8**).
- Explore the carotid sheath up to the angle of the mandible (**FIG 7**).

Gland Identification and Excision

- Normal parathyroids are approximately 3 × 2 × 4 mm and tan in appearance.
- Abnormal glands have a characteristic rubbery feel and reddish brown appearance.
- They are freed from the surrounding tissue and the vascular pedicle is clamped and divided.
- Parathyroid confirmation can be achieved through histologic examination. Biopsy of the antihilar tip of the gland using sharp dissection is performed with great care to not disturb the fragile blood supply.

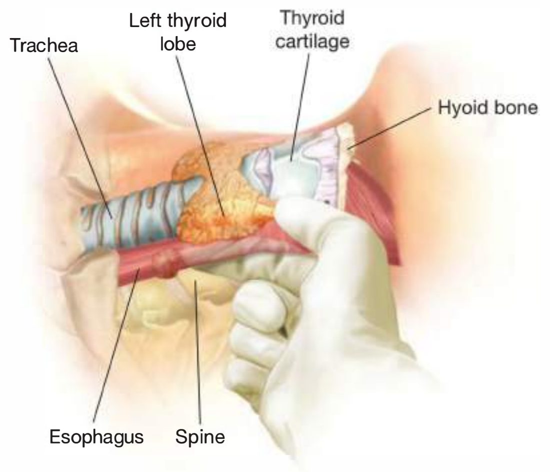

FIG 6 ● The lateral wall of the esophagus and the tracheoesophageal groove are exposed from the hypopharynx superiorly down to the mediastinum. Missing glands may be found in the prevertebral space and the search for parathyroids in this region is augmented by digital palpation.

- Intraoperative PTH monitoring improves the cure rate and guides the extent of exploration.
- A drop in PTH by 50% of baseline and within normal limits at 10 minutes is indicative of cure. If operating for multigland disease (as opposed to a missed adenoma), the PTH level at 10 minutes should also be within normal limits.
- Exploration continues if levels do not fall precipitously and the process is repeated until an appropriate drop is achieved.

Additional Maneuvers

- Because inferior adenomas are usually displaced into the anterior aspect of superior mediastinum, they may be intimately associated with the thymus gland.
- Cervical thymectomy may be performed in the case of absent glands (**FIG 8**). Gentle traction cephalad with sequential grasps and blunt mobilization are used to deliver the thymus into the cervical wound with the aim of removal of thymus tissue to the level of the innominate vein.
- Similarly, thyroid lobectomy on the side of a missing parathyroid may be performed.
- Staged procedures are common with nonlocalized reoperative parathyroid surgery. Closure and relocalization should be performed if the offending gland cannot be found.

Closure

- Meticulous hemostasis is achieved; strap muscles are reapproximated in midline (or to SCM if lateral approach done), followed by platysma reapproximation and skin closure.
- Drains are not regularly used unless there is extensive dissection or exploration.

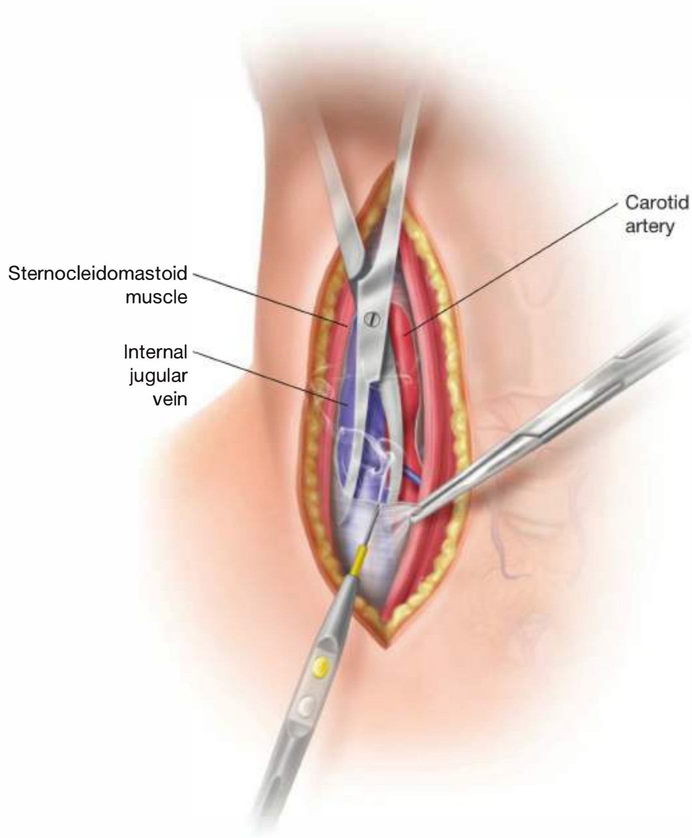

FIG 7 ● If the search fails to disclose an adenoma, the carotid sheath is opened.

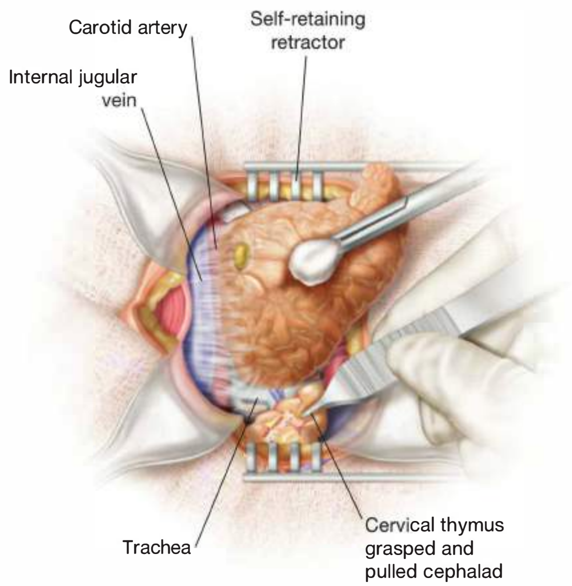

FIG 8 ● Because it is not infrequent that parathyroid glands are found partially embedded in the thymus, cervical thymectomy may be performed in the case of a missing gland. The superior aspect of the thymus is grasped and pulled by continuous traction from the chest. It can be grabbed sequentially and lifted cephalad until the often single posterior vessel is seen and divided. If a gland remains missing, it is the practice of some surgeons to perform a thyroid lobectomy on the affected side. The mediastinum should not be split unless there is definite evidence of a mediastinal tumor by preoperative imaging.

MEDIASTINAL EXPLORATION[1,3]

Approach

- Mediastinal exploration should not be performed without localization evidence of a hyperfunctioning gland in the mediastinum. Preferably, two different localizing studies should identify gland location prior to surgery.
- Most adenomas in the posterior mediastinum or anterior mediastinum above the aortic arch can be approached and excised through neck.
- Those deep in the anterior mediastinum or in the middle mediastinum require a thoracic approach (**FIG 9**).
- Precise localization is paramount and may allow less invasive approaches of anterior mediastinotomy or thoracoscopy rather than partial or median sternotomy (**FIG 10**).
- Choice of approach depends on gland location and surgeon expertise.

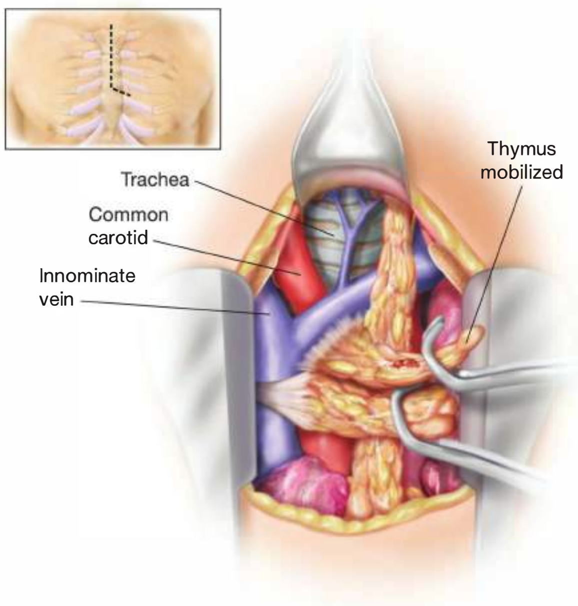

FIG 9 ● Median sternotomy or partial sternotomy to 3 cm below the predicted level of the adenoma provides access to the mediastinum (inset shows where the incision would be on the chest). The area of exploration is bound by the innominate vein superiorly and the pericardium inferiorly. Adenomas commonly lie in the thymic remnant in the anterior mediastinum.

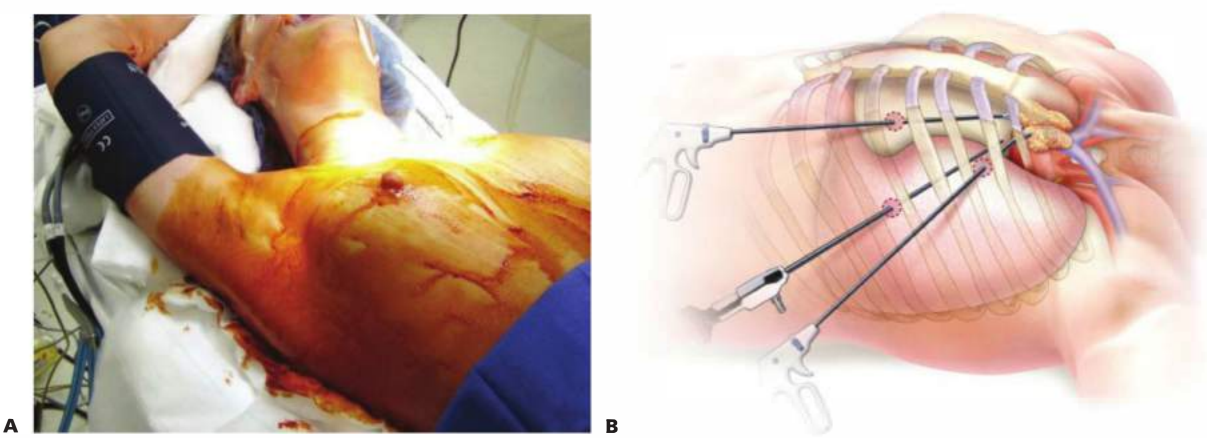

FIG 10 ● Thoracic approaches should not be performed without positive localization studies. **A.** The image indicates positioning for a thoracoscopic approach. The patient is supine, with the ipsilateral arm elevated above the head to allow transthoracic access between ribs. **B.** Position placement for thoracoscopic trocars.

PARATHYROID REIMPLANTATION

Procedure

- For multigland disease or when the vasculature of remaining parathyroid tissue is compromised, parathyroid reimplantation may be performed to preserve function. Grafts have a high success rate but may take several weeks to function.
- Approximately 50 mg of the most normal-appearing parathyroid tissue is minced into 1-mm pieces and placed into muscular pockets in the forearm. Alternatively, it may be placed in the subcutaneous tissue overlying the forearm or anterior chest wall (**FIG 11**).

FIG 11 ● Parathyroid tissue to reimplant is minced into 1-mm pieces and placed into intramuscular pockets in the forearm as seen in the figure. Alternatively, they can be placed subcutaneously in the forearm or on the anterior chest wall.

PEARLS AND PITFALLS

Indications	■ Complete history and physical with symptoms and severity of hypercalcemia should be obtained. Biochemical diagnosis of recurrent or persistent hyperparathyroidism must be confirmed.
Preoperative planning	■ Review of initial operative notes and pathology is required. ■ Preoperative localization provides a map for reoperative surgery.
Placement of incision	■ Incisions are created, keeping in mind the localization of pathology and the operative plan. ■ Cosmesis is improved when placed in a natural skin crease.
Cervical approach	■ Entry into the neck may be via focused, posterolateral, thyrothymic ligament, or revision midline cervicotomy approach.
Exploration	■ Eutopic locations for superior and inferior glands should first be searched. ■ Exploration in expected ectopic sites along the tracheoesophageal groove, carotid sheath, thyrothymic ligament, cervical thymus, and intrathyroid should follow.
Mediastinal lesions	■ Accurate preoperative localization allows the least invasive procedure for lesions in the mediastinum, which may be approached via cervical or thoracoscopic approach.
Additional maneuvers	■ Cervical thymectomy or ipsilateral thyroid lobectomy can be performed when an offending gland cannot be located. ■ Parathyroid reimplantation provides a useful adjunct to patients with multigland disease.
Closure	■ Layered closure without drain

POSTOPERATIVE CARE

- Patients should be monitored for respiratory compromise in the immediate postoperative period.
- Patients with reimplantation, extensive dissection, gland or vascular manipulation, or multiple gland removal are at increased risk of postoperative hypoparathyroidism.
- Postoperative hypocalcemia can be mitigated with calcium and vitamin D prophylaxis versus expectant monitoring of serum calcium and PTH. Calcium supplements are generally continued for 3 to 6 months to avoid reactive secondary hyperparathyroidism from a chronic hypocalcemic state.

OUTCOMES

- Success rates between 82% and 98% are expected of reoperative parathyroid surgery, with rates as low as 37% to 73% in multigland disease.
- RLN injury ranges from 0% to 2.7%, whereas permanent hypocalcemia rates vary from 1% to 18%.

COMPLICATIONS

- Neck seroma
- Hematoma
- Infection
- Voice change
- RLN injury
- Hypocalcemia, hypoparathyroidism
- Failure of cure, recurrence

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Chapter 46

Adrenalectomy: Open Anterior

Barbra S. Miller

DEFINITION

- Adrenal masses may be functional or nonfunctional and benign or malignant. Most are incidentally discovered when imaging is obtained for other reasons. Laparoscopic adrenalectomy is the gold standard for appropriately sized benign (most often functional) adrenal masses and for some metastatic tumors to the adrenal gland (see Part 5, Chapters 49 and 50). If adrenocortical carcinoma is a concern, adrenalectomy by an open approach should be performed.[1] Several genetic syndromes are associated with adrenal abnormalities and appropriate testing should be obtained if indicated.

DIFFERENTIAL DIAGNOSIS

- Adenoma
- Metastatic cancer
- Pheochromocytoma
- Ganglioneuroma
- Primary adrenocortical carcinoma
- Cyst
- Adjacent paraganglioma
- Soft tissue tumor

PATIENT HISTORY AND PHYSICAL FINDINGS

- All adrenal abnormalities should be evaluated in a systematic fashion, including a thorough history and physical examination investigating the possibility of a hormone-secreting mass. This includes the possibility of a pheochromocytoma, Cushing's syndrome, primary hyperaldosteronism, and hypertestosteronemia. Specifically, the patient should be questioned regarding poorly controlled hypertension, diabetes, edema, diaphoresis, tachycardia, palpitations, sudden severe headaches, flushing, and easy bruising. The physical exam should look for evidence of central obesity, edema, peripheral wasting, core muscle weakness, a buffalo hump, striae, thin skin, and facial plethora. Because the adrenal gland is situated in the retroperitoneum, unless it is extremely large, palpation of the mass is usually unable to be achieved.

IMAGING AND OTHER DIAGNOSTIC STUDIES

- All adrenal masses should undergo appropriate biochemical testing. Even in the absence of signs or symptoms, patients should have at a minimum the following: potassium, aldosterone, renin, plasma fractionated metanephrines (followed by 24-hour urine metanephrines and normetanephrines, catecholamines, and vanillylmandelic acid [VMA] if plasma values are abnormal), 24-hour urine-free cortisol, and adrenocorticotropic hormone (ACTH). Some physicians may also perform a low-dose dexamethasone suppression test and obtain dehydroepiandrosterone-sulfate (DHEA-S) and free testosterone, among other laboratory tests.
- Imaging studies should include an adrenal protocol computed tomography (CT) scan (to assess imaging characteristics and calculate washout percentage of contrast from the tumor) or magnetic resonance imaging (MRI) (to assess for loss of signal intensity between in and out of phase images) and a positron emission tomography (PET) scan if malignancy is questioned (**FIG 1**).
- Additional imaging studies may be required depending on the functionality of the tumor (metaiodobenzylguanidine [MIBG] for pheochromocytoma in select cases, adrenal vein sampling for hyperaldosteronism, etc.).
- Fine needle aspiration or core biopsy is not recommended if adrenocortical carcinoma is suspected but may be useful if metastasis to the adrenal gland is in the differential and the adrenal tumor is the most accessible site of metastasis for biopsy in the setting of multiple sites of metastatic disease. If biopsy is performed, it is imperative to first biochemically rule out a pheochromocytoma.

SURGICAL MANAGEMENT

- Adrenal tumors, if benign appearing by imaging criteria, nonfunctional, and therefore not requiring resection, should be reevaluated with at least one additional CT scan or MRI 6 to 12 months after the initial imaging study to ensure stability in size and internal imaging characteristics. Some advocate for a longer period of follow-up imaging for 2 years with reevaluation of biochemistry for 4 more years.[2]
- Functional tumors leading to hormone excess, indeterminate masses, and those suspected of being adrenocortical carcinoma or isolated metastatic disease from another primary tumor without evidence of widespread metastatic disease should be removed.

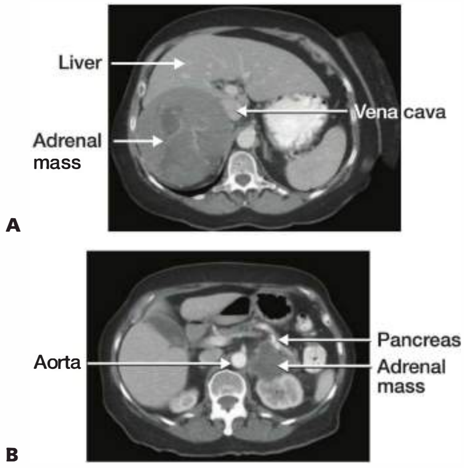


FIG 1 ● **A.** CT scan showing large heterogeneous right adrenal mass concerning for adrenocortical carcinoma. **B.** CT scan showing a large left adrenal mass.

Preoperative Planning

- The surgeon must evaluate available imaging studies for tumor involvement of adjacent organs, vessels, and lymphadenopathy. Invasion of major vessels (vena cava) or adjacent organs may require additional teams or different approaches to the tumor. As CT tends to overestimate invasion of adjacent vessels, MRI with magnetic resonance venogram can be especially helpful to assess for vena cava invasion or intracaval tumor thrombus.
- The risks, benefits, and alternatives to surgery are discussed with the patient, including potential need for steroid supplementation in the postoperative setting. Patients with pheochromocytomas should be adequately alpha blocked and volume replete. Beta blockade may also be necessary. In patients with hyperaldosteronism, a potassium level should be checked the morning of surgery and treated if necessary.
- Routine prophylactic antibiotics and deep vein thrombosis (DVT) prophylaxis is administered prior to surgery, and sequential compression devices are applied.
- A general endotracheal anesthetic is administered and an epidural is often placed for postoperative pain management.
- Common to all approaches, skin preparation with clipping rather than shaving is preferred, and the surgical area is prepped and draped in a sterile fashion.

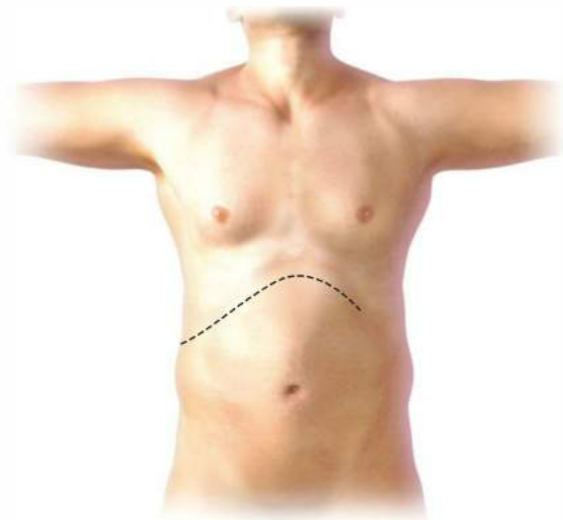


FIG 2 • The patient is placed supine on the table with arms out. Pressure points are padded. An incision is marked 2 cm inferior to the costal margin and carried from the lateral abdominal wall across the midline to facilitate exposure.

Positioning

- The patient is placed supine on the table with arms out to the side, and all pressure points are padded appropriately (**FIG 2**).

TECHNIQUES

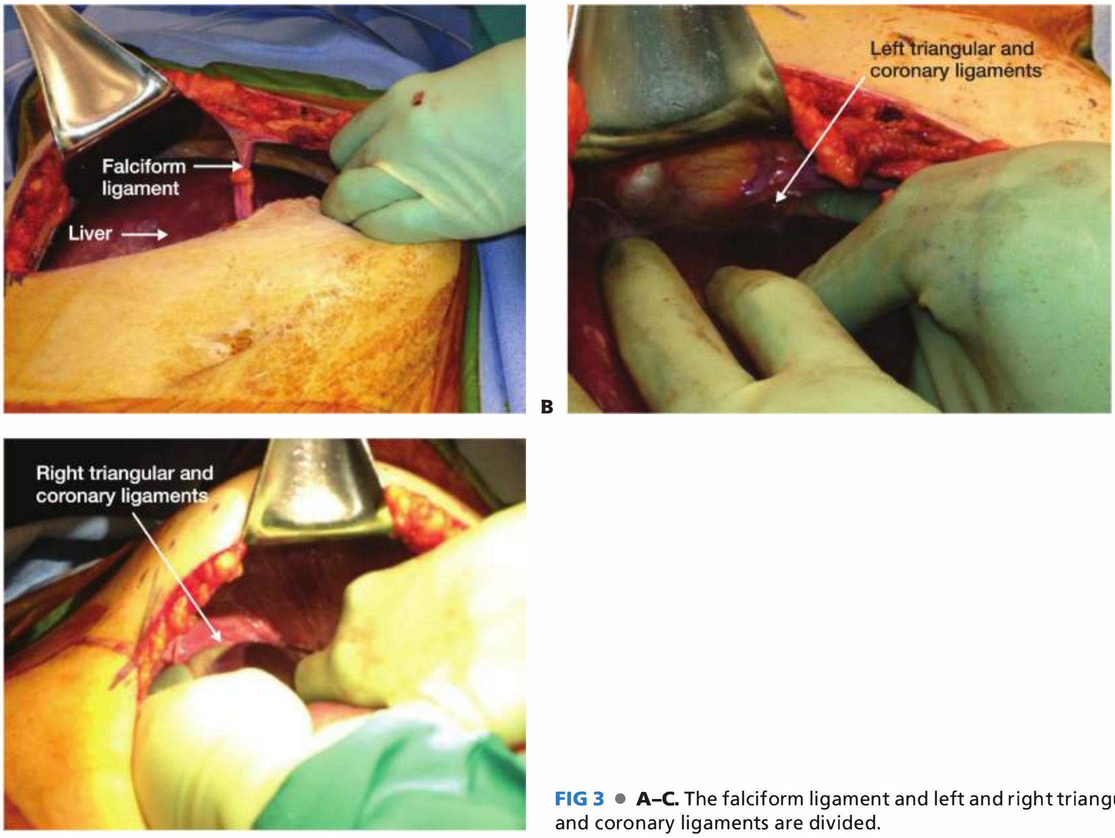
RIGHT ADRENALECTOMY

Exposure

- A wide right subcostal incision is made and carried across the midline to the midleft abdomen. The subcutaneous fat, fascia, abdominal wall musculature, and posterior fascia are incised with cautery. The peritoneum is entered sharply with scissors and the incision opened to its full length. The ligamentum teres is divided between sutures and the peritoneal cavity is inspected in a systematic manner, assessing for evidence of metastatic disease or other abnormalities. The falciform ligament, triangular, and coronary ligaments of the left and right lobes of the liver are divided to allow for full mobility of the liver during retraction (**FIGS 3** and **4**).
- Ultrasound of the liver is also performed to assess for metastatic disease not identified on preoperative imaging, and the vena cava may also be evaluated sonographically for evidence of intracaval tumor thrombus or direct tumor invasion.
- The hepatic flexure of the colon may need to be mobilized, and if a Kocher maneuver is needed, it should be done at this time. The right lobe of the liver is retracted medially to expose the retroperitoneum and allow access to the area of the tumor and vena cava. A retractor system is placed. The Omni retractor provides excellent retraction as well as the critically important ability to retract the costal margin and ribs as superiorly and anteriorly as possible. A large saline-soaked towel is placed against the bowel with retractors to not only provide exposure but also to exclude the rest of the peritoneal cavity and minimize potential seeding of the peritoneal cavity by a malignant tumor (**FIG 5**).

Dissection

- The posterior peritoneal lining over the retroperitoneum is incised over the superior half of the right kidney and carried from medial to lateral out to the side of the abdominal wall. Medial dissection should proceed carefully to the vena cava, making sure not to divide branches of the renal artery supplying the upper portion of the kidney or venous branches draining to the renal vein. Small branches supplying and draining the adrenal gland should be carefully ligated and divided. Any lymph nodes posterior to the renal hilum should be included in the dissection (**FIGS 6** and **7**).
- The fat overlying and just superior to the kidney is mobilized from inferior to superior, making this tissue the inferior margin, using cautery, silk sutures, and other hemostatic devices as needed, making sure not to create a nonexistent plane between the inferior aspect of the tumor and the superior aspect of the kidney. The peritoneal lining should remain intact over the anterior



A B C

FIG 3 ● **A–C.** The falciform ligament and left and right triangular and coronary ligaments are divided.

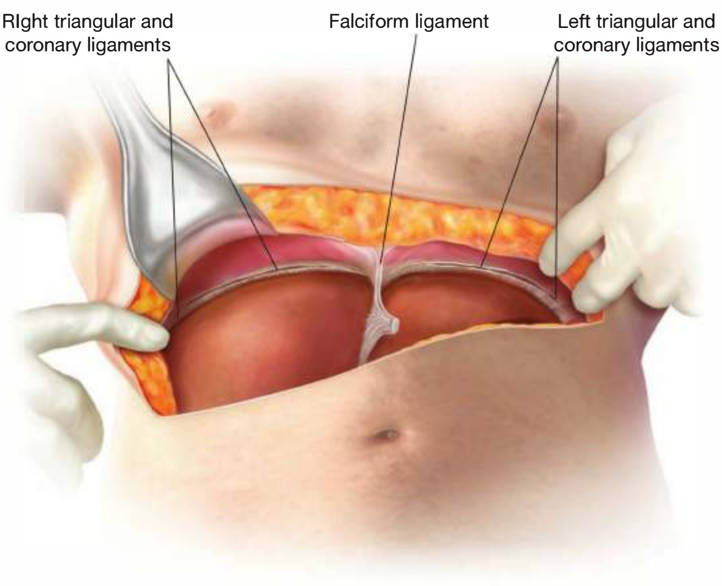


FIG 4 ● With the ligamentum teres, falciform ligament, and triangular and coronary ligaments divided, this allows adequate retraction of the liver and access to the tumor and vena cava.

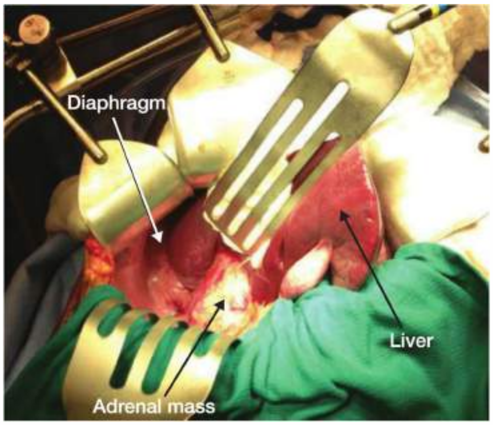


FIG 5 ● A retractor system is placed to retract the ribs superiorly and anteriorly and to retract the liver medially. A moist towel is placed inferiorly to retract the bowel and exclude the rest of the peritoneal cavity.

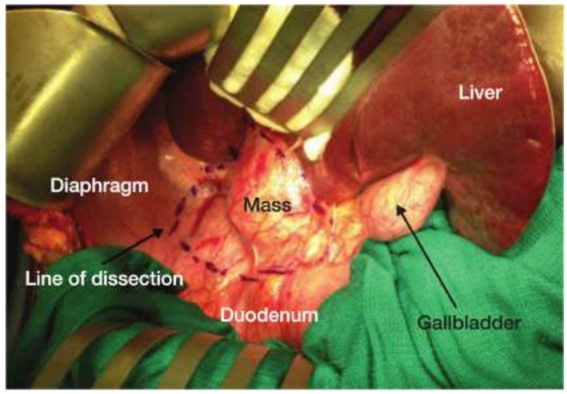


FIG 7 ● The intended line of dissection to include the tumor and all retroperitoneal soft tissue is marked.

aspect of the tumor to serve as the anterior margin if not already invaded by the tumor (**FIG 8**).

- The dissection continues superiorly along the diaphragm, making sure to ligate and divide any feeding vessels, most commonly branches from the inferior phrenic vessels.
- Posterior dissection should proceed from lateral to medial, making sure to remove all fat posterior to the tumor in an en bloc fashion. If the tumor invades the muscle, a portion of the muscle should be included with the tumor to ensure negative margins.
- The anterior surface of the vena cava should be identified and the peritoneal lining overlying this should be incised along its length. Using a vein retractor to retract the vena cava medially, soft tissue attachments medial to the gland and posterior to the vena cava, including lymphatics, are ligated and divided. As the midpoint of the adrenal gland is reached, the right adrenal vein should be identified, ligated, and divided (**FIG 9**). The vein should be inspected and carefully palpated to assess for any tumor thrombus so that the tumor thrombus

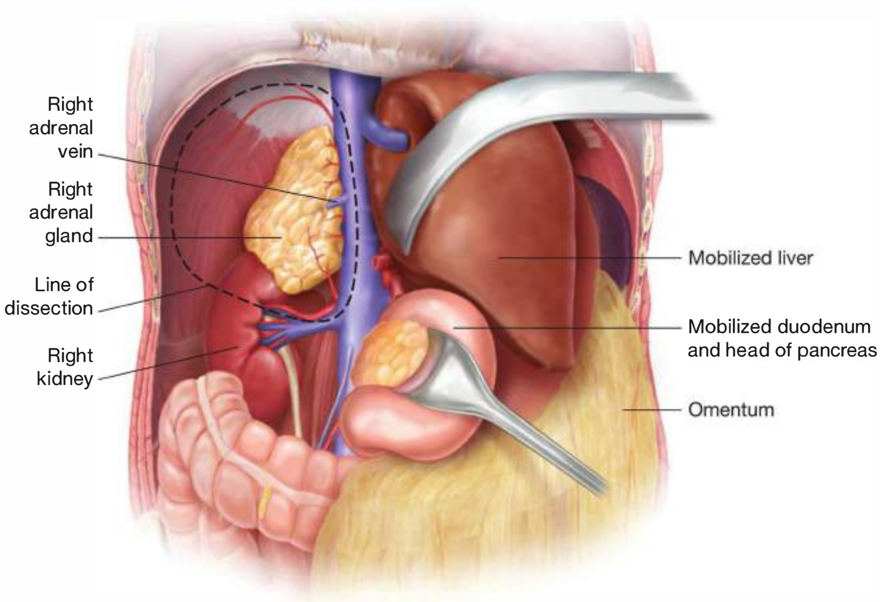


FIG 6 ● With the liver retracted medially, the adrenal vein and inferior vena cava are exposed. The *dotted line* demonstrates the intended line of dissection.

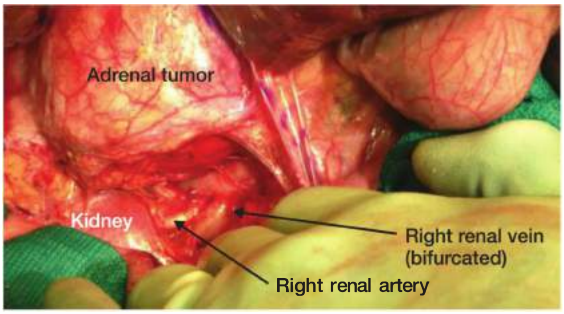


FIG 8 ● The inferior portion of the dissection is shown. A branch of the right renal artery is seen between two branches of the right renal vein.

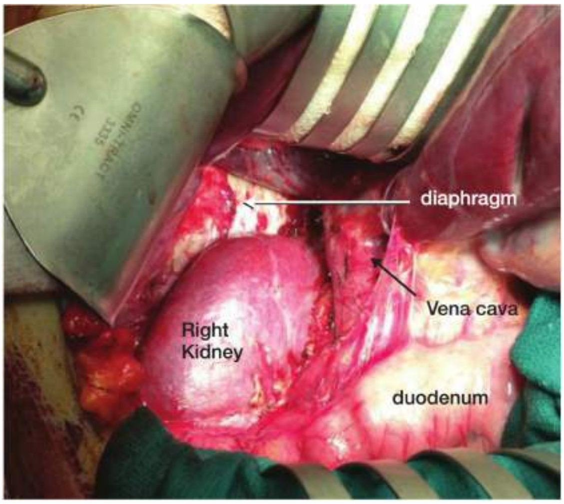


FIG 10 ● The adrenal tumor and all retroperitoneal soft tissue has been removed en bloc. The right kidney has migrated superiorly against the diaphragm to fill the space.

can be included with the specimen in an en bloc fashion. Advanced techniques for managing large tumor thrombi within the vena cava are beyond the scope of this chapter. If removing a pheochromocytoma, the anesthesiologist should be warned well in advance prior to ligating the adrenal vein in anticipation of ensuing hypotension. The dissection is continued superiorly until all medial attachments have been released (**FIG 10**).

- The adrenal gland and the periadrenal soft tissue are removed, marked with orienting sutures for the pathologist, and sent to the pathology lab (**FIG 11**).

Closure

- A small amount of water should be used for irrigation and final hemostasis is achieved. The area encompassed by the dissection should be marked with large clips to assist with postoperative external beam radiation therapy if needed.
- A drain may be placed if desired but is not required in many cases.
- The retractor system is removed, the organs replaced in their normal anatomic positions, and the abdominal wall musculature is closed in two separate layers. The subcutaneous tissue may be reapproximated with interrupted absorbable sutures if needed and the skin closed with staples or suture. A sterile dressing is applied.

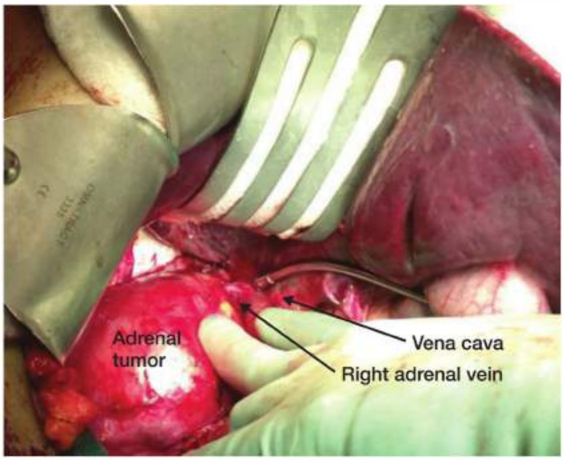


FIG 9 ● The right adrenal vein has been dissected free of its attachments. More superiorly along the vena cava, a second vein from the adrenal to the inferior vena cava has been clipped and divided.

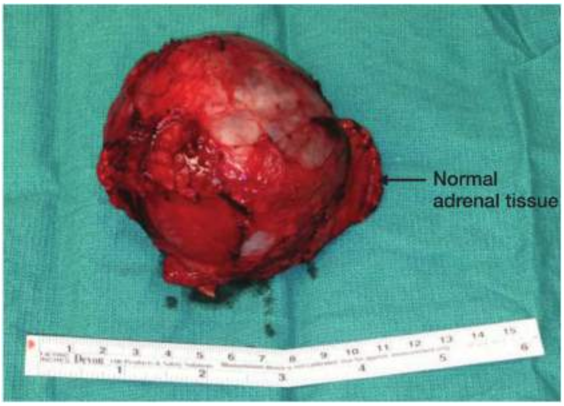


FIG 11 ● A small portion of normal adrenal tissue remains and is seen at the right side of the gland in this image. Surrounding soft tissue and the overlying anterior peritoneal lining remain on the anterior surface of the gland.

LEFT ADRENALECTOMY

Exposure

- A wide left subcostal incision is made and carried across the midline to the midright abdomen (FIG 12). The subcutaneous fat, fascia, abdominal wall musculature, and posterior fascia are incised with cautery. The peritoneum is entered sharply with scissors and the incision opened to its full length. The ligamentum teres is divided between sutures and the peritoneal cavity is inspected in a systematic manner, assessing for evidence of metastatic disease or other abnormalities.
- Ultrasound of the liver is also performed to assess for metastatic disease and the vena cava may also be evaluated for evidence of intracaval tumor thrombus from the left adrenal and renal veins.
- The falciform ligament and left triangular and coronary ligaments of the left lobe of the liver are divided to allow for mobility of the liver during retraction (FIG 13).
- The descending colon is mobilized along the line of Toldt and the colon reflected medially. The mobilization is continued superiorly to divide the splenic attachments to the abdominal side wall and the diaphragm. The spleen, stomach, pancreas, splenic flexure, and colon should be reflected medially, allowing exposure of the left retroperitoneum (FIG 14). A retractor system is placed. A large saline-soaked towel with retractors is placed against the bowel, pancreas, spleen to not only provide exposure but also to exclude the rest of the peritoneal cavity to minimize potential seeding of the peritoneal cavity by a malignant tumor. The left side of the aorta should be clearly appreciable if the exposure is adequate.

Dissection

- Because the peritoneal covering on the left has been reflected with the spleen and pancreas, the surgeon should make every effort to manipulate the tumor surface as little as possible (no-touch technique). The soft tissue overlying the superior half of the left kidney is incised and carried from medial to lateral out to the side of the abdominal wall. Inferior dissection should proceed carefully to the aorta medially along the left renal vein, making sure not to divide branches of the posteriorly situated renal artery supplying the upper portion of the kidney or venous branches draining to the renal vein. Small branches supplying and draining the adrenal gland should be carefully ligated and divided. Any lymph nodes posterior to the renal hilum should be included in the dissection.
- The left adrenal vein will be identified at the medial aspect of the left renal vein as it courses anterior to the aorta (FIG 15). It generally enters the adrenal gland in the 7 o'clock position. It should be ligated and divided. The adrenal vein and renal vein should be inspected and carefully palpated to assess for any tumor thrombus so that the tumor thrombus can be included with the

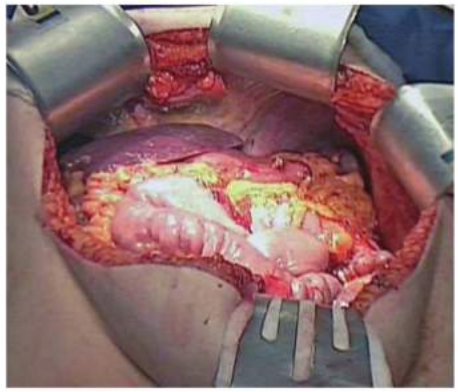


FIG 13 ● The falciform ligament and left triangular and coronary ligaments are divided, allowing exposure of the left upper abdomen and mobility of the liver.

FIG 12 ● The patient is placed supine on the table with arms out. Pressure points are padded. A wide left subcostal incision is marked 2 cm inferior to the costal margin and carried across the midline to the right abdomen to facilitate exposure.

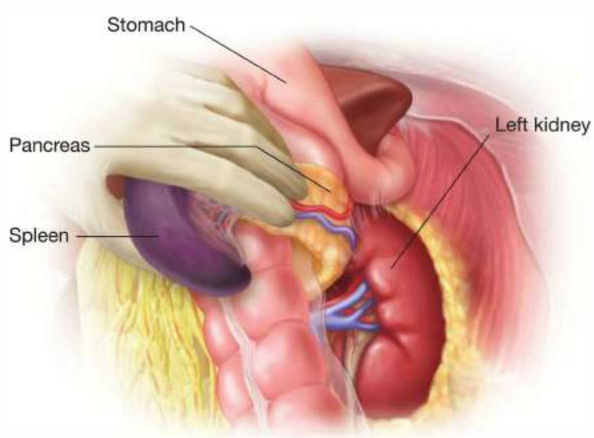


FIG 14 ● The spleen, stomach, and pancreas are mobilized medially.

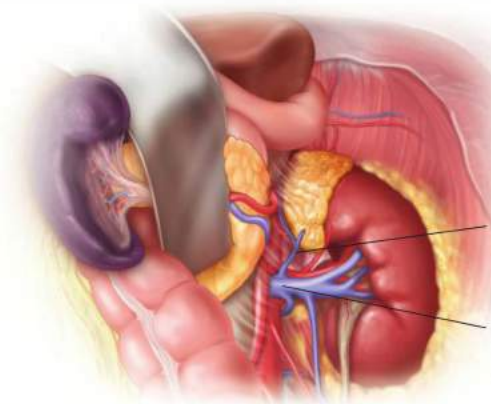


FIG 15 ● With retractors in place, the left retroperitoneum is exposed and excluded from the rest of the peritoneal cavity. The left side of the aorta, renal vein, and adrenal vein are visualized, with the left adrenal vein identified at the medial aspect of the left renal vein. The adrenal vein can be ligated and divided at its junction with the renal vein.

specimen in an en bloc fashion. Advanced techniques for managing large tumor thrombi within the renal vein and vena cava are not discussed in this chapter.

- The fat overlying and just superior to the kidney is mobilized from inferior to superior, making this tissue the inferior margin, using cautery, silk sutures, and other hemostatic devices as needed, making sure not to create a nonexistent plane between the inferior aspect of the tumor and the superior aspect of the kidney.
- Lateral dissection should continue along the abdominal side wall. The dissection continues superiorly along the diaphragm, making sure to ligate and divide any feeding vessels, most commonly branches from the inferior phrenic vessels.
- Posterior dissection should proceed from lateral to medial, making sure to remove all fat and any involved muscle posterior to the tumor in an en bloc fashion.
- The left lateral surface of the aorta should be identified, and the soft tissue attachments including small vessels and lymphatics are ligated and divided. If removing a pheochromocytoma, the anesthesiologist should be warned well in advance prior to ligating the adrenal vein in anticipation of ensuing hypotension. The dissection is continued superiorly until all medial attachments have been released. Any lymph nodes along the aorta or identified near the superior mesenteric artery or celiac axis should be included with the specimen.
- The adrenal gland and the periadrenal soft tissue are removed, marked with orienting suture for the pathologist, and sent to the pathology lab.

Closure

- A small amount of water should be used for irrigation and final hemostasis is achieved. The area encompassed by the dissection should be marked with large clips to assist with postoperative external beam radiation therapy if needed. A drain may be placed.
- The retractor system is removed, the organs replaced in their normal anatomic position, and the abdominal wall musculature is closed in two separate layers. The subcutaneous tissue may be reapproximated with interrupted absorbable sutures if needed and the skin closed with staples or suture. A sterile dressing is applied.

PEARLS AND PITFALLS

Bleeding—arterial and venous	■ May result from disruption of the vena cava, renal vein or artery, and aorta. Kitners, sponge sticks, and vascular clamps are helpful. Obtain proximal and distal control prior to potentially dangerous maneuvers.
Liver mobilization	■ Mobilize right and left lobes to obtain best exposure for right adrenalectomy. Mobilize left lobe to obtain best exposure for left adrenalectomy.
Tumor capsule penetration	■ Avoid this as penetration leads to peritoneal spread, which will result in recurrence and often shortened survival compared to alternate sites of recurrence. En bloc resection is critical to prevent creating a plane through microscopically positive tumor margins.

POSTOPERATIVE CARE

- Most patients will not need intensive care unit (ICU) care, although pheochromocytoma patients often need closer monitoring for the first 24 hours, depending on intraoperative stability and volume status.
- Hydrocortisone should be given administered to patients with overt Cushing's syndrome. A cosyntropin stimulation test can be performed the morning after surgery in subclinical or mild Cushing's cases if there is a question about the requirement for steroid supplementation.
- Electrolytes should be checked the morning after surgery. Patients undergoing surgery for primary hyperaldosteronism may experience rebound hyperkalemia.
- After bilateral adrenalectomy, high-dose intravenous (IV) hydrocortisone should be weaned to replacement

dose oral hydrocortisone and fludrocortisone 0.1 mg daily.

- Antihypertensive medications are withheld in the immediate postoperative setting and reinstituted as needed.
- Routine postoperative care is pursued and patients are discharged 3 to 7 days after surgery.
- Follow-up is typically 1 to 2 weeks after surgery with endocrine testing as needed.

OUTCOMES

- Although laparoscopic surgery has become the gold standard for benign adrenal disease due to decreased bleeding, infection, pain, and hospital stay, open adrenalectomy is still performed if conversion from laparoscopic adrenalectomy is required for various reasons, for very large adrenal tumors, and when adrenocortical carcinoma is in the differential diagnosis, as some studies have found a significantly higher incidence of incomplete positive margin resections, a higher incidence of and shorter time to tumor bed and peritoneal cavity recurrence, and decreased survival compared to laparoscopic surgery.[3–5] A greater number of oncologic principles of resection can be respected with open surgery for adrenal cancer compared to a laparoscopic approach.

COMPLICATIONS

- Bleeding
- Infection
- Adrenal insufficiency in those with Cushing's syndrome
- Postoperative hypotension in those with pheochromocytoma
- Rebound hyperkalemia in those with Conn's syndrome
- Lymphatic leak
- Pneumothorax
- Neurogenic pain
- Abdominal wall laxity

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Chapter 47

Adrenalectomy: Open Thoracoabdominal

Barbra S. Miller

DEFINITION

- Adrenal masses may be benign or malignant. If adrenocortical carcinoma is a concern, adrenalectomy by an open approach should be performed. Adrenal masses may be functional or nonfunctional with regard to excess hormone secretion. Several genetic syndromes are associated with adrenal abnormalities and should be evaluated if indicated.

DIFFERENTIAL DIAGNOSIS

- Primary adrenal adenoma
- Primary adrenocortical carcinoma
- Cyst
- Metastatic cancer
- Pheochromocytoma
- Ganglioneuroma
- Adjacent paraganglioma
- Soft tissue tumor

PATIENT HISTORY AND PHYSICAL FINDINGS

- All adrenal abnormalities should be evaluated in a systematic fashion, including a thorough history and physical examination investigating the possibility of a hormone-secreting mass. This includes the possibility of a pheochromocytoma, Cushing's syndrome, primary hyperaldosteronism, and hypertestosteronemia. Specifically, the patient should be questioned regarding poorly controlled hypertension, diabetes, edema, diaphoresis, tachycardia, palpitations, sudden severe headaches, flushing, and easy bruising. The physical exam should look for evidence of central obesity, edema, peripheral wasting, core muscle weakness, a buffalo hump, striae, thin skin, and facial plethora. Because the adrenal gland is situated in the retroperitoneum, unless it is extremely large, palpation of the mass is usually unable to be achieved.

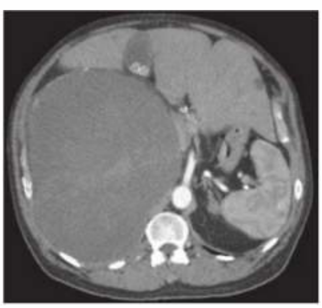


FIG 1 • CT image (axial cut) showing large heterogeneous right adrenal mass concerning for adrenocortical carcinoma.

IMAGING AND OTHER DIAGNOSTIC STUDIES

- All adrenal masses should undergo appropriate biochemical testing. Even in the absence of signs or symptoms, patients should have at a minimum the following: potassium, aldosterone, renin, plasma fractionated metanephrines (followed by 24-hour urine metanephrines and normetanephrines, catecholamines, and vanillylmandelic acid [VMA] if plasma values are abnormal), 24-hour urine-free cortisol, and adrenocorticotropic hormone (ACTH). Some physicians may also perform a low-dose dexamethasone suppression test, dehydroepiandrosterone-sulfate (DHEA-S), and free testosterone, among other laboratory tests.
- Imaging studies (**FIGS 1** and **2**) should include an adrenal protocol computed tomography (CT) scan (noncontrast, contrast, 15-minute–delayed scan to calculate washout percentage of contrast from the tumor) or magnetic resonance imaging (MRI) (to assess for loss of signal intensity between in and out of phase images) and a positron emission tomography (PET) scan if malignancy is questioned.
- Additional imaging studies may be required depending on the functionality of the tumor (metaiodobenzylguanidine [MIBG] for pheochromocytoma in select cases, adrenal vein sampling for hyperaldosteronism, etc.).
- Fine needle aspiration or core biopsy is not recommended if adrenocortical carcinoma is possible but may be useful if metastasis to the adrenal gland is in the differential and the adrenal tumor is the most accessible site of metastasis in the setting of multiple sites of metastatic disease. If biopsy is performed, it is imperative to first biochemically rule out pheochromocytoma as a diagnosis.

FIG 2 • CT image (coronal cut) showing large heterogeneous right adrenal mass concerning for adrenocortical carcinoma.

SURGICAL MANAGEMENT

- Adrenal tumors, if benign appearing by imaging criteria and hormonally nonfunctional, should be reevaluated with at least one additional CT scan or MRI 6 to 12 months after the initial imaging study to ensure stability in size and internal imaging characteristics. Some advocate for a longer period of follow-up imaging for 2 years with reevaluation of biochemistry for 4 more years.[1]
- Functional tumors leading to hormone excess, indeterminate masses, and those suspected of being adrenocortical carcinoma or isolated metastatic disease from another primary tumor without evidence of widespread metastatic disease should be removed.
- Adrenalectomy may be performed by anterior, posterior, or thoracoabdominal approach. The thoracoabdominal approach is particularly useful for providing excellent exposure and access to large adrenal tumors.[2–5] Although excellent exposure can be achieved by an anterior approach in most cases, the thoracoabdominal approach is most beneficial in patients who have undergone prior abdominal surgery, thereby avoiding the time and potential morbidity associated with extensive lysis of adhesions.

Preoperative Planning

- The surgeon must evaluate available imaging studies for possible involvement of adjacent organs and vessels and lymphadenopathy. Invasion of major vessels (vena cava) or adjacent organs may require additional teams or different approaches to the tumor. As CT tends to overestimate invasion of adjacent vessels, MRI with magnetic resonance venogram can be especially helpful to assess for vena cava invasion or intracaval tumor thrombus.
- The risks, benefits, and alternatives to surgery are discussed with the patient including potential need for steroid supplementation in the postoperative setting. Patients with pheochromocytomas should be adequately alpha blocked and volume replete. Beta blockade may also be necessary. A potassium level should be checked the morning of surgery and treated as necessary in patients with hyperaldosteronism.
- Routine prophylactic antibiotics and deep vein thrombosis (DVT) prophylaxis are administered prior to surgery, and sequential compression devices are applied.
- A general endotracheal anesthetic is administered. A dual lumen endotracheal tube may be placed for improved exposure but in general is not required.
- An epidural is often placed for postoperative pain management.
- Common to all approaches, skin preparation with clipping rather than shaving is prepared, and the surgical area is prepped and draped in a sterile fashion.

Positioning

- For a right adrenalectomy, the patient is placed in semi–left lateral decubitus position on a beanbag with an axillary roll beneath the left axilla. The right arm is held in place parallel over the left arm with a thoracic arm holder (**FIG 3**). For a left adrenalectomy, the opposite setup is performed. The pelvis remains flat. This allows access to the chest and abdomen. The bed is flexed to increase the space between the ribs and the pelvis.
- All pressure points are padded appropriately.
- The patient is prepped and draped.

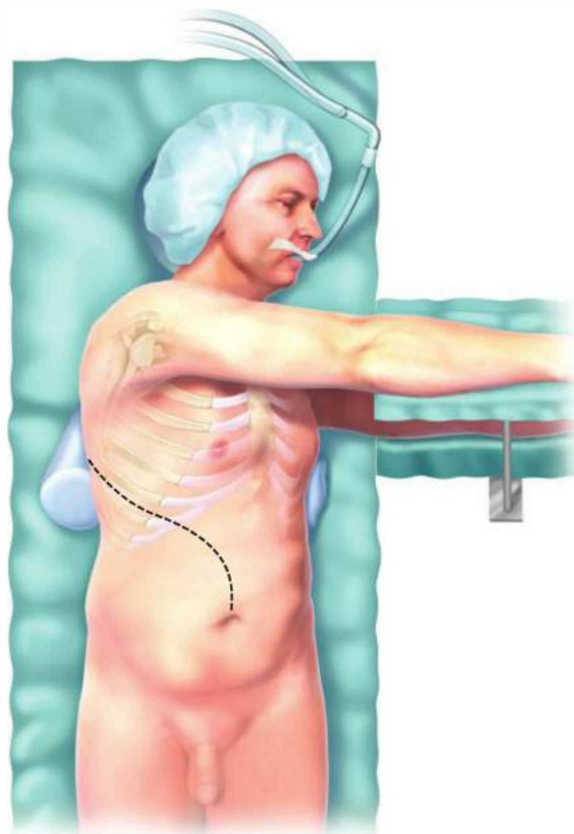


FIG 3 ● The patient is placed in semi–left lateral decubitus position on a beanbag with an axillary roll beneath the left axilla. The chest is nearly fully lateral, and the pelvis remains flat (corkscrew twist). The right arm is held in place parallel over the left arm with a thoracic arm holder.

RIGHT ADRENALECTOMY

Exposure

- An incision is made 2 cm inferior to the tip of the right scapula and extended to a point midway between the xiphoid process and the umbilicus (**FIG 4**). If necessary, the incision can then be carried inferiorly along the midline of the abdomen. The subcutaneous tissue and muscle are divided, sparing the latissimus dorsi and incising the serratus anterior. The chest is entered at the 8th intercostal space, the pulmonary ligament divided, and the lung retracted superiorly. The diaphragm is incised 2 to 4 cm from its attachments, sparing the phrenic nerve. Several marking stitches should be placed intermittently on either side of the divided diaphragm to aid with reapproximation at the end of the case (**FIG 5**). The costochondral cartilage is divided. A portion may be excised. The abdominal incision is extended and the peritoneal cavity is entered. A self-retaining retractor system can be placed.
- The diaphragmatic attachments to the right lobe of the liver are released with electrocautery as is the falciform ligament. The ligamentum teres is ligated and divided with silk ligatures. If the adrenal tumor is adherent to the diaphragm, that portion of the diaphragm should be removed en bloc with the tumor and can be reconstructed with mesh or other material. Inspection of the peritoneal cavity is performed as much as possible in a systematic

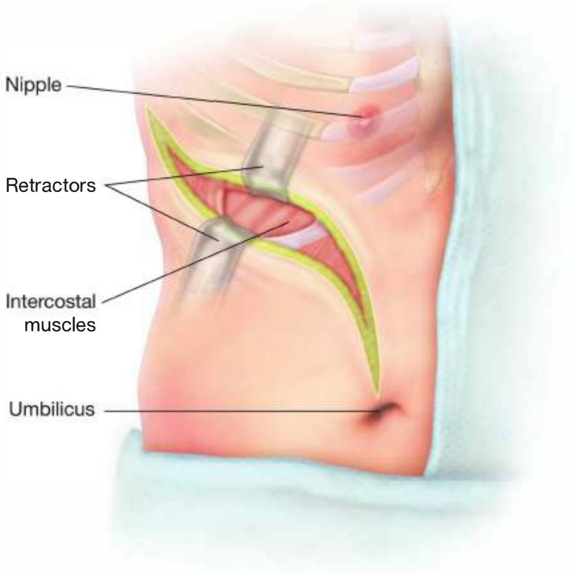
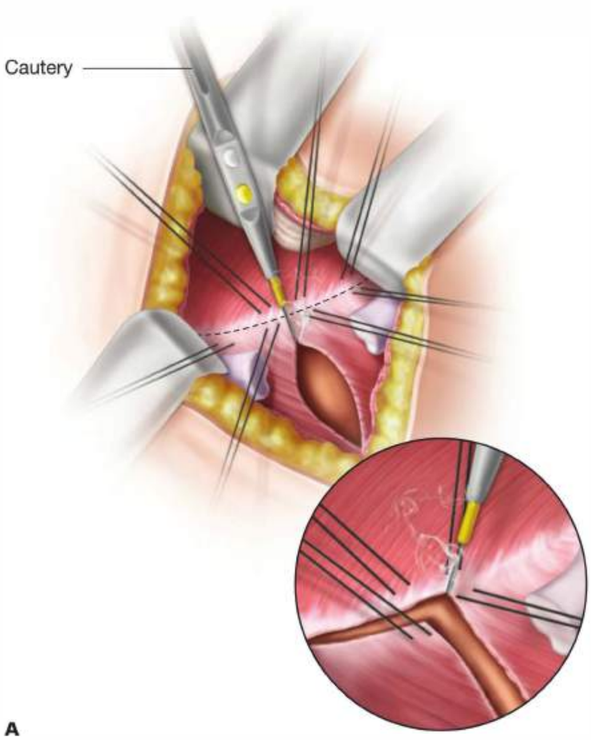


FIG 4 ● An incision is made 2 cm inferior to the tip of the right scapula and extended to a point midway between the xiphoid process and the umbilicus. The incision can then be carried inferiorly along the midline of the abdomen. The subcutaneous tissue and muscle are divided, sparing the latissimus dorsi and incising the serratus anterior. The chest is entered at the 8th intercostal space.



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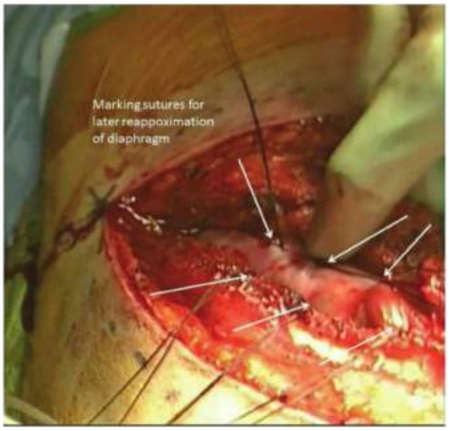

B

FIG 5 ● **A.** The diaphragm is incised 2 to 4 cm from its attachments, sparing the phrenic nerve. **B.** Several marking stitches *(arrows)* can be placed intermittently on either side of the divided diaphragm to aid with reapproximation at the end of the case.

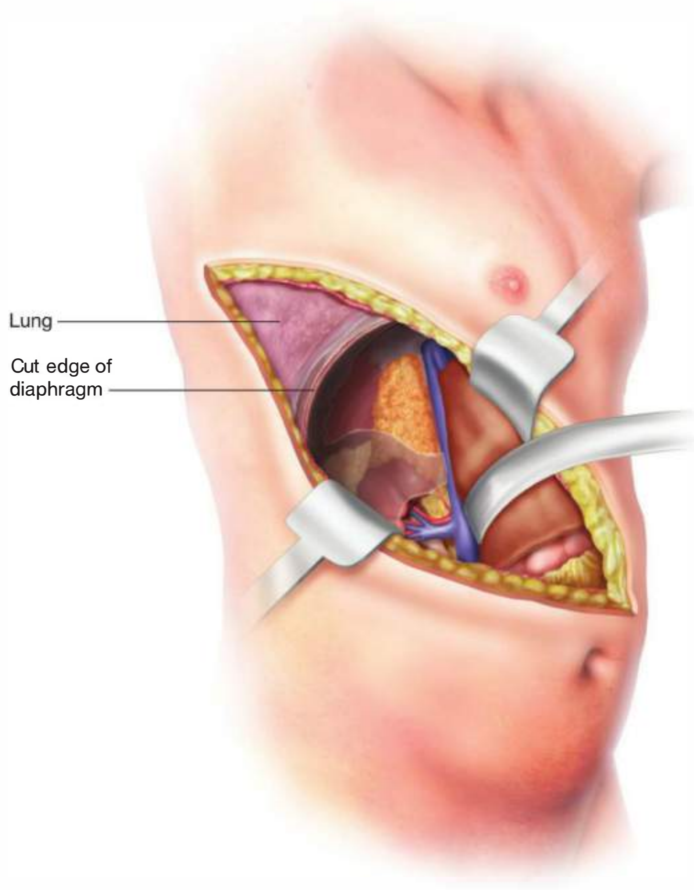

FIG 6 ● The diaphragmatic attachments to the right lobe of the liver are released with electrocautery as is the falciform ligament. Both lobes of the liver are mobilized. A portion of the diaphragm should be removed en bloc with any adherent tumor.

fashion and an ultrasound of the liver is performed. The right lobe of the liver is retracted toward the left side, allowing access to the retrohepatic inferior vena cava (**FIG 6**).

Dissection

- The posterior peritoneal lining over the retroperitoneum in incised over the superior half of the right kidney and carried from medial to lateral out to the side of the abdominal wall (**FIG 7**). Medial dissection should proceed carefully to the vena cava, making sure not to divide branches of the renal artery supplying the upper portion of the kidney or venous branches draining to the renal vein. Small branches supplying and draining the adrenal gland should be carefully ligated and divided. Any lymph nodes posterior to the renal hilum should be included in the dissection.
- The fat overlying and just superior to the kidney is mobilized from inferior to superior, making this tissue the

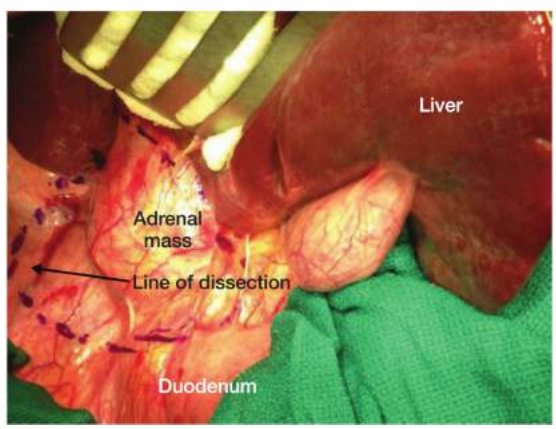

FIG 7 ● The posterior lining over the retroperitoneal fat and kidney is incised over the superior half of the right kidney and carried from medial to lateral out to the side of the abdominal wall.

inferior margin, using cautery, silk sutures, and other hemostatic devices as needed, making sure not to create a nonexistent plane between the inferior aspect of the tumor and the superior aspect of the kidney. The peritoneal lining should remain intact over the anterior aspect of the tumor to serve as the anterior margin if not already invaded by the tumor. The dissection continues superiorly along the diaphragm, making sure to ligate and divide any feeding vessels, most commonly branches from the inferior phrenic vessels. Posterior dissection should proceed from lateral to medial, making sure to remove all fat posterior to the tumor in an en bloc fashion. If the tumor invades the muscle, a portion of the muscle should be included with the tumor to ensure negative margins.

- The anterior surface of the vena cava should be identified and the peritoneal lining overlying this should be incised along its length. Using a vein retractor to retract the vena cava medially, soft tissue attachments, including small vessels and lymphatics, are ligated and divided. As the midpoint of the adrenal gland is reached, the right adrenal vein should be identified, ligated, and divided. The vein should be inspected and carefully palpated to assess for any tumor thrombus so that the tumor thrombus can be included with the specimen in an en bloc fashion. Advanced techniques for managing large tumor thrombi within the vena cava are not discussed in this chapter. If removing a pheochromocytoma, the anesthesiologist should be warned well in advance prior to ligating the adrenal vein in anticipation of ensuing hypotension. The dissection is continued superiorly until all medial attachments have been released. Retraction of the vena cava allows access to posterior tissue, which should be removed as well. The adrenal gland and the periadrenal soft tissue are removed, marked with orienting suture for the pathologist, and sent to the pathology lab.

Closure

- A small amount of water should be used for irrigation and final hemostasis is achieved. The area encompassed by the dissection should be marked with large clips to assist with postoperative external beam radiation therapy if needed. A drain may be placed in the adrenal bed, and a chest tube is placed.
- Closure is begun, and the bed is taken out of the flexed position. A chest tube is placed. The diaphragm is repaired with no. 1 polydioxanone (PDS) suture in a running locking or interrupted fashion.
- At the junction of the diaphragm and abdominal fascia, a no. 2 Vicryl figure-of-eight suture is used to reapproximate the tissue en masse. If a portion of the costochondral cartilage has not been excised, it may be reapproximated using a microdrill and a no. 2 Vicryl suture. The ribs are also reapproximated with no. 2 Vicryl sutures, with or without the microdrill (**FIGS 8** and **9**).

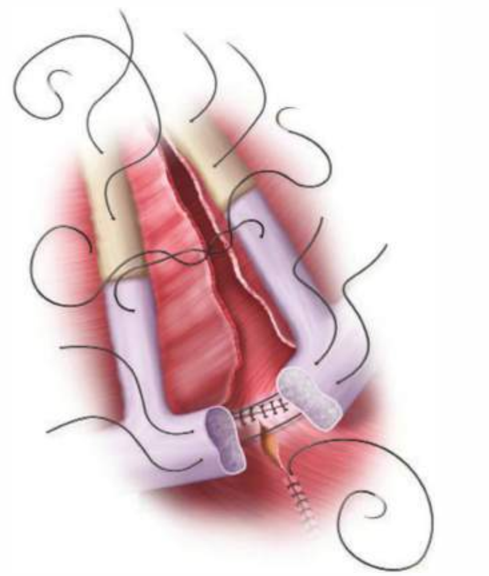

FIG 8 ● A portion of the costal margin can be excised to minimize postoperative rubbing of the ends and costochondritis. If a portion of the costochondral cartilage has not been excised, it may be reapproximated using a microdrill and a no. 2 Vicryl suture. The ribs are reapproximated with no. 2 Vicryl sutures, with or without the microdrill.

A rib approximator device helps decrease the tension required to tie the sutures. The abdominal midline is reapproximated with running no. 1 PDS suture. The chest wall musculature is closed in two separate layers using no. 1 Vicryl suture. The skin is closed with staples and a sterile dressing is applied (**FIG 10**).

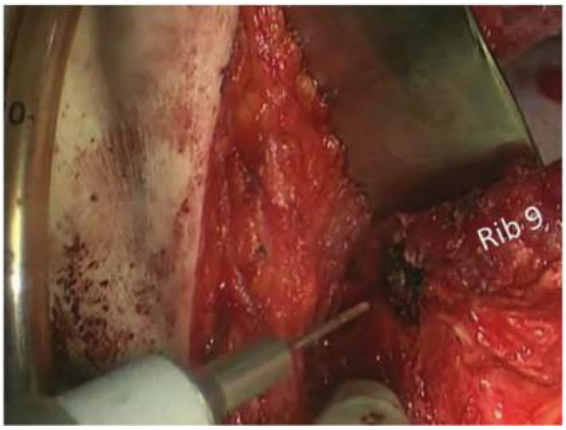

FIG 9 ● The microdrill is used to help reapproximate the ribs.

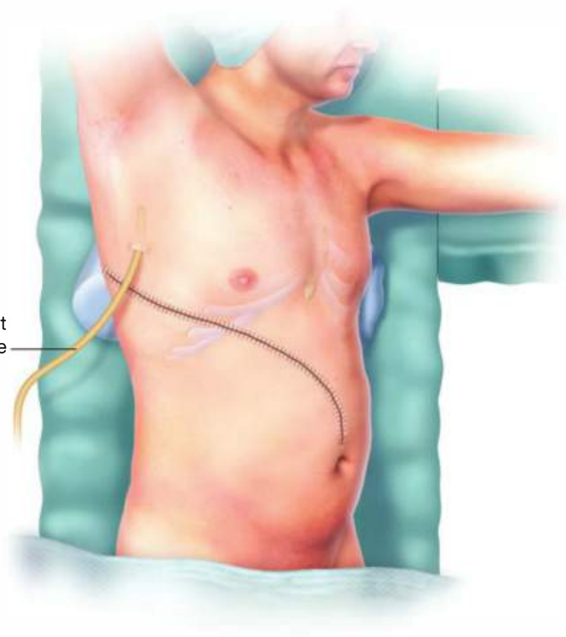

FIG 10 ● During closure, a chest tube is inserted. The abdominal midline is reapproximated in a single layer. The chest wall musculature is closed in several layers. The skin is closed with staples and a sterile dressing is applied.

LEFT ADRENALECTOMY

Exposure

- An incision is made 2 cm inferior to the tip of the right scapula and extended to a point midway between the xiphoid process and the umbilicus (**FIGS 11** and **12**). If necessary, the incision can then be carried inferiorly along the midline of the abdomen. The subcutaneous tissue and muscle are divided, sparing the latissimus dorsi and incising the serratus anterior. The chest is entered at the 8th intercostal space, the pulmonary ligament divided, and the lung retracted superiorly. The diaphragm is incised 2 to 4 cm from its attachments, sparing the phrenic nerve. Several marking stitches should be placed intermittently on either side of the divided diaphragm to aid with reapproximation at the end of the case. The costochondral cartilage is divided. A portion may be excised. The abdominal incision is extended and the peritoneal cavity is entered. A self-retaining retractor system is placed.
- The diaphragmatic attachments to the spleen are released with electrocautery and reflected toward the right side along with the stomach and pancreas. If the adrenal tumor is adherent to the diaphragm, that portion of the diaphragm should be removed en bloc with the tumor and can be reconstructed with mesh or other material. The splenocolic attachments will require release and the omentum is released from the colon. The ligamentum teres is ligated and divided with silk ligatures.
- Inspection of the peritoneal cavity is performed as much as possible in a systematic fashion, and an ultrasound of the liver is performed.
- The left lobe of the liver is retracted toward the right side, allowing for better mobilization of the stomach, spleen, and pancreas.
- A large saline-soaked towel with retractors is placed against the bowel, pancreas, and spleen to not only provide exposure but also to exclude the rest of the

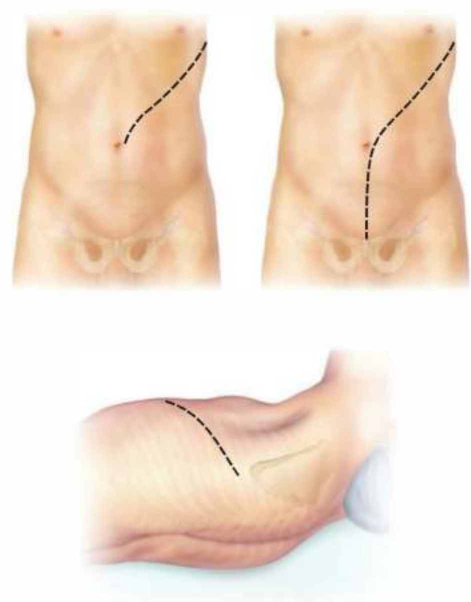

FIG 11 ● Options for left thoracoabdominal incision for adrenalectomy.

FIG 12 ● An incision is made 2 cm inferior to the tip of the right scapula and extended to a point midway between the xiphoid process and the umbilicus.

peritoneal cavity to minimize potential seeding of the peritoneal cavity. The left side of the aorta should be appreciable if the exposure is adequate (**FIG 13**).

Dissection

- Because the peritoneal covering on the left has been reflected with the spleen and pancreas, the surgeon should make every effort to manipulate the tumor surface as little as possible (no-touch technique). The soft tissue overlying the superior half of the left kidney is incised and carried from medial to lateral out to the side of the abdominal wall. Inferior dissection should proceed carefully to the aorta medially along the left renal vein, making sure not to divide branches of the posteriorly situated renal artery supplying the upper portion of the kidney or venous branches draining to the renal vein. Small branches supplying and draining the adrenal gland should be carefully ligated and divided. Any lymph nodes posterior to the renal hilum should be included with the dissection. The left adrenal vein will be identified at the medial aspect of the left renal vein as it courses anterior to the aorta. It generally enters the adrenal gland in the 7 o'clock position. It should be ligated and divided. The adrenal vein and renal vein should be inspected and carefully palpated to assess for any tumor thrombus so that the tumor thrombus can be included with the specimen in an en bloc fashion. Advanced techniques for managing large tumor thrombi within the renal vein and vena cava are not discussed in this chapter. The fat overlying and just superior to the kidney is mobilized from inferior to superior, making this tissue the inferior margin, using cautery, silk sutures, and other hemostatic devices as needed, making sure not to create a nonexistent plane between the inferior aspect of the tumor and the superior aspect of the kidney. Lateral dissection should continue along the abdominal side wall. The dissection continues superiorly along the diaphragm, making sure to ligate and divide any feeding vessels, most commonly branches from the inferior phrenic vessels. Posterior dissection should proceed from lateral to medial, making sure to remove all fat posterior to the tumor in an en bloc fashion. If the tumor invades the muscle, a portion of the muscle should be included with the tumor to ensure negative margins. The left lateral surface of the aorta should be identified, and the soft tissue attachments including small vessels and lymphatics are ligated and divided. If removing a pheochromocytoma, the anesthesiologist should be warned well in advance prior to ligating the adrenal vein in anticipation of ensuing hypotension. The dissection is continued superiorly until all medial attachments have been released. Any lymph nodes along the aorta or identified near the superior mesenteric artery or celiac axis should be included with the specimen. The adrenal gland and the periadrenal soft tissue is removed, marked with orienting suture for the pathologist, and sent to the pathology lab.

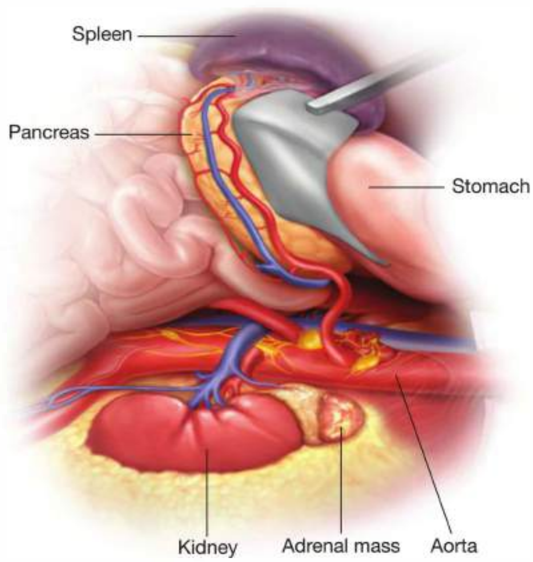

FIG 13 ● With the stomach, pancreas, and spleen retracted medially, the aorta, adrenal mass, and kidney are exposed and excluded from the rest of the peritoneal cavity.

Closure

- A small amount of water should be used for irrigation and final hemostasis achieved. The area encompassed by the dissection should be marked with large clips to assist with postoperative external beam radiation therapy if needed. A drain may be placed in the adrenal bed, and a chest tube is placed. Closure is begun, and the bed is taken out of the flexed position. The diaphragm is repaired with no. 1 PDS suture in a running locking or interrupted fashion. At the junction of the diaphragm and abdominal fascia, a no. 2 Vicryl figure-of-eight suture is used to reapproximate the tissue en masse. If a portion of the costochondral cartilage has not been excised, it may be reapproximated using a microdrill and a no. 2 Vicryl suture. The ribs are also reapproximated with no. 2 Vicryl sutures, with or without the microdrill. A rib approximator device helps decrease the tension required to tie the sutures. The abdominal midline is reapproximated with running no. 1 PDS suture. The chest wall musculature is closed in two separate layers using no. 1 Vicryl suture. The skin is closed with staples and a sterile dressing is applied.

PEARLS AND PITFALLS

Atelectasis	▪ Ensure excellent respiratory care and pulmonary toilet due to increased pain limiting respiratory effort.
Bleeding	▪ Access to the suprahepatic inferior vena cava is improved during left adrenalectomy with this approach, allowing for easier vascular control.
Pain	▪ Thoracoabdominal incisions are associated with greater pain than other incisions. Local anesthetic blocks may be helpful.
Neurovascular bundle of rib	▪ Avoid transection of the bundle and damage to the nerve by incising along the superior border of the rib.
Phrenic nerve palsy	▪ Take care to stay away from the phrenic nerve when incising the diaphragm.

POSTOPERATIVE CARE

- Most patients will need intensive care unit (ICU) care for 24 to 48 hours, either for pulmonary care or for resuscitation. The chest tube may be managed in standard fashion and removed when appropriate.
- Hydrocortisone should be administered to patients with overt Cushing's syndrome. A cosyntropin stimulation test can be performed the morning after surgery in subclinical or mild Cushing's cases if there is a question about the requirement for steroid supplementation. After bilateral adrenalectomy, high-dose intravenous (IV) hydrocortisone should be weaned to replacement dose oral hydrocortisone and fludrocortisone 0.1 mg daily. Electrolytes should be checked the morning after surgery. Patients undergoing surgery for primary hyperaldosteronism may experience rebound hyperkalemia. Antihypertensive medications are withheld in the immediate postoperative setting and reinstituted as needed. Routine postoperative care is pursued and patients are discharged approximately 5 to 7 days after surgery. Follow-up is typically 1 to 2 weeks after surgery with endocrine testing as needed.

OUTCOMES

- Excellent outcomes can be expected with low morbidity if aggressive respiratory care and pain control is initiated early in the postoperative period.

COMPLICATIONS

- Prolonged atelectasis: 21%
- Prolonged ileus: 9%
- Phrenic nerve injury and diaphragmatic paralysis
- Chronic pain

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Chapter 48

Adrenalectomy: Open Posterior

Barbra S. Miller

DEFINITION

- Adrenal masses may be benign or malignant and functional or nonfunctional with regard to excess hormone secretion. An open posterior approach should be considered if:
  - An anterior, lateral, or posterior retroperitoneoscopic approach is not feasible in a patient with a benign or metastatic adrenal tumor.
  - An open anterior approach is not feasible in patients who have undergone previous extensive upper abdominal surgery and are presumed to have dense adhesions limiting access.
  - Conversion from a retroperitoneoscopic posterior approach to an open approach is required.
  - Both adrenals need to be removed and repositioning of the patient during the case is to be avoided.

DIFFERENTIAL DIAGNOSIS

- Primary adrenal adenoma
- Primary adrenocortical carcinoma
- Cyst
- Metastatic cancer
- Pheochromocytoma
- Ganglioneuroma
- Adjacent paraganglioma
- Soft tissue tumor

PATIENT HISTORY AND PHYSICAL FINDINGS

- All adrenal abnormalities should be evaluated in a systematic fashion, including a thorough history and physical examination investigating the possibility of a hormone-secreting mass. This includes the possibility of a pheochromocytoma, Cushing's syndrome, primary hyperaldosteronism, and hypertestosteronemia. Specifically, the patient should be questioned regarding poorly controlled hypertension, diabetes, edema, diaphoresis, tachycardia, palpitations, sudden severe headaches, flushing, and easy bruising. The physical exam should look for evidence of central obesity, edema, peripheral wasting, core muscle weakness, a buffalo hump, striae, thin skin, and facial plethora. Because the adrenal gland is situated in the retroperitoneum, unless it is extremely large, palpation of the mass is usually unable to be achieved.

IMAGING AND OTHER DIAGNOSTIC STUDIES

- All adrenal masses should undergo appropriate biochemical testing. Even in the absence of signs or symptoms, patients should have at a minimum: potassium, aldosterone, renin, plasma fractionated metanephrines (followed by 24-hour urine metanephrines and normetanephrines, catecholamines, and vanillylmandelic acid (VMA) if plasma values are abnormal), 24-hour urine-free cortisol, and adrenocorticotropic hormone (ACTH). Some physicians may also perform a low-dose dexamethasone suppression test and obtain dehydroepiandrosterone Sulfate (DHEA-S) and free testosterone, among other laboratory tests.
- Imaging studies should include an adrenal protocol computed tomography (CT) scan (to assess imaging characteristics and calculate washout percentage of contrast from the tumor) or magnetic resonance imaging (MRI) (to assess decrease in signal between in and out of phase images) and 18F-Fluorodeoxyglucose (18FDG) positron emission tomography (PET) CT if malignancy is questioned (**FIG 1**).
- Additional imaging studies may be required depending on the functionality of the tumor (metaiodobenzylguanidine [MIBG] for some pheochromocytoma patients, adrenal vein sampling for hyperaldosteronism, etc.).
- Fine needle aspiration or core biopsy is not recommended if adrenocortical carcinoma is questioned. FNA may be useful if metastasis to the adrenal gland is in the differential and the adrenal tumor is the most accessible site of metastasis in the setting of multiple sites of metastatic disease. If biopsy is performed, it is imperative to first biochemically rule out pheochromocytoma.

SURGICAL MANAGEMENT

- Adrenal tumors, if benign appearing by imaging criteria, nonfunctional, and therefore not requiring resection, should be reevaluated with at least one additional CT scan or MRI 6 to 12 months after the initial imaging study to ensure stability in size and internal imaging characteristics. Some advocate for a longer period of follow-up imaging for 2 years with reevaluation of biochemistry for 4 years.[1]
- Functional tumors leading to hormone excess, indeterminate masses, and those suspected of being adrenocortical carcinoma or isolated metastatic disease from another primary tumor without evidence of widespread metastatic disease should be removed.

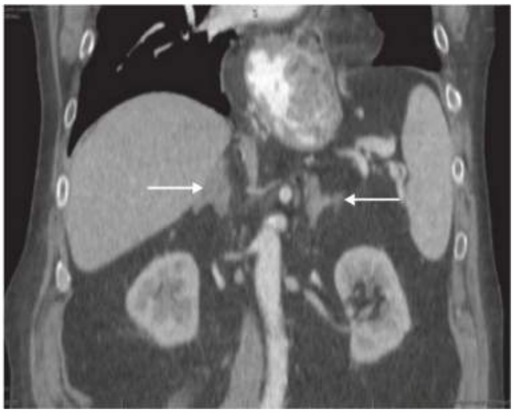

FIG 1 ● Bilateral hyperplastic adrenal glands *(arrows)* with benign imaging characteristics are shown in an obese patient with Cushing's disease requiring bilateral adrenalectomy.

Preoperative Planning

- The surgeon must evaluate available imaging studies for possible adrenocortical carcinoma or tumor involvement of adjacent organs, vessels, and lymphadenopathy. An open posterior approach is not optimal for removing adrenocortical carcinomas or large tumors, as the working space is limited by the rib cage and does not allow for multivisceral resections. These types of tumors should be approached by an open anterior or thoracoabdominal approach.
- The surgeon should evaluate the position of the adrenal gland with respect to the overlying rib that will need to be resected as well as any visible vasculature supplying or draining the adrenal gland.
- The risks, benefits, and alternatives to surgery are discussed with the patient including potential need for steroid supplementation in the postoperative setting. Patients with pheochromocytomas should be adequately alpha blocked and volume replete. Beta blockade may also be necessary. A potassium level should be checked the morning of surgery and treated as necessary in patients with Conn's syndrome (hyperaldosteronism).
- Routine prophylactic antibiotics and deep vein thrombosis (DVT) prophylaxis are administered prior to surgery, and sequential compression devices are applied.
- A general endotracheal anesthetic is administered.
- Common to all approaches, skin preparation with clipping rather than shaving is prepared, and the surgical area is prepped and draped in a sterile fashion.

Positioning

- Patients are intubated and a Foley catheter is placed prior to placing the patient in a modified prone position. Several methods for positioning may be used, including use of the Wilson frame, the Cloward surgical saddle, gel rolls, and flexion of the table (**FIG 2**). All of these have the common goal of creating a gentle flexion of the spine. Space is also created for the abdominal contents to shift away from the retroperitoneum.
- All pressure points are padded appropriately.

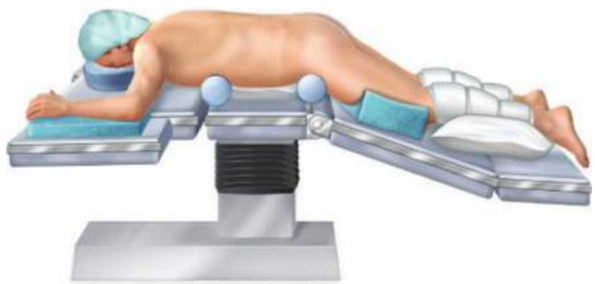

FIG 2 • The patient is placed in a modified prone position. Pressure points are padded.

TECHNIQUES

LEFT ADRENALECTOMY

Exposure

- A curvilinear incision is made from a paramedian position (4 to 5 cm from the spine) over the left 10th rib and carried inferolaterally toward the iliac crest. Alternatively, a straighter incision over the 11th or 12th rib, depending on the position of the gland on CT scan, with a more vertical upward incision medially may be made (**FIGS 3** and **4**).
- The subcutaneous tissue and musculature (latissimus dorsi and lumbodorsal fascia) are divided. The sacrospinalis is retracted medially with a handheld retractor. The 12th rib (and occasionally the 11th rib) is cleared of its attachments in a subperiosteal fashion using cautery and a Doyen or periosteal elevator, making sure to preserve the neurovascular bundle (**FIGS 5** and **6**). The rib is transected as far medially as possible with bone cutters and removed in its entirety. Bone wax may be used to assist with hemostasis.
- Entrance into the diaphragm and pleura should be avoided and the diaphragm is reflected superiorly. The retroperitoneal fat will be evident (**FIG 7**).

Dissection

- Using retractors to separate the tissue and rib(s), Gerota's fascia is incised after identifying the upper pole of the kidney. The surgeon's hand places downward (inferior and toward the peritoneal cavity) pressure on the kidney to facilitate exposure of the adrenal gland (**FIG 8**).
- The inferior, lateral, superior, and medial attachments may be divided in similar fashion to the standard open anterior approach, but the peritoneum overlying the anterior surface of the gland as described in the anterior open approach is not included with the specimen. The inferior attachments should be left until last, as they assist in retraction and exposure of the gland.
- The left adrenal vein should be ligated and divided when encountered during the course of dissection of the inferior attachments and will be found medially near the junction of the superior aspect of the left renal vein with the lateral aspect of the aorta in a 5 o'clock position due to the prone position. The left adrenal vein will be slightly posterior while in the prone position beneath some of the fatty attachments between the adrenal gland and left renal vein.
- The adrenal gland with the periadrenal soft tissue is removed en bloc, marked with orienting sutures for the pathologist, and sent to the pathology lab.

Closure

- A small amount of water should be used for irrigation and final hemostasis is achieved. A drain may be placed if desired but is not required in most cases.
- The musculature and subcutaneous tissue are closed in layers and the skin closed with staples or suture. A sterile dressing is applied.

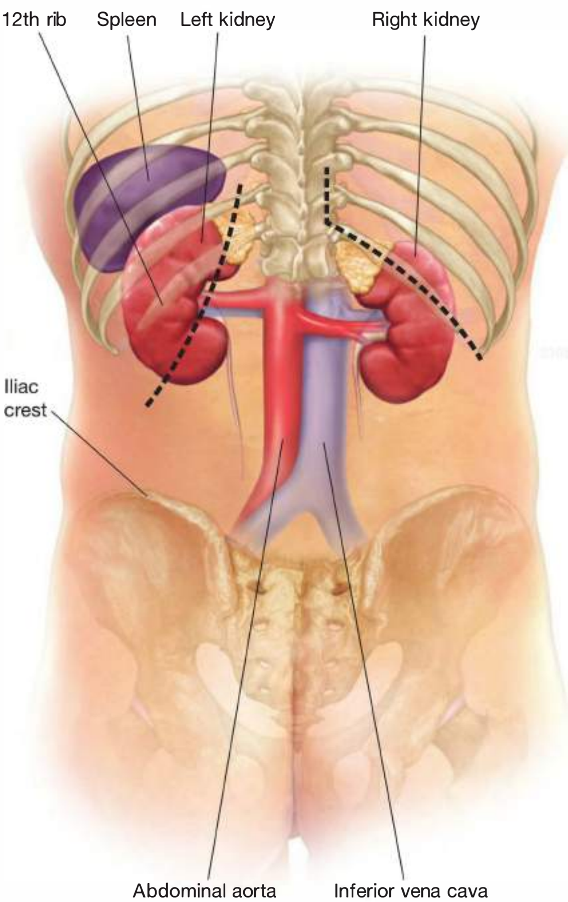

FIG 3 ● The incision can be made in a linear or curvilinear fashion to facilitate access to the 11th and 12th ribs.

FIG 4 ● Intraoperative image of curvilinear incision carried from 10th rib medially across the 11th rib and inferior to the 12th rib laterally.

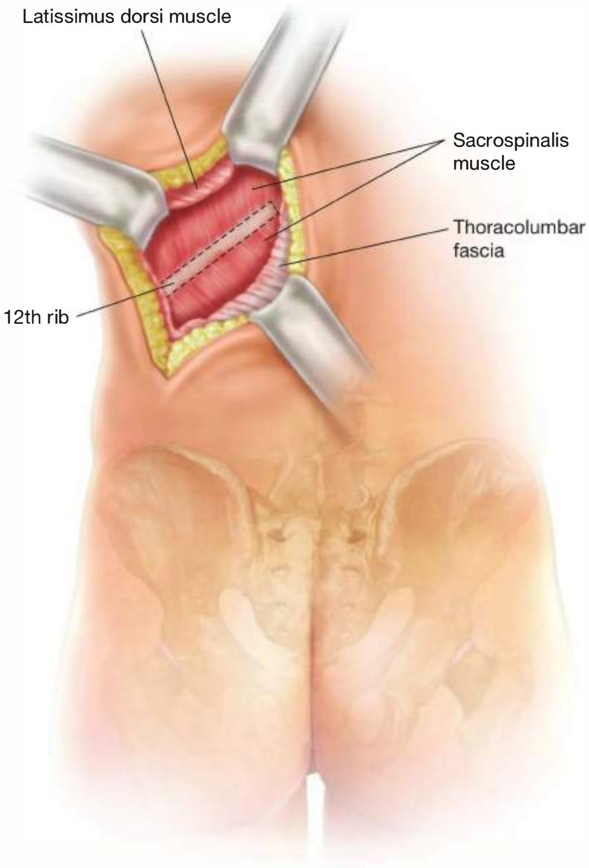

FIG 5 ● Schematic of exposure of the 12th rib that is cleared of its attachments in a subperiosteal fashion using cautery and a Doyen or periosteal elevator, making sure to preserve the neurovascular bundle.

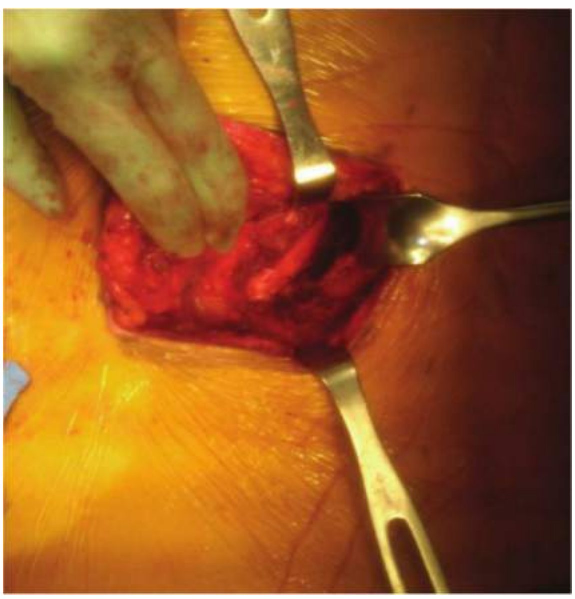

FIG 6 ● Intraoperative photo showing exposure of the 12th rib.

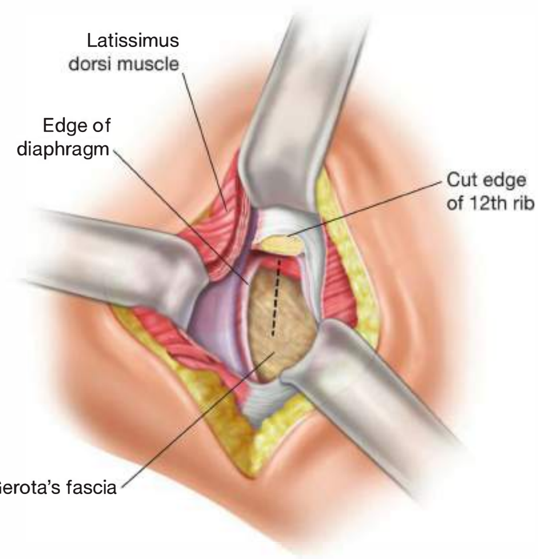

FIG 7 ● After removal of the 12th rib, Gerota's fascia and the retroperitoneal fat is evident.

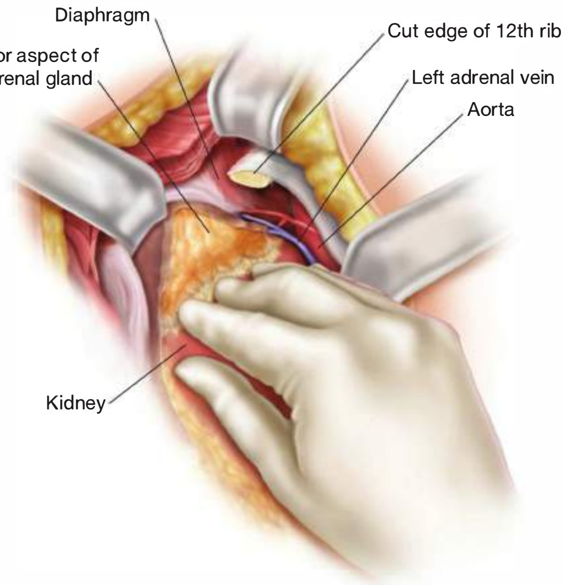

FIG 8 ● The left adrenal gland is best exposed using retractors and downward retraction using the hand on the upper pole of the kidney. The left adrenal vein is located in a 5 o'clock position.

RIGHT ADRENALECTOMY

Exposure

- A curvilinear incision is made from a paramedian position (4 to 5 cm from the spine) over the right 10th rib and carried inferolaterally toward the iliac crest. Alternatively, a straighter incision over the 11th or 12th rib, depending on the position of the gland on CT scan, with a more vertical upward incision medially may be made.
- The subcutaneous tissue and musculature (latissimus dorsi and lumbodorsal fascia) are divided. The sacrospinalis is retracted medially with a handheld retractor. The 12th rib (and occasionally the 11th rib) is cleared of its attachments in a subperiosteal fashion using cautery and a Doyen or periosteal elevator, making sure to preserve the neurovascular bundle. The rib is transected as far medially as possible with bone cutters and removed in its entirety. Bone wax may be used to assist with hemostasis.
- Entrance into the diaphragm and pleura should be avoided and is reflected superiorly. The retroperitoneal fat will be evident.

Dissection

- Using retractors to separate the tissue and rib(s), Gerota's fascia is incised after identifying the area of the upper pole of the kidney. The surgeon's hand places downward (inferior and toward the peritoneal cavity) pressure on the kidney to facilitate exposure of the adrenal gland (**FIG 9**).

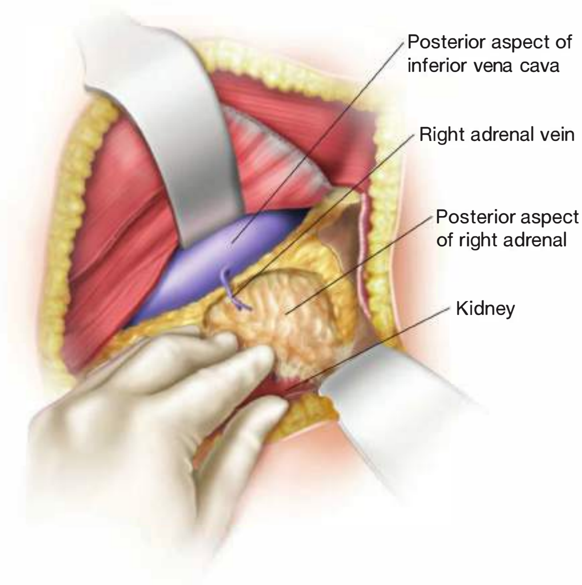

FIG 9 ● The right adrenal gland is best exposed using retractors and downward retraction using the hand on the upper pole of the kidney. The right adrenal vein is located in a 9 o'clock position.

- The right adrenal vein will be found along the medial aspect of the gland in a more anterior position off of the inferior vena cava (IVC) due to the prone position of the patient and should be ligated and divided.
- The inferior, lateral, superior, and medial attachments may be divided in similar fashion to the standard approach, but the peritoneum overlying the anterior surface of the gland as described in the anterior open approach is not included with the specimen. The inferior attachments should be left until last, as they assist in retraction and exposure of the gland.
- The adrenal gland with the periadrenal soft tissue is removed en bloc, marked with orienting sutures for the pathologist, and sent to the pathology lab.

Closure

- A small amount of water should be used for irrigation and final hemostasis is achieved.
- A drain may be placed if desired but is not required in many cases.
- The musculature and subcutaneous tissue are closed in layers and the skin closed with staples or suture. A sterile dressing is applied.

PEARLS AND PITFALLS

Bleeding—arterial and venous	■ May result from disruption of the vena cava, renal vein or artery, and aorta. A laparoscopic knot pusher, Allis clamp, and/or Kitner may be helpful given limited access due to the overlying ribs.
Diaphragmatic penetration	■ May occur upon entry to the retroperitoneum. May be closed in standard fashion.
Neurovascular bundle injury	■ Chronic pain may result if care is not taken to spare the bundle when removing the rib or upon closure of the wound.

POSTOPERATIVE CARE

- Most patients will not need intensive care unit (ICU) care, although pheochromocytoma patients often need closer monitoring for the first 24 hours, depending on intraoperative stability and volume status.
- Hydrocortisone should be given to patients with overt Cushing's syndrome. A cosyntropin stimulation test can be performed the morning after surgery in subclinical or mild Cushing's cases if there is a question about the requirement for steroid supplementation.
- Electrolytes should be checked the morning after surgery. Patients undergoing surgery for primary hyperaldosteronism may experience rebound hyperkalemia.
- After bilateral adrenalectomy, high-dose intravenous (IV) hydrocortisone should be weaned to replacement dose oral hydrocortisone and fludrocortisone 0.1 mg daily.
- Routine postoperative care is pursued. Diets may be begun early, as ileus is not usually an issue due to the entirely retroperitoneal dissection. Patients are discharged 2 to 3 days after surgery.
- Follow-up is typically 1 to 2 weeks after surgery with endocrine testing as indicated.

OUTCOMES

- Outcomes in general are quite good; however, hospital stay is longer, pain is greater, and morbidity can be higher compared to other approaches.[2]
- Neurologic changes due to injury of the neurovascular bundle coursing along the inferior aspect of the rib can be problematic.

COMPLICATIONS

- Bleeding
- Infection
- Adrenal insufficiency in those with Cushing's syndrome
- Postoperative hypotension in those with pheochromocytoma
- Rebound hyperkalemia in those with Conn's syndrome
- Lymphatic leak
- Pneumothorax
- Neurogenic pain
- Laxity of flank musculature

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Chapter 49

Laparoscopic Retroperitoneal Adrenalectomy

Michael G. Johnston James A. Lee

INDICATIONS

- Adrenalectomy is indicated for a variety of different clinical scenarios, including patients with (1) a functional tumor; (2) a solid adrenal mass larger than 3 to 4 cm, due to increasing risk of adrenocortical carcinoma; (3) growth of 0.5 cm or greater in 6 months based on serial cross-sectional imaging, again due to a risk of adrenocortical carcinoma; and (4) isolated metastasis from a remote primary malignancy.
- Laparoscopic adrenalectomy is now considered standard practice due to its shorter duration of postoperative pain, shorter hospitalization, and faster return to work compared to an open procedure.
- Contraindications to the transabdominal laparoscopic approach include severe cardiopulmonary disease and coagulopathy. Relative contraindications include prior intraabdominal surgery and very large tumor size.
- The laparoscopic retroperitoneal approach is based on the historical open posterior approach. This approach is gaining popularity as it offers advantages over a laparoscopic transabdominal approach. These advantages include faster operating times, potentially less postoperative pain, a lower risk of complications (especially of incisional hernia), and improved intraoperative hemostasis as the surgeon has the ability to increase the insufflation pressure to 30 mmHg (a maneuver not feasible in a laparoscopic transabdominal approach given the negative impact on central venous return and renal perfusion).
- The laparoscopic retroperitoneal approach does have some potential drawbacks. There is a slightly longer learning curve associated with the nontraditional "back-door" anatomic view. This approach may also be more difficult in patients with large tumors or who are morbidly obese.
- The posterior approach is the ideal approach for bilateral procedures because it eliminates the need for patient repositioning. It is also preferable for patients who have had previous transabdominal operations.
- Absolute contraindications to the laparoscopic retroperitoneal approach include the need to explore the rest of the abdomen and coagulopathy.
- Relative contraindications include an adrenal mass greater than 8 cm due to the smaller working space, patient body mass index greater than 45 due to the patient's pannus and visceral fat compressing the retroperitoneal working space. Severe cardiopulmonary disease is also a relative contraindication but may be less of an issue than for the transabdominal laparoscopic approach, as the diaphragm is not compressed to the same extent. Theoretically, increased ocular pressures are also a relative contraindication, as an extended time in a prone position would put the optic nerve at risk. This is usually only a problem for very long operations, however, and the vast majority of laparoscopic retroperitoneal adrenalectomies should not threaten the optic nerve.

PREOPERATIVE PLANNING

- As with any endocrine disease, the workup of adrenal disease typically follows a logical progression, from making a biochemical diagnosis to localizing the lesion to determining the indications for an operation. In deciding if an operation is indicated, the two principal questions to be answered are (1) "Is the mass functional?" and (2) "What is the risk for cancer (either primary or metastatic disease)?" Most functional tumors and most malignant lesions should be considered for resection, taking into account the patient's overall health, prognosis, and preferences.
  - Aldosteronoma. Ideally, the potassium level should be normalized preoperatively. Potassium supplements and/or aldosterone antagonists may be employed to achieve this goal. Maintain or optimize the antihypertensive regimen preoperatively.
  - Pheochromocytoma. Give the patient an α-blocker such as phenoxybenzamine. Start at 10 mg twice daily and increase the frequency and dose as tolerated until the patient becomes slightly symptomatic (including mild orthostasis and stuffy nose). A selective α-blocker is a good alternative in an older male patient due to less reflex tachycardia and potential prostatism benefits. In addition, some patients may be candidates for calcium channel therapy instead. As α-blockade proceeds, it is critical to replete the intravascular space with liberal fluid and some additional salt intake preoperatively. β-Blockade may be started a few days prior to the operation if the patient becomes tachycardic. Do *not* start β-blockade prior to adequate α-blockade or the resulting unopposed α-mediated vasoconstriction may cause stroke, myocardial infarction, and even death. Close communication with the anesthesia team is critical throughout the operation as manipulation of the tumor may cause wide swings in hemodynamics. Ensure that the anesthesia team is equipped with short-acting vasoactive agents to control or support intraoperative blood pressure as needed.
  - Cortisol-producing tumor. Give stress-dose steroids prior to induction. The patient will require a careful steroid taper postoperatively and endocrinology consultation is recommended. Although no level I data is available, perioperative antibiotics should be considered due to the relative immunosuppressed state in a patient with cortisol excess.
  - Adrenocortical carcinoma. Primary adrenal cancers may manifest any or all of the biochemical irregularities found in the aforementioned tumors and should be addressed as appropriate. It is important to assess the vasculature for evidence of venous invasion and tumor thrombus, ideally with a magnetic resonance venogram or formal venogram. The

laparoscopic retroperitoneal approach should not be used in cases of very large or locally invasive adrenal tumors.

ANATOMY

- The retroperitoneal space is bounded by the peritoneum laterally, the paraspinous muscle medially, the rib cage posteriorly (i.e., away from table), the kidney/adrenal gland/peritoneum anteriorly (i.e., toward the table), and the diaphragm superiorly.
- The superior pole of the kidney and the paraspinous muscle serve as the major landmarks.

TECHNIQUES

PATIENT POSITIONING

- A modification of the "Walz position"
- Intubate, obtain intravenous/arterial access as indicated, and place a urinary catheter while patient is still on stretcher. Administer stress-dose steroids and perioperative antibiotics if indicated.
- Place patient prone on two noncompressible bolsters with the lower bolster positioned at the break in the operating room (OR) table. The hips rest on the lower bolster. The lower ribcage rests on the upper bolster. The pannus should hang freely in between the bolsters to allow for the greatest amount of retroperitoneal working space. Place the operative side of the patient flush with that side of the table so that the table will not hinder the full range of motion of instruments, especially in the lateral-most port. If performing a bilateral adrenalectomy, the only patient repositioning necessary will be to shift the patient to the other edge of the bed (**FIG 1**).
- The lower back should be in a completely horizontal plane. This can be accomplished by lowering the leg portion of the OR table as much as possible to stretch the back and counter the natural convexity of the lower back.
- Raising the leg extension with the knees flexed and lower legs horizontal/parallel to the floor will help to prevent the patient from slipping further down on the bed.
- Flex arms at elbows, pad pressure points, and secure patient in place. Prep from midchest to just above buttocks.

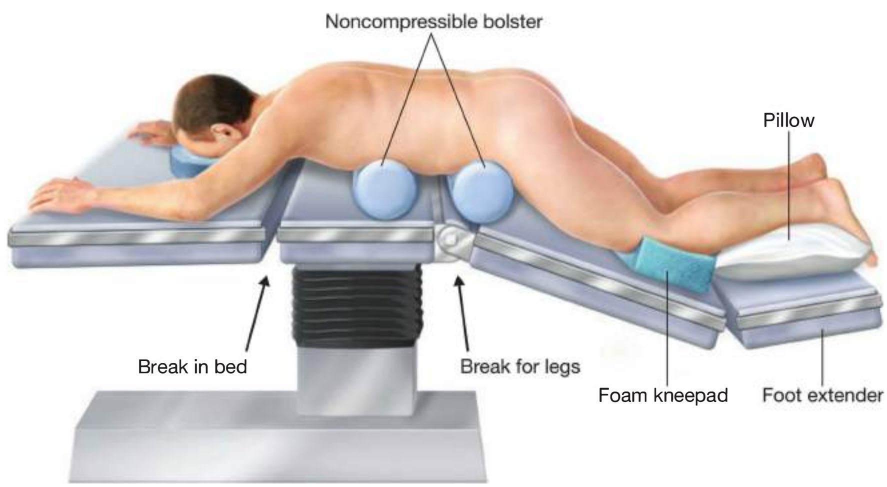


FIG 1 ● Patient positioning for a laparoscopic retroperitoneal adrenalectomy.

PORT PLACEMENT

- Three ports (lateral, middle, and medial) (**FIG 2**)
  - Medial: 5-mm "pediatric" or short port. Place this just lateral to paraspinous muscle and a few centimeters inferior to the costal margin.
  - Middle: 10-mm port with a "donut" balloon. Place this halfway in between the medial and lateral ports.
  - Lateral: 5-mm pediatric or short port. Place this as laterally as possible.
- The middle port is placed first via a direct cutdown by making a transverse incision just large enough to admit a finger immediately inferior to the tip of 12th rib or the costal margin. The position of this port is determined as discussed earlier.
- Dissection proceeds through the subcutaneous tissue to the muscle just inferior to the costal margin by spreading with a Metzenbaum scissors. The retroperitoneal space is entered by blunt dissection with the Metzenbaum scissors through the fascia and muscle using a technique similar to placing a chest tube (except that the hole is made directly *inferior* to the costal margin). Feeling the smooth undersurface of the ribs provides confirmation that the correct space has been entered. Use blunt dissection with the finger both laterally and medially to develop space for the placement of the subsequent 5-mm ports

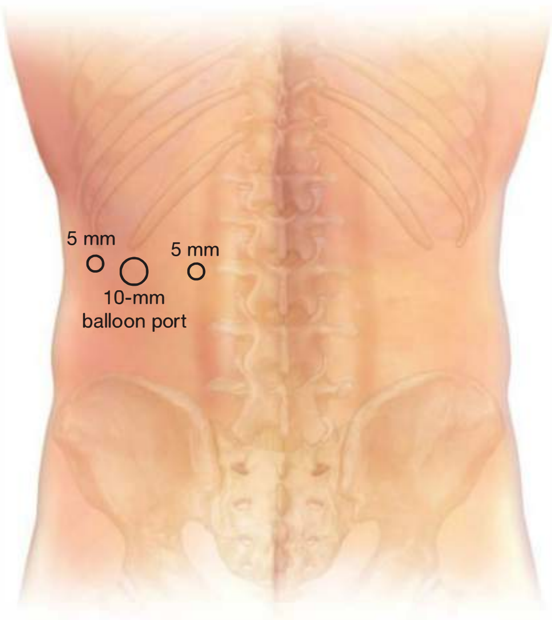


FIG 2 ● Right-sided port placement.

under direct palpation. Dissection should not be carried superiorly as this can make entering Gerota's fascia more challenging.

- Place the medial port 3 to 4 cm inferior to the costal margin just lateral to the paraspinous muscle entering the retroperitoneal space on a bias/angle cephalad of approximately 45 degrees such that the port enters the retroperitoneal space just inferior to the inferior margin of 12th rib. This angling of the port will improve visualization, obviating the need to torque the port.
- Place the lateral port just inferior to the costal margin as far laterally as possible.
- Place a balloon port in the middle port site to form a seal for the retroperitoneal insufflation.

DISSECTION OF THE RETROPERITONEAL SPACE

- Insufflate to 20 mmHg, liberally increasing as needed to maximum of 30 mmHg.
- Place camera into the middle port and a sealing device into the lateral port.

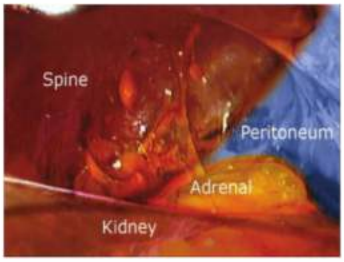
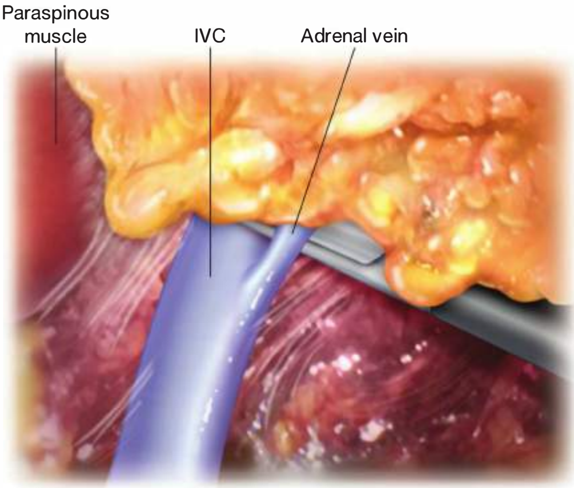


FIG 3 ● Retroperitoneoscopic view of the spatial relationships during initial dissection of a right adrenal gland. (Image courtesy of www.coachsurgery.com.)

- Enter Gerota's fascia bluntly and open it widely from left to right.
- Sweep the filmy posterior attachments of the periadrenal and perirenal fat anteriorly (i.e., toward the table). Continue this dissection to expose the peritoneum laterally, paraspinous muscle medially, and peritoneum superiorly.
- Switch camera to medial port and place a grasper into the middle port (**FIG 3**).
- Identify the superior border of the kidney. Starting laterally, divide the adrenal-renal connections using a combination of blunt and sharp dissection. Carry this dissection toward the paraspinous muscle following the superior contour of the kidney, which will allow the kidney to be retracted inferomedially.
- Carefully dissect the filmy plane between the adrenal gland and the paraspinous muscle medially to allow identification of the inferior vena cava during a right adrenalectomy or the inferior phrenic vein during a left adrenalectomy. The adrenal arteries will be in a plane that is posterior (i.e., away from the table) to the level of the adrenal vein. These arteries may be ligated with a sealing device.

IDENTIFICATION OF THE ADRENAL VEIN

- Right adrenal vein (**FIG 4**). Once the inferior vena cava is identified, follow the cava superiorly. The adrenal vein can typically be found entering the adrenal gland at the junction of the middle and superior third of the adrenal gland. The adrenal vein enters the adrenal gland anteriorly (i.e., toward the table). Divide the vein with clips or a sealing device.
- Left adrenal vein (**FIG 5**). Identify the adrenal vein either by tracing the inferior phrenic vein from superiorly to inferiorly or by dissecting the inferior border of the adrenal gland from lateral to medial until the confluence



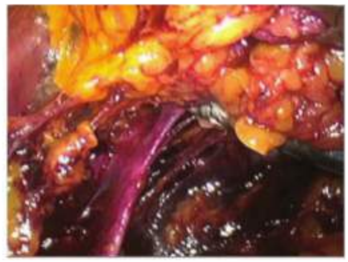
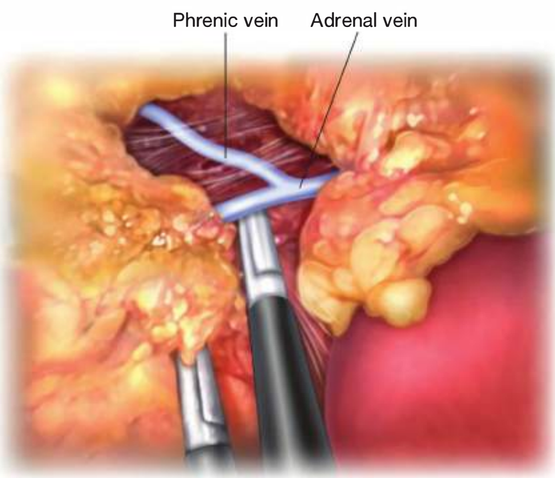


FIG 4 ● The short right adrenal vein is seen here at the end of the instrument in the middle of the picture. Note the relatively flat inferior vena cava due to the insufflation pressure. (Image courtesy of www.coachsurgery.com.)

of the adrenal vein and inferior phrenic vein is encountered. Ensure that the inferior-medial border of the adrenal gland is fully dissected from the surrounding tissue, as there is often a tongue of adrenal tissue extending toward the renal hilum. Divide the left adrenal vein with clips or a sealing device. The inferior phrenic vein may be either ligated or spared.

- Once the vein is divided, the remainder of the adrenal gland can be dissected with mostly blunt dissection and a minimum of sharp dissection.



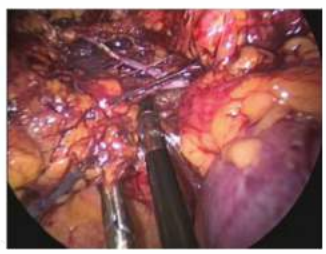


FIG 5 ● The left adrenal gland (notable for its distinct color that differentiates it from surrounding retroperitoneal fat) seen here at the end of the left adrenal vein (directly above the instrument in the middle of the picture). The left phrenic vein joins at an angle from above and can often be spared. The red-toned structure in the right foreground is the paraspinous muscle. (Image courtesy of www.coachsurgery.com.)

SPECIMEN EXTRACTION

- The adrenal gland can be placed in a specimen bag and removed through the middle port site, usually without the need to enlarge this site.
- Replace the middle port and inspect for hemostasis. Decrease insufflation to 5 to 7 mmHg to assist in identification of bleeding.
- A closed suction drain is not normally necessary.
- Remove the ports and close the middle port site fascia with a single absorbable figure-of-eight stitch, taking care to avoid the subcostal nerve.
- Close the skin with subcuticular stitches.

PEARLS AND PITFALLS

Patient positioning	■ Proper patient positioning is critical. ■ Make sure the rib cage and hips rest on the bolsters with the pannus hanging freely. ■ Place the operative side flush with the side of the table. ■ Lower the leg portion of the OR table to stretch the back so it is completely horizontal. Then raise the leg extension with the knees flexed to prevent the patient slipping down the bed.
Port placement and insufflation	■ The middle port is placed just inferior to the tip of 12th rib. Use blunt dissection with Metzenbaum scissors and fingers to enter the correct plane and allow the other two ports under direct palpation. ■ Make liberal use of increased insufflation pressures (20 to 30 mmHg) to improve visualization and hemostasis.
Dissection	■ Because of the nontraditional view of the anatomy, there is a longer learning curve associated with this approach. ■ Dissecting the superior pole of the kidney from lateral to medial and then retracting the kidney inferomedially allows for the best exposure to the adrenal gland and adrenal vein.

POSTOPERATIVE MANAGEMENT

- Remove the urinary catheter 4 to 6 hours postoperatively.
- Patients may ambulate and eat a regular diet on the day of surgery.
- Aldosteronoma. Draw potassium, aldosterone, and renin levels the morning after surgery. Stop potassium supplements and aldosterone antagonists. Implementation of the antihypertensive regimen differs from patient to patient. Some clinicians will choose to stop all antihypertensives and add them back as needed, whereas others will cut the patient's typical doses in half and add them back as needed. Typically, beta-blockers are continued postoperatively.
- Pheochromocytoma. Monitor hemodynamics closely and treat as indicated until stabilized. Stop all α-blockade. After removal of a pheochromocytoma, the major hemodynamic change to watch for is hypotension.
- Cortisol-producing tumor. Begin steroid taper. Consider keeping patients in-house for a day or two to begin the steroid taper under observed conditions.

COMPLICATIONS

- Bleeding. Significant bleeding occurs in less than 1% of cases. Increasing insufflation pressures as high as 30 mmHg often tamponades small bleeding sites. Even with a significant caval injury, increasing the insufflation pressure can cause tamponade that allows time either to repair the injury laparoscopically or to convert to an open procedure.
- Significant intraoperative hypertension occurs in 1% to 2% of cases.
- Conversion to an open operation occurs in approximately 1% of cases. Emergent conversion (such as for significant bleeding) should be done through a posterior approach, obviating the need for patient repositioning and minimizing the dissection needed to get to the affected area. Resection of the 12th rib improves exposure to the retroperitoneal space significantly. If conversion is not emergent, conversion to a laparoscopic transabdominal adrenalectomy or an open lateral approach should be considered.
- Incisional hernia, pneumothorax, and wound infection occur in less than 1% of cases.
- Hyperesthesia and abdominal wall laxity occur in approximately 5% to 8% of cases but are usually temporary.

RESULTS

- Walz et al. reported in 2006 a prospective study of 560 laparoscopic retroperitoneal adrenalectomies on 520 patients, demonstrating a 2% conversion rate, a median operating time of 55 minutes that decreased throughout the study, and a median intraoperative blood loss of 10 mL.
- More recently, Dickson et al. reported a prospective series of 118 laparoscopic retroperitoneal adrenalectomies on 109 patients. A conversion rate of 6.6% was reported, mainly due to a failure to maintain an adequate working space with CO_2 insufflation, not due to uncontrolled bleeding.

SUGGESTED READINGS

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Chapter **50**

Laparoscopic Adrenalectomy—Lateral Approach

Geoffrey B. Thompson   Anna Kundel

DEFINITION

- Lateral laparoscopic adrenalectomy is defined as a minimally invasive procedure to remove all or part of an adrenal gland via a lateral transperitoneal approach with the patient in a nearly full decubitus position.

ANATOMY

- The adrenal glands lie partially anterior, medial, and superior to the upper pole of the kidneys. The caudal limb of the left adrenal gland often lies in close proximity to the left renal hilum.
- The left adrenal vein frequently joins with the medially located inferior phrenic vein to form a common channel entering the left renal vein. This anatomic configuration, resulting in hormonal dilution within the common channel, is very important in understanding and interpreting the results of adrenal venous sampling (**FIG 1**).
- The right adrenal vein is short, often wide, and empties directly into the posterolateral aspect of the inferior vena cava. On occasion, additional right adrenal veins may drain directly into the inferior vena cava or the right hepatic vein. Arterial inflow to the adrenals is less predictable but generally arises as small arteries originating from the renal artery (inferior adrenal artery), the aorta (middle adrenal artery), and the inferior phrenic artery (superior adrenal artery).
- Paired small veins may accompany these arteries. It is these anatomic findings that allow for cortical-sparing adrenalectomy in familial pheochromocytoma syndromes, such as von Hippel-Lindau (vHL), neurofibromatosis type 1 (NF1), and multiple endocrine neoplasia type 2 (MEN-2) (**FIG 2**).
- Rarely, small rests of adrenocortical tissue may be found at sites near the adrenal bed or within the gonads. This has particular importance when treating corticotropin-dependent hyperadrenocorticism.

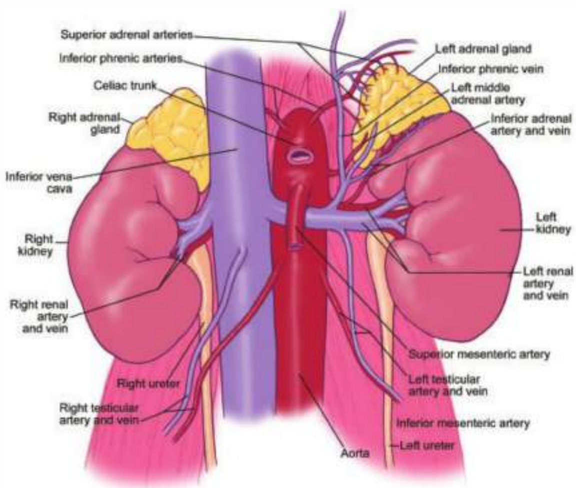

FIG 1 ● Vascular anatomy of the adrenal glands.

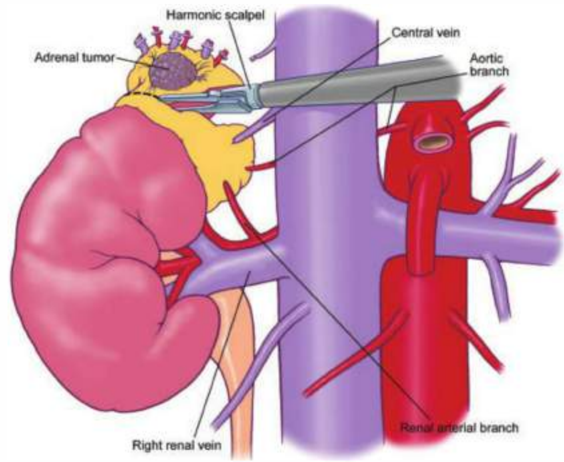

FIG 2 ● Cortical-sparing adrenalectomy.

PATHOGENESIS

- Pheochromocytomas, aldosteronomas, and cortisol-secreting tumors produce catecholamines and hormones in an uncontrolled fashion, resulting in potentially life-threatening hormonal sequelae. Some of these tumors are seen in familial cases (MEN, vHL, NF1); most occur sporadically.

NATURAL HISTORY

- Untreated functional tumors can lead to death and disability. Undiagnosed adrenocortical carcinomas are most often fatal.

PATIENT HISTORY AND PHYSICAL FINDINGS

- Laparoscopic adrenalectomy is used for small functional and nonfunctional adrenal tumors, the latter being removed because of suspicion of underlying malignancy (either primary or metastatic).
- Adrenal incidentalomas are incidentally discovered (asymptomatic) adrenal masses, typically picked up on cross-sectional imaging studies performed for some other reason. For example, a patient comes to the emergency room with renal colic and a computed tomography (CT) with stone protocol is performed, revealing a ureteral calculus and an incidentally discovered 4-cm right adrenal mass.
- Indications for removal an adrenal incidentaloma include (1) a functional lesion because of the risk associated with excess hormonal sequelae; (2) a growing lesion or a lesion greater than 4 cm in diameter because of the risk of adrenocortical malignancy; or (3) an abnormal radiographic phenotype, which can be an indicator of an underlying malignancy.

Table 1: Absolute Contraindications to the Laparoscopic Approach

Obvious, large adrenocortical carcinomas
Pheochromocytomas >8 cm or clearly malignant pheochromocytomas associated with direct invasion, nodal metastases, or distant metastases
Extensive upper abdominal surgery in which the surgeon should consider a posterior endoscopic approach (see Part 5, Chapter 49)

- Absolute contraindications to the lateral laparoscopic approach are described in Table 1.

IMAGING AND OTHER DIAGNOSTIC STUDIES

Diagnostic Studies

- Evaluation of an adrenal incidentaloma should include a 24-hour urine collection for fractionated catecholamines and total metanephrines or plasma metanephrines and normetanephrines.
- In patients who are hypertensive, regardless of their serum potassium level, plasma aldosterone concentration (PAC) divided by plasma renin activity (PRA) should be calculated to screen for primary aldosteronism. In the case of a high PAC:PRA ratio, confirmation of primary aldosteronism is obtained by salt loading and demonstration of a failure to suppress urinary aldosterone in a 24-hour sample. Autonomous cortisol secretion should be ruled out with an overnight 1 mg or 8 mg dexamethasone suppression test. The demonstration of autonomous cortisol secretion is confirmed by a two-day low-dose dexamethasone suppression test.
- Other studies available include a 24-hour urinary free cortisol level or demonstration of loss of diurnal variation between a.m. and p.m. plasma cortisol levels.
- Midnight salivary cortisol levels are also being used with increasing frequency for case detection of cortisol hypersecretion.
- Studies for estrogen and androgen excess are obtained when clinically indicated but are not routinely done.

Imaging

- Imaging of pheochromocytomas (**FIG 3**), aldosteronomas, cortisol-secreting tumors, and adrenocortical carcinomas is best performed with CT or magnetic resonance imaging (MRI). Tumors that are round, homogeneous, and low in Hounsfield units on CT scan with rapid washout of intravenous contrast are thought to represent lipid-rich cortical adenomas (**FIG 4**).
- Malignancies tend to be large and heterogeneous, with areas of hemorrhage or necrosis associated with high Hounsfield units on CT and delayed washout of intravenous contrast (**FIG 5**). These lesions appear bright on T2 weighted MRI images.
- Approximately 25% of lesions 6 cm and greater are likely to be malignant, whereas 6% of lesions between 4 and 6 cm turn out to be primary malignancies. It is for this reason that the 4-cm cutoff is used. This avoids taking out an excessive amount of nonfunctional cortical adenomas while missing very few adrenocortical carcinomas.
- CT imaging is also valuable in picking up small aldosteronomas, but because of the high incidence of nonfunctional incidentalomas in patients older than 50 years of age, adrenal venous sampling has become the localizing procedure of choice for determining lateralization of an aldosterone-producing adenoma or hyperplasia.
- Metaiodobenzylguanidine (MIBG) scanning is useful for detecting occult pheochromocytomas, paragangliomas, metastatic disease, and multiple tumors in familial cases.

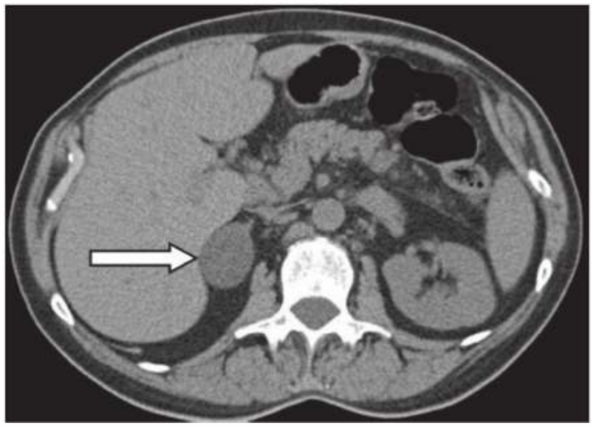

FIG 4 • CT scan of benign cortical adenoma.

FIG 3 • CT scan of pheochromocytoma.

FIG 5 • CT scan of left adrenocortical carcinoma.

NONOPERATIVE MANAGEMENT

- Pheochromocytomas can be managed, albeit less effectively, with medical blockade (α-blockers). Aldosteronomas can be treated with mineralocorticoid receptor blockers, but this is not an ideal choice for younger patients.

SURGICAL MANAGEMENT

Preoperative Considerations

- Laparoscopic adrenalectomy via a lateral approach is indicated in the following circumstances:
  - All benign, functional adrenal masses less than 6 cm in maximal diameter (aldosteronomas, cortisol-secreting tumors) and pheochromocytomas less than 8 cm in diameter
  - All nonfunctional adrenocortical tumors greater than 4 cm but less than 6 cm in diameter
  - All nonfunctional tumors less than 4 cm in diameter demonstrating interval growth by cross-sectional imaging (CT or MRI)
  - All tumors regardless of size with a worrisome radiographic phenotype (high Hounsfield units on noncontrast CT, poor washout of intravenous contrast on CT, bright image on T2 weighted MRI)

Preoperative Preparation

- For pheochromocytomas, pharmacologic blockade (α-blockade for 7 to 10 days, then β-blockade for 24 to 48 hours preoperatively for atrial tachyarrhythmias and calcium channel blockers) is instituted. Effective circulating volume is restored using salt loading and increased fluid intake over a period of 10 to 14 days. α-Methyl-para-tyrosine, Demser® (Valeant Pharmaceuticals International, Inc, Montreal, Quebec, Canada), can be added in refractory cases.
- When treating aldosteronomas, optimal blood pressure control must be achieved and hypokalemia should be corrected. Mineralocorticoid receptor blockade is often instituted.
- The patient with Cushing's syndrome undergoes perioperative steroid preparation as well as prophylaxis for deep venous thrombosis, stress ulcer, and opportunistic infection.

Table 2: Equipment Typically Recommended to Perform a Lateral Laparoscopic Adrenalectomy

Four 10-mm trocars
An OptiView port
10-mm scopes, both straight and 30 degrees (occasionally 45-degree scopes are necessary)
Insufflator, light source, and camera
Two monitors: InsideView (LSI Solutions, Victor, NY)
5-mm Harmonic scalpel
L cautery tip
10-mm clip applier
Suction/irrigation apparatus

Surgical Equipment

- The equipment typically used to perform a lateral laparoscopic adrenalectomy in my practice is shown in Table 2.

Preoperative Steps

- In addition to one or two large-bore peripheral intravenous lines, a radial artery line should also be placed preoperatively. A central line should be used in the elderly, the infirmed, and select pheochromocytoma patients.
- General endotracheal anesthesia is used. Antibiotics and deep venous prophylaxis are administered.
- Nitroprusside, labetalol, nicardipine, and intravenous pressors should be readily available for pheochromocytoma patients.
- An orogastric tube is placed.

Positioning and Port Placement

- The patient is placed in (near-complete) lateral decubitus position with the side of the tumor facing.
- Three to four ports are placed on the left; the fourth port is used for a fan retractor in obese patients and the most medial port is used for a liver retractor for right-sided tumors. The ports should be spread out between the midaxillary line and the midabdomen, approximately two to three fingerbreadths below the costal margin.
- The OptiView® (Ethicon Endo-Surgery, Cincinnati, OH) system and a straight scope are used for introduction of the first trocar, typically along the anterior axillary line.
- Patient pressure is maintained between 14 and 18 mmHg.

LEFT ADRENALECTOMY

- The splenic flexure is mobilized using the L cautery with caudal displacement of the large bowel (FIG 6).
- The lateral splenic attachments are divided with medial rotation of the spleen and body and tail of the pancreas, exposing Gerota's fascia and the adrenal gland.
- The surgeon opens the avascular plane between the posterior aspect of the pancreas and the adrenal gland, much like opening a book. The adrenal vein often can be found directly across the "valley" from the splenic vein.
- The adrenal vein, inferior phrenic vein, and common channel are exposed.

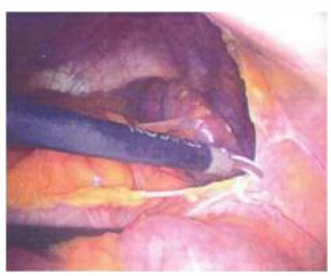

FIG 6 ● Mobilization of splenic flexure.

- No attempts should be made to dissect out the renal artery and vein.
- The surgeon doubly clips the veins and divides them (FIG 7).
- The caudal tip of the adrenal gland is elevated away from the area of the renal hilum; very often, renal artery pulsation is visible.
- The surgeon dissects up along the medial aspect of the gland using the Harmonic scalpel. If the inferior phrenic vein does not fall away from the dissection, it may require further division between clips at this level.
- Arterial tributaries from the aorta can be divided using the Harmonic scalpel as can the inferior phrenic artery tributaries, as dissection is carried around the superior aspect of the gland (FIG 8).
- The plane between the adrenal gland and the kidney is dissected using the Harmonic scalpel. This can be performed just outside the edge of the adrenal gland or, when thin, just inside Gerota's fascia.
- The gland is then elevated anteriorly and a small arterial branch from the renal artery, often present, is divided with the Harmonic scalpel.
- Any remaining areolar attachments are divided and the gland is removed using a commercially available retrieval device (FIG 9).
- The adrenal bed is irrigated and aspirated completely, and hemostasis is ensured. A sheet of a topical hemostatic agent can be left within the adrenal bed for added hemostasis.

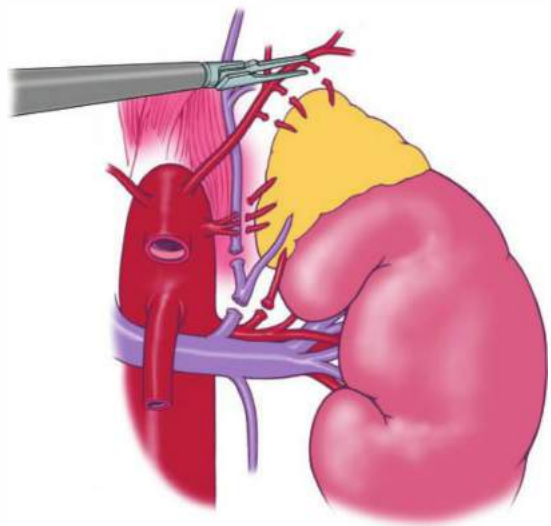

FIG 8 ● Division of arterial tributaries.

- If bladeless ports are used and dilation was not necessary for specimen retrieval, no deep fascial sutures are placed.
- Dilated port sites undergo fascial closure with interrupted suture, using a fascial closure device.
- Skin incisions are closed in a subcuticular fashion with an absorbable suture and are covered with Steri-Strips.
- Sterile dressings are applied.

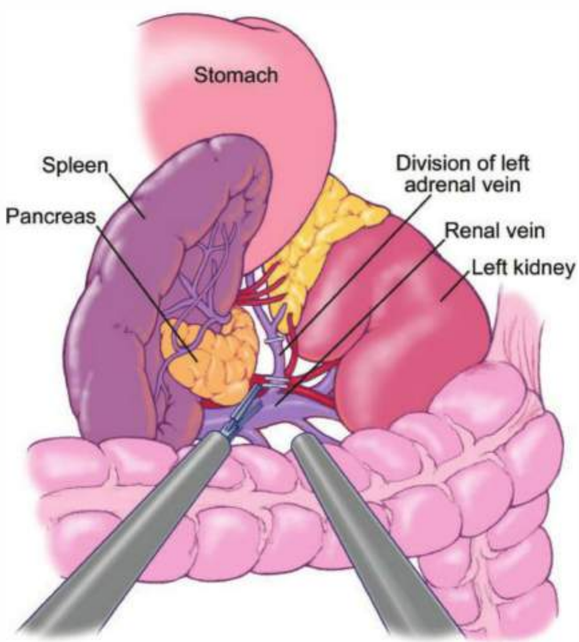

FIG 7 ● Division of left adrenal vein.

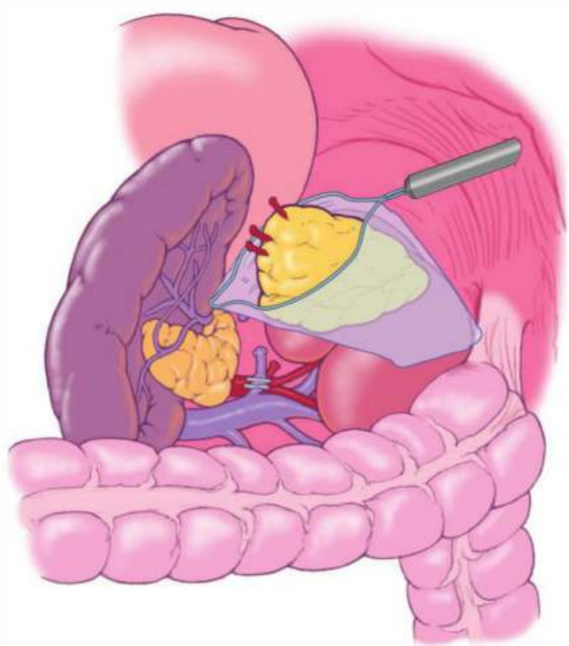

FIG 9 ● Retrieval of resected adrenal gland.

RIGHT ADRENALECTOMY

- Attachments to the right lobe of the liver are divided using the Harmonic scalpel so as to allow the liver to be fully retraced medially. This brings the adrenal gland and inferior vena cava into view (**FIG 10**).
- The peritoneum overlying the lateral border of the inferior vena cava is incised using the L cautery on a low setting.
- If possible, the right renal vein is exposed to define the lower limit of the dissection.
- A blunt-ended instrument is used to gently retract the adrenal gland away from the inferior vena cava (**FIG 11**).
- Using the L cautery or Harmonic scalpel, the areolar tissue posterior and lateral to the inferior vena cava is divided. This may contain arterial tributaries directly from the aorta.
- The dissection is carefully carried out along the lateral border of the inferior vena cava up to the level of the adrenal vein (**FIG 12**).
- If the adrenal vein is easily exposed at this stage, it can be doubly clipped and divided; otherwise, it can be done later when visualization is optimal (**FIGS 13, 14**).
- In a larger pheochromocytoma, the adrenal vein really should be divided after the gland has been mobilized to avoid venous congestion and bleeding.
- The superior pole, including its inferior phrenic artery branches, is mobilized using the Harmonic scalpel to free the gland from the diaphragm posteriorly. Care must be taken to control additional veins at the junction of the medial and superior portions of the gland.
- Using the distal right renal vein as a landmark, the caudal aspect of the gland is exposed, dissected, and elevated, often revealing a renal artery branch to the adrenal, which is divided using the Harmonic scalpel.
- Final step in the dissection is freeing the lateral aspect of the gland from the kidney using cautery or Harmonic scalpel.

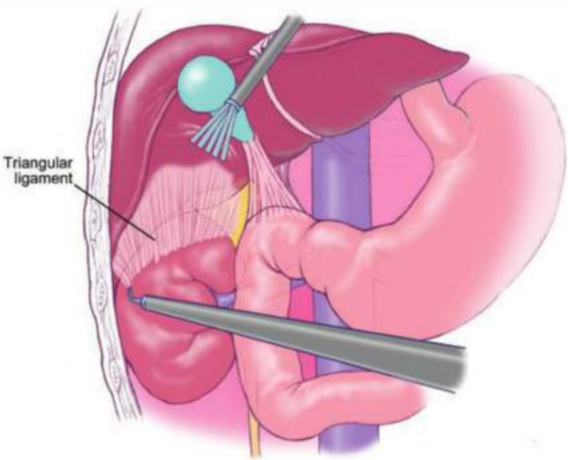

FIG 10 ● Liver retractor placement and division of triangular ligament.

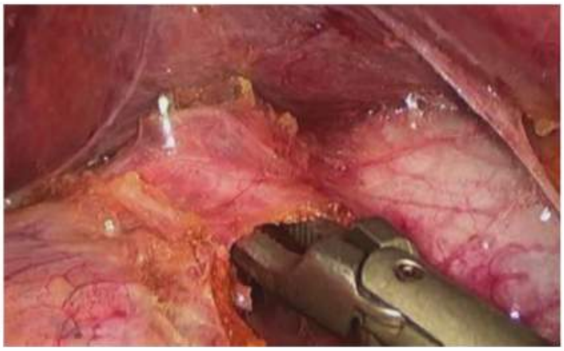

FIG 12 ● The right adrenal vein is encircled.

FIG 11 ● A right-sided pheochromocytoma is separated from the inferior vena cava.

FIG 13 ● The right adrenal vein is doubly clipped and divided.

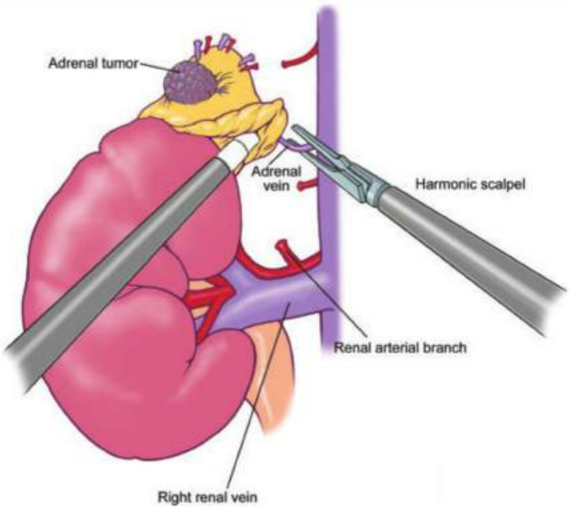

FIG 14 ● Division of right adrenal vein.

PEARLS AND PITFALLS

Adrenal vein	■ The adrenal vein does not have to be ligated as a first step in adrenalectomy; do it when it is safe and easy, even in patients with pheochromocytoma.
Accessory renal arteries	■ When dissecting on the posterior aspect of the adrenal gland, watch out for accessory renal arteries. If a large vessel is present, follow its course before considering ligation.
Low pressure bleeding	■ If bleeding occurs, remember that most of the time, it is low pressure bleeding. Pack the area with a sheetlike hemostatic agent. Work above and below the area, in which case, oftentimes, the bleeding site will become clear and manageable.
Renal hilum	■ Once the adrenal vein has been divided on the left side, never dissect caudally or posterior to the plane of the adrenal vein stump. This will avoid injury to the renal hilum.

POSTOPERATIVE CARE

Pheochromocytoma

- Pheochromocytoma (**FIG 15**) patients will often be mildly hypotensive, with systolic blood pressures in the 90s for 8 to 12 hours postoperatively. Greater or more prolonged falls in blood pressure accompanied by oliguria or tachycardia should prompt investigation for bleeding.
- All blood pressure medications should be stopped after the morning preoperative doses have been administered; the exception being β-blockers used long-term for ischemic heart disease. Rarely, pressors may be required, although volume replacement may be all that is necessary for a short period of time.
- Plasma metanephrines and normetanephrines are drawn prior to dismissal.

Primary Aldosteronism

- Patients with primary aldosteronism (**FIG 16**) may require decreasing antihypertensive agents for weeks and will need careful monitoring.

FIG 15 ● Pheochromocytoma.

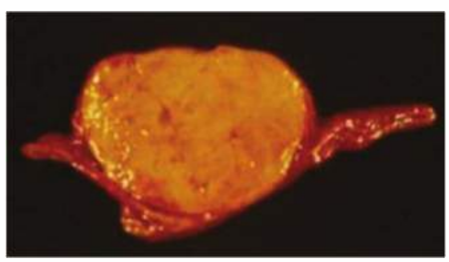

FIG 16 ● Aldosteronoma.

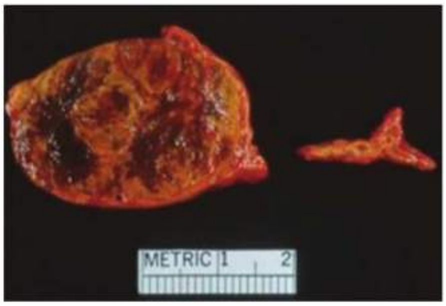

FIG 17 ● Cortical-secreting tumor.

- Potassium supplements should be withheld and only given on an as-needed basis because severe hyperkalemia may otherwise ensue with ongoing supplementation.
- PAC is collected prior to dismissal, and serum potassium levels are checked weekly for the first month.

Cushing's Syndrome

- Patients with Cushing's syndrome (**FIG 17**) are released on a tapering steroid dose to be monitored and adjusted by their endocrinologist.
- Resumption of oral intake is rapid.
- Dismissal usually occurs within 24 to 48 hours after surgery.
- Hemoglobin, electrolytes, and creatinine are checked the day after surgery, along with a serum amylase in left adrenal gland patients to rule out pancreatic injury.
- Patients undergoing bilateral adrenalectomy for adrenocorticotropic hormone (ACTH)–dependent Cushing's syndrome require lifelong replacement of glucocorticoids and mineralocorticoids, with increased doses during times of stress (illness, trauma, surgery).

OUTCOMES

- Outcomes for laparoscopic adrenalectomy are no different than open procedures with regard to cure rates. Morbidity is certainly less (pain, return to work, paresthesias, hypesthesias, and bulging flank muscles).

COMPLICATIONS

- Bleeding
- Spleen, pancreatic, renal, colon, and gastric injury (rare)
- Diaphragmatic injury (pneumothorax)

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Chapter 51 Insulinomas

Douglas L. Fraker

DEFINITION

- Insulinomas are neoplasms arising from the beta cells of the pancreas. The vast majority are benign, sporadic, and unifocal.[1,2] These neoplasms release insulin in a dysregulated manner and therefore cause decreased blood sugar, resulting in neuroglycopenic symptoms. Surgical excision uniformly provides long-term cure for the majority of benign insulinomas and corrects all of the associated symptoms.

ANATOMY

- The beta cells of the pancreas are distributed amongst the pancreatic islets uniformly throughout the pancreas. For this reason, insulinomas can occur in all areas of the pancreas. Virtually all large series of insulinomas demonstrate that there is a uniform distribution related to the volume of pancreatic tissue.[3–5] Half of insulinomas occur in the pancreatic head, neck, and uncinate process and the other half are distributed across the body and tail of the pancreas. Most series report insulinomas only occurring within the parenchyma of the pancreas. They can be exophytic and extend off the surface and these exophytic lesions may not be appreciated by standard cross-sectional imaging. There are reports of less than 2% of insulinomas being located outside of the pancreas parenchyma.[1] Virtually all of these lesions are found in the wall of the duodenum and presumably, they occur within embryologic pancreatic rest tissue that is physically separate from the pancreatic parenchyma, such that the insulinoma occurs within the duodenal wall with a similar appearance to duodenal gastrinomas.
- In most surgical series, insulinomas are small, measuring under 2 cm in cross-sectional diameter. Because symptomatology is caused by release of hormone and not by direct effects of tumor mass, lesions as small as 5 to 6 mm may present with significant clinical symptoms. In most series, 90% to 97% of insulinomas are benign. The average size of malignant insulinomas is over 6 cm and the majority of those present with concurrent regional lymph node or hepatic metastases.[1,2]

NATURAL HISTORY

- Insulinomas cause virtually all of their symptoms due to excess circulation of insulin and the subsequent hypoglycemic effects. The first clinical case of insulinoma was described in 1927 when a patient who had severe hypoglycemic episodes had an abdominal operation with a large tumor of the pancreas and lymph node and liver metastases.[2] Extracts of this tumor actually were injected into animals and caused hypoglycemia. Allen Whipple described the triad carrying his name that is known to define the symptoms of insulinoma in 1938. *Whipple's triad* consists of hypoglycemia, documentation of hypoglycemia during periods of fasting, and relief of symptoms with administration of glucose. On analysis, this constellation of signs and symptoms is not truly a distinct triad but rather makes a single point of symptoms related to low blood sugar.[6]
- The majority of symptoms experienced by patients relate to lack of blood glucose to the central nervous system. These are called *neuroglycopenic symptoms* and can range from mild confusion to coma. Patients may experience visual disturbances and there are numerous reports in the literature of insulinoma being misdiagnosed as an epileptic seizure. A second set of symptoms relate to the sympathetic nervous system release of adrenaline due to the effects of the hypoglycemia. This catecholamine release leads to palpitations, diaphoresis, and tremors. In most series, the onset of symptoms initially noted by the patient may be years before the specific time of diagnosis of the insulinoma. The average interval from onset of symptoms to diagnosis is between 2 to 3 years but sometimes may exist for over 10 years. Patients adapt and know that when they experience their symptoms, intake of food, particularly carbohydrates, provide rapid relief; however, this practice of glucose intake may not be elicited when taking a clinical history. Although the majority of patients exhibit weight gain in the anabolic state of hyperinsulinemia, some patients maintain a normal weight.
- The vast majority of patients with insulinoma have sporadic tumors with no family history. A small proportion is associated with multiple endocrine neoplasia type 1 (MEN-1).[5] The most common functional neuroendocrine tumor in MEN-1 is gastrinoma; outnumbering insulinoma by three- or fourfold. Insulinoma is the second most common pancreatic tumor in this syndrome. Because patients with MEN-1 may have multifocal nonfunctional neuroendocrine tumors throughout the pancreas, it may be difficult to distinguish the lesion making insulin versus other tumors. Typically, the dominant neuroendocrine tumor is the insulinoma but occasionally, patients will have multiple large lesions. Intraoperative measurement of insulin from direct tumor aspiration has been reported as an adjunct to insulinoma identification in this unusual situation.

LABORATORY DIAGNOSIS

- The key to diagnosis of insulinoma is not with imaging but rather with biochemical testing. The cornerstone of diagnosing hypoglycemia is detecting glucose levels typically below 40 mg/dL. Additional blood tests that should be obtained are insulin levels, proinsulin levels, and C-peptide levels.[7] Virtually all patients will have a plasma insulin concentration greater than 5 μU/mL at the time of low blood glucose. The vast majority of patients have insulin levels greater than 10 μU/mL. The insulin to glucose ratio can define hypoglycemia due to insulinoma as opposed to other causes with high specificity and sensitivity.[8] The measurements of proinsulin levels and C peptide are helpful in eliminating the diagnosis of surreptitious insulin abuse. The majority of patients have a proinsulin to insulin ratio greater than 25% and a C-peptide concentration greater than 1.7 ng/mL.

- The gold standard for confirming the diagnosis of an insulinoma is a monitored 48-hour or 72-hour fast.[9,10] Patients are typically in the inpatient setting given intravenous normal saline without glucose or allowed to drink noncaloric compounds while monitored for clinical symptoms and sequential blood analysis. The vast majority of patients who truly have an insulinoma causing hypoglycemia become symptomatic within the first 24 hours of the fast and virtually 100% of patients will become symptomatic by 72 hours. As time progresses, patients' symptoms include decreased mental acuity, confusion, or other neuroglycopenic symptoms, which are documented by the nursing staff and physicians during the monitored fast. When symptoms reach a significant level, blood is drawn for glucose, insulin, and proinsulin before administering glucose to relieve the neurologic symptoms.

DIFFERENTIAL DIAGNOSIS

- The differential diagnosis of hypoglycemia includes surreptitious use of either insulin or oral hypoglycemic agents and noninsulinoma pancreatogenous hypoglycemia syndrome (NIPHS).[7,11] In general, blood tests for proinsulin, C peptide, as well as specific tests for sulfonylureas can eliminate the use of surreptitious agents. NIPHS is distinguished from insulinoma by the timing of hypoglycemia. These patients often do not become symptomatic during a 72-hour monitored fast but will become profoundly hypoglycemic after ingesting glucose orally.[7] Pathology often shows significant beta cell hypertrophy but does not show a mass on imaging.

IMAGING

- The vast majority of insulinomas are small and are located within the substance of the pancreatic parenchyma. The three choices of imaging that have been highly specific for identifying the insulinoma are contrast-enhanced computed tomography (CT) scan, magnetic resonance imaging (MRI) scan, or endoscopic ultrasound.[12,13] Insulinomas are hypervascular with very well-defined margins and have a classic appearance on enhanced CT and MRI scans (**FIGS 1** and **2**). They are

FIG 1 ● Axial cut of MRI scan demonstrating an insulinoma in the body tail junction of the pancreas (marked by *arrows*). The insulinoma is small, oval shaped, and hypervascular compared to the surrounding pancreas.

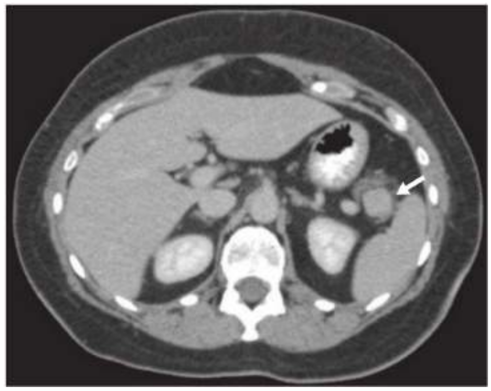

FIG 2 ● Axial cut of a CT scan demonstrating a 2-cm insulinoma in the tail of the pancreas (marked by *arrow*). This scan, an MRI scan, and an endoscopic ultrasound all reported this lesion to be an accessory spleen as it was exophytic off the pancreas tail and had identical imaging characteristics as the spleen on all three imaging modalities.

oval-shaped, well-marginated, and show a characteristic vascular blush.[12] The limitations of imaging relate to the size of the lesions. Again, insulinomas may cause symptoms that mandate surgical resection for correction with sizes smaller than 5 to 6 mm. Small insulinomas are ones that would be potentially missed on cross-sectional imaging studies. Also, exophytic lesions which may not be surrounded by pancreatic parenchyma may be a challenge to identify on CT or MRI, particularly if they are small. Insulinomas located near the tip of the pancreatic tail are the most common location for false-negative imaging; insulinomas may be incorrectly identified as lymph nodes, accessory spleens, and splenic vessels.

- Since the early 1990s, a variety of institutions with large experience in insulinoma have used endoscopic ultrasound as the primary imaging technique.[12,13] Endoscopic ultrasound allows for direct imaging in three dimensions with very close field ultrasonography of the head, neck, and uncinate process. The pancreatic body is less well imaged as it can only be seen from the placement of the ultrasound probe within the stomach and depending on the patient's body habitus, the tail may be a blind zone for endoscopic ultrasound. The ultrasound appearance of insulinoma is an oval hypoechoic mass with well-defined margins (**FIG 3**). Endoscopic ultrasound also allows a relatively straightforward fine needle

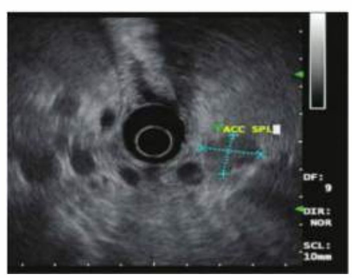

FIG 3 ● Endoscopic ultrasound image of the same patient in **FIG 2**. The insulinoma is oval shaped and hypoechoic. The gastroenterologist has incorrectly labeled the insulinoma as accessory spleen.

aspiration biopsy, which would produce neuroendocrine cells on cytology to confirm the diagnosis. Positive imaging may occur with identification of peripancreatic lymph nodes that are often embedded on the surface of the pancreas or accessory spleen, which can be found on the surface or actually within the parenchyma of the pancreas primarily in the tail region. Standard fluorodeoxyglucose-positron emission tomography (FDG-PET) scans have been shown to be of limited value in insulinomas as these may not be particularly hypermetabolic lesions.[14] A recent report showed a specific targeting agent of indium-labeled glucagonlike peptide-1 receptor that was sensitive for insulinomas and also could allow the use of a handheld intraoperative probe to detect these lesions.[15] This technique is being developed in Switzerland and has not been widely adapted elsewhere.

- Despite the high sensitivity of cross-sectional imaging and endoscopic ultrasound, a portion of patients with well-documented biochemical insulinoma may have no lesions imaged.[16,17] Historically, an interventional radiology invasive procedure called portal venous sampling was used in which a transhepatic portal vein cannulation was performed and blood was drawn from various regions and tributaries from the portal vein and assayed for insulin.[18,19] Portal venous sampling has now been replaced by intraarterial calcium stimulation with hepatic vein sampling. In this technique, two catheters are placed: one in the right hepatic vein and a second standard arterial angiogram catheter advanced into arterial branches feeding the pancreas. Calcium is injected into branches of the splenic artery supplying the body or tail or branches of the superior pancreaticoduodenal artery off the gastroduodenal artery or the inferior pancreaticoduodenal artery off the superior mesenteric artery. Blood is drawn from the right hepatic vein at 0 second, 30 seconds, and 60 seconds after calcium infusion and an increased gradient of greater than twofold in the hepatic vein insulin levels is significant.[18] This procedure does not image insulinoma but rather identifies the region of production of insulin. It is a highly specific test and may be helpful in focusing efforts in the operating room to one area or the other. It may justify performance of a blind distal pancreatectomy for patients without imaged lesions that have gradient in the body and tail, but a blind pancreaticoduodenectomy is virtually never indicated.

NONOPERATIVE MANAGEMENT

- The choices for nonoperative management include diet modification or hypoglycemic agents. One approach for management of hypoglycemic symptoms is small frequent meals, particularly of slowly absorbed carbohydrates to provide more of a steady level particularly while patients are sleeping.[2,5] Diazoxide is a benzothiazide analog with antihypertensive effects but also with potent hyperglycemic effects. It inhibits insulin release from the beta cells and enhances glycogenolysis to also contribute to elevation of blood sugar. Side effects include sodium retention causing edema and some patients have nausea. A second agent that has been used for control of hypoglycemic symptoms in insulinoma is somatostatin analogs. However, due to relatively low expression of somatostatin receptors on most well-differentiated insulinomas, these have not been markedly effective.

PREOPERATIVE PLANNING

- The cornerstone to performing an insulinoma resection is being absolutely certain the patient has the disease proven by definitive biochemical workup. In patients who have imaged lesions, particularly if they are biopsied as neuroendocrine tumors or have classic appearance on CT or MRI, this provides very good evidence that the patient has the disease. In patients who have no definitive imaging of the site of the lesion, the surgeon has to review in detail the preoperative blood chemistries. This analysis includes reviewing the data related to a 72-hour fast, looking at concurrent glucose, insulin, and proinsulin levels as described earlier.
- It is very important for patients to either be the first case of the day or to be admitted to the hospital and have dextrose solution running so that they do not suffer from severe hypoglycemia while they are nil per os (NPO) prior to general anesthesia. In general, for abdominal procedures, anesthesiologists do not administer glucose-containing fluids as they are infused at a relatively rapid rate and patients are catabolic. When operating on patients with insulinoma, it is very important to communicate to the anesthesia team that dextrose needs to be administered often and frequent analysis of glucose levels need to be performed.

SURGICAL APPROACH AND PATIENT POSITIONING

- Over the past few decades, the majority of patients in most surgical series have been treated with an open surgical technique. There have been many recent reports of laparoscopic excision of insulinomas, particularly in the body and tail, with high success rate. We will describe primarily identification and resection of insulinomas using an open technique and also provide information on laparoscopic approaches.
- The approach for the open resection of an insulinoma is performed with the patient lying supine with either an upper midline incision or a bilateral subcostal incision. The vast majority of the substance of the pancreas can be assessed with an upper midline incision with the exception of the far distal tail, which may be somewhat difficult particularly in obese patients. For patients with a well-localized insulinoma in the head and neck, uncinate process, or proximal body, a midline incision is preferred if the patient's body habitus is appropriate. Any patient can be approached with a bilateral subcostal incision.

EXPOSURE OF THE PANCREAS

- The initial steps of an insulinoma resection is to briefly assess the liver, although insulinoma is a benign disease in the vast majority of patients, and if liver metastases existed, they should have been identified on preoperative imaging. The next step is exposure of the pancreas parenchyma. Exposure of the head and neck of the pancreas as well as uncinate process can be achieved with a Kocher maneuver (**FIG 4**). The duodenum and head of the pancreas are brought up from the retroperitoneal location to allow bimanual palpation for mass lesions as well as visual inspection of both the anterior and posterior surfaces of the pancreatic head. The greater omentum is taken off the transverse colon along its entire length using energy devices with the omentum reflected superiorly, pulling the stomach off the pancreas. There are avascular attachments of the posterior stomach to the anterior pancreas that can be divided sharply. There is always a bridge of vascular tissue from the right gastroepiploic to the middle colic vessels, which crosses anterior to the neck and proximal pancreatic body that needs to be controlled with either energy devices or suture ligation. By dissection along the inferior border of the pancreatic body and tail, the posterior surface can be exposed and the majority of the substance of the pancreatic body and tail can be palpated between two digits (**FIG 5**). By doing these maneuvers, 95% of the pancreatic parenchyma is accessible for palpation and virtually all of the anterior surface and most of the posterior surface of the body and proximal tail are accessible for visual inspection as well. The only inaccessible area is the very tip of the tail of the pancreas, which may be located completely behind the spleen and require dividing the lateral margins of the splenic ligaments to reflect the spleen medially and expose that area of the very tip of the pancreatic tail.
- Insulinomas are identified by a combination of visual inspection, palpation, and intraoperative ultrasound. Insulinomas are uniformly red-brown in color against the yellow-gray background of the pancreas and lesions near the surface or exophytic lesions can be easily identified by visual inspection (**FIG 6**). Neuroendocrine tumors have

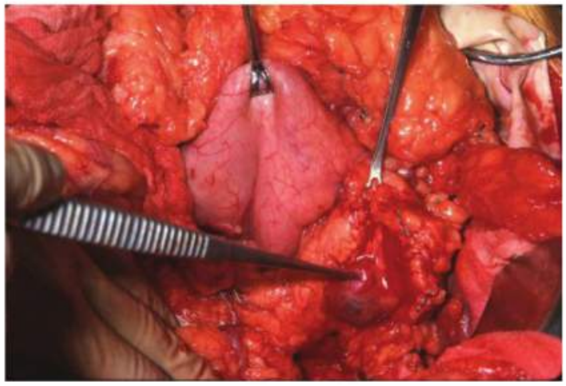

FIG 5 ● The lesser sac is exposed by reflecting the stomach and omentum superiorly and the transverse colon inferiorly. By dividing the retroperitoneum at the inferior edge of the pancreatic body and tail, the posterior surface of the pancreas is visualized as well. A large posterior body insulinoma is seen pointed at by the forceps.

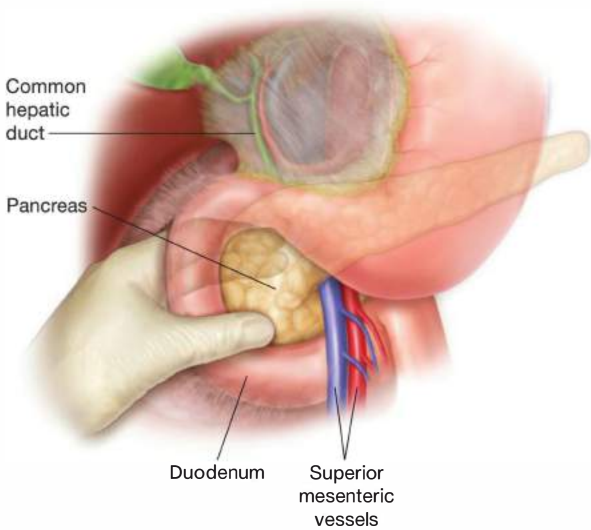

FIG 4 ● The lateral retroperitoneal attachments of the duodenum are divided along the entire length of the duodenum from the pylorus to the superior mesenteric vessel. By doing the Kocher maneuver, the entire head and uncinate process can be palpated between two fingers. By clearing the surface, all of the anterior head and uncinate process and most of the posterior surface can be visually inspected.

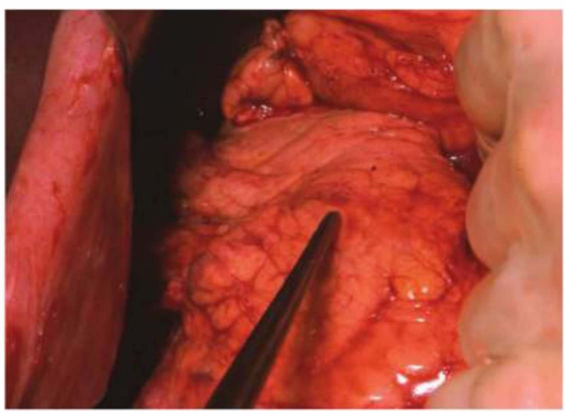

FIG 6 ● The anterior surface of the body and tail of the pancreas is skeletonized and exposed by retracting the stomach superiorly (posterior stomach on the left side of the picture) and the transverse colon inferiorly (retracted by the hand on the right side of the picture). The forceps is pointing at a red-brown insulinoma near the surface of the body of the pancreas.

a classic ultrasound appearance and intraoperative ultrasound is a key to management (FIG 7). Even in patients with lesions of the head and uncinate process of the pancreas that are well seen by preoperative endoscopic ultrasound, it is mandatory to have intraoperative ultrasound available. The reason for having intraoperative ultrasound available is because if the small lesion is deep within the parenchyma of the pancreas, it is essential to know exactly where the insulinoma is located so an appropriate enucleation can be performed. It is impossible to use preoperative imaging alone to know where to cut into the pancreas in the same way breast surgeons need intraoperative localizing techniques to remove nonpalpable breast tumors.

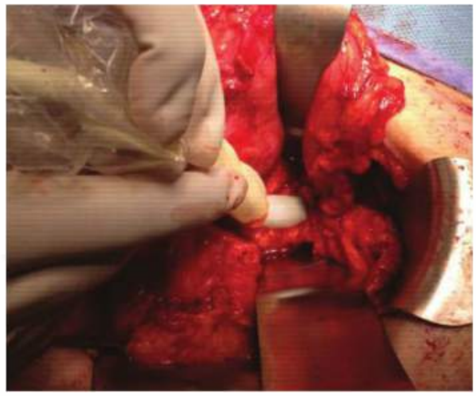

FIG 7 ● The head, neck, body, tail, and uncinate process of the pancreas are exposed and the intraoperative ultrasound probe is placed directly on the pancreatic surface. Ultrasound not only identifies the insulinoma but can also demonstrate precise relationships to the pancreatic duct and main vessels.

EXCISION OF THE INSULINOMA

- After exposure and identification of the insulinoma, the choices for excision of the lesion are enucleation versus a segmental pancreatic resection. In most surgical series, the majority of insulinomas are removed by enucleation, with one-third or more removed by distal pancreatectomy with or without splenic preservation and a very small fraction removed with pancreaticoduodenectomy or a Whipple procedure. The ability to enucleate an insulinoma relates to how close the insulinoma is located to the pancreatic duct. For patients who have their lesion identified by preoperative imaging, the proximity of the insulinoma to the main pancreatic duct is known prior to surgery. The pancreatic duct generally runs along the length of the midline of the pancreas slightly superior and slightly toward the dorsal or deep side of the pancreas. The duct can virtually always be identified on intraoperative ultrasound as a tubular structure with no vascular flow within on color Doppler. Even in the case of insulinomas that are well localized on the pancreatic surface, routine use of intraoperative ultrasound is helpful, partly to look for additional lesions and mostly to identify the proximity of the insulinoma to the duct.
- For lesions that are on the surface or visible from the surface, enucleation is relatively straightforward (FIG 8). The reddish brown color of the insulinoma is easily differentiated from the glandular tissue of the pancreas. The plane on the capsule of the insulinoma is quite distinct and easily separated from the parenchyma with gentle traction. The attachment of the insulinoma to the pancreatic tissue can be controlled with ties, clips, or use of energy device such as a Harmonic scalpel. The large bleeding vessels could be treated with a suture ligature. Even lesions as large as 4 to 5 cm when they are exophytic off the surface can be enucleated as long as they are not near the main pancreatic duct such that all exocrine pancreas duct branches are controlled to prevent postoperative fistula.

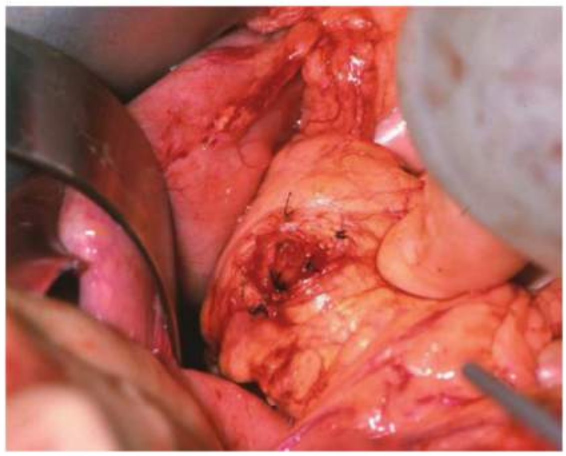

FIG 8 ● Enucleation of the insulinoma seen in FIG 6. Ultrasound confirms the lesion does not abut the pancreatic duct and the insulinoma is enucleated on the capsule of the tumor.

- Enucleation of an insulinoma that is deep in the parenchyma and not seen by inspection requires continuous use of intraoperative ultrasound. Generally, insulinomas are softer in terms of their substance compared to the tissue density of the normal pancreas and therefore, unless lesions are quite large, they cannot be felt by manual palpation with a finger behind and a finger in front of the pancreas. Ultrasound is used to mark the precise location of the lesion and the distance from the pancreatic surface to the closest margin of the insulinoma can be accurately measured to know exactly how deep to go for an enucleation (FIG 9). In general, a cruciate incision centered

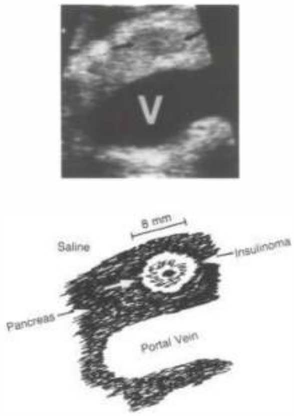

FIG 9 ● The *top panel* shows an image from an intraoperative ultrasound demonstrating the hypoechoic insulinoma indicated by the *black arrows*. The drawing on the *lower panel* shows the 8-mm insulinoma and the precise distance between the tumor and the underlying portal vein.

right over the mass is made using an energy device such as a Harmonic scalpel. Any sizable vessels are controlled with small hemoclips or ties as needed. Ultrasound is continuously used to monitor the progress of the enucleation to make certain the defect in the pancreas is aimed toward the tumor until the capsule of the insulinoma is seen. Once a small surface area of the tumor is definitely visualized, ultrasound becomes unnecessary as the tumor enucleation is completed, staying right on the capsule of the lesion just as for lesions located on the surface (**FIG 10**). Again, specific knowledge of the main pancreatic duct anatomy is crucial as an injury to the main duct by either making a defect in it or transecting it may lead

A

B

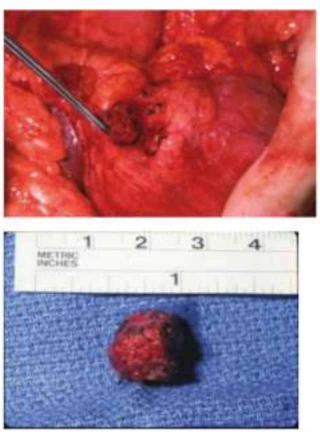

FIG 10 ● **A.** Enucleation of an insulinoma from the deep tissue of the head of the pancreas. Once the capsule of the insulinoma is seen, intraoperative ultrasound is no longer needed to guide the dissection. **B.** Intact pancreatic head insulinoma after enucleation. Small amounts of pancreatic parenchyma are attached to the lesion.

A

B

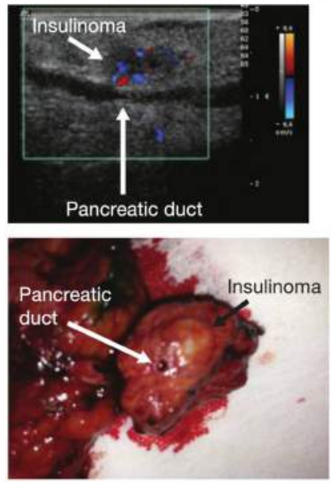

FIG 11 ● The patient had a small midbody insulinoma seen by CT scan. Intraoperative ultrasound **(A)** shows the insulinoma clearly but it indents the main pancreatic duct. Color Doppler ultrasound identifies the duct as there is no blood flow and the insulinoma is hypervascular. Due to the proximity of the main pancreatic duct to the insulinoma, a distal pancreatectomy was performed. **B** shows the insulinoma bordering a mildly dilated pancreatic duct. If the insulinoma was enucleated, there would be a high likelihood of a significant pancreatic leak.

to a significant pancreatic or cutaneous fistula that may require reoperation.

- For larger lesions or lesions that abut or distort the main pancreatic duct located in the body and tail of the pancreas, there is no question that the appropriate operation is a distal pancreatectomy (**FIG 11**). Again, intraoperative ultrasound is used to map the transection of the pancreas to the right of the lesion to get a margin. This resection can be either spleen preserving or a distal pancreatectomy plus splenectomy, depending on the preference of the operating surgeon. There are some minor advantages of preserving the spleen in adult patients but the incidence of postsplenectomy sepsis is exceedingly rare. Again, the location of the lesion is mapped out or if it is not visible on the surface, mapped using ultrasound. Distal pancreatectomy is generally done by dissecting the short gastric vessels along the greater curvature of the stomach using an energy device. At this point, when doing a distal pancreatectomy plus splenectomy, a large silk tie is placed around the splenic artery at the site of pancreatic transection to control blood inflow to the spleen. The lateral margins of the spleen are divided and the spleen and tail of the pancreas are reflected medially. The spleen and tail and body of the pancreas are reflected up and to the right off the left adrenal gland to the point of the targeted pancreatic transection line. The artery is then double ligated and divided, and the splenic vein is either stapled separately with vascular staples or stapled with the stapling device used to transect the pancreas.

A gas-powered stapler in which pressure can slowly be applied over 30 to 60 seconds to close the jaws of the stapling device minimizes fracturing the pancreatic parenchyma before firing the stapler load. Always inspect the margin and ensure complete excision of the insulinoma either by cutting into the pancreas on the back table or by having the pathologist do a gross evaluation of the specimen.

- Only for very large lesions in the head of the pancreas that abut the main pancreatic duct would a pancreaticoduodenectomy be performed for a benign insulinoma (**FIGS 11** and **12**). A Whipple procedure for insulinoma is a generally relatively straightforward procedure in terms of the resection portion as major vascular structures are virtually never invaded and can be done with pylorus-preserving technique. It may be somewhat more challenging to do the reconstruction as these patients typically have normal-sized pancreatic duct and bile duct, as even large insulinomas do not cause ductal obstruction, as well as a soft normal pancreas increasing the incidence of pancreatic leak.
- The most challenging situation for a surgeon is to be in the operating room and to be unable to identify the insulinoma.[17] Understanding the correct interpretation of the biochemical diagnosis of insulinoma should avoid the pitfall of operating on a patient who does not have the disease, which is a procedure obviously destined for failure. Historically, performance of a stepwise blind distal pancreatectomy with interval checks of blood glucose was advocated by some. In the era of high-resolution ultrasound, this blind resection of tissue should never be done. The key to success in this situation is the use of intraoperative ultrasound and evaluating areas where small insulinomas may be difficult to identify. Specifically, the very tip of the pancreatic tail lateral to the spleen, the uncinate process adjacent to the superior mesenteric vein, and the neck of the pancreas under the vascular bridge between the right gastroepiploic middle colic vessels should be closely examined.
- In the unusual or rare case of a malignant insulinoma, tumor debulking may be very beneficial in terms of controlling hypoglycemic symptoms. In general, this would require either a pancreaticoduodenectomy or distal pancreatectomy to remove the primary lesion and lymph node metastases. If there is limited number of liver metastasis, simultaneous liver resection or ablation may be performed. Chemoembolization also has benefit in controlling the hormone output from these hypervascular lesions and benefits the patients in terms of hypoglycemic control.

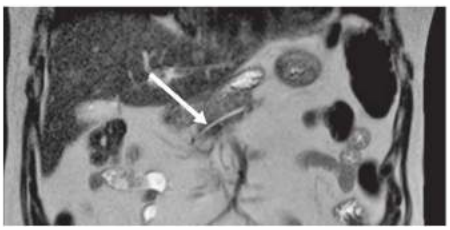

FIG 12 ● A coronal MRI scan shows a 2-cm insulinoma in close proximity to the main pancreatic duct in the head of the pancreas *(white arrow)*. After confirmation of the duct by intraoperative ultrasound, a pylorus-preserving pancreaticoduodenectomy was performed.

LAPAROSCOPIC RESECTION OF INSULINOMAS

- Although the majority of insulinomas are excised using standard open techniques described earlier, several surgeons have reported successful excision of insulinomas using laparoscopic techniques over the past two decades.[19–21] The precise location of the insulinoma and the success of preoperative localization studies are the keys to patient selection for laparoscopic excision.
- Insulinomas located in the body and proximal tail are the ones that are best approached by laparoscopy. Patients are positioned supine and a 30-degree scope is used in a central periumbilical port. The gastrocolic ligament is divided and the omentum and stomach are retracted superiorly to expose the pancreas at the base of the lesser sac. Laparoscopic ultrasound is used in an identical manner to intraoperative ultrasound in open procedures both to identify the insulinoma and the main pancreatic duct. Either enucleation or distal pancreatectomy is chosen based on tumor location again with the same decision-making process as in open procedures.
- Several studies, including a meta-analysis, have confirmed that laparoscopic removal of insulinomas is safe and has advantages over open excision. In institutional comparative studies, there was no difference in operative time, overall cure rate (which is uniformly 100%), and the incidence of pancreatic fistula. Length of hospital stay and blood loss generally favors laparoscopic excision. For surgeons who have experience in managing insulinomas and who have advanced laparoscopic skills, selected patients should have their insulinomas resected laparoscopically. However, as opposed to adrenalectomy in which video-assisted techniques are absolutely the standard of care, insulinoma procedures are much less common and the majority of procedures are still done with an open technique.

PEARLS AND PITFALLS

Indications	■ Confirm definitive biochemical diagnosis by review of primary laboratory reports including glucose levels with simultaneous insulin, proinsulin, and C-peptide levels. ■ Insist on a 72-hour monitored fast with appropriate documentation of symptoms and biochemical disease in patients with equivocal diagnosis and negative imaging.
Imaging	■ Obtain cross-sectional imaging with either contrast-enhanced CT scan or MRI scan to look for hypervascular lesion. ■ For image-negative patients, have endoscopic ultrasound performed by skilled invasive gastroenterologist. ■ If definitive diagnosis and negative imaging by CT and endoscopic ultrasound (EUS), consider calcium-stimulated angiogram with hepatic vein sampling.
Exposure of pancreas	■ Expose head and uncinate process by doing a complete Kocher maneuver all the way to the fourth portion of the duodenum. ■ Expose body and tail by dividing gastrocolic ligament and reflecting omentum and stomach superiorly and colon inferiorly. ■ Expose tip of pancreatic tail by dividing lateral attachments of the spleen.
Resection	■ Be certain to have intraoperative ultrasound available to evaluate the insulinoma and the proximity of the main pancreatic duct. ■ Decide between enucleation versus segmental pancreatectomy based on tumor size and relationship to the pancreatic duct.
Enucleation techniques	■ For surface lesions, stay right on the capsule of the insulinoma using energy device or clips to divide and seal tissue. ■ For deep lesions, continuously monitor progress with intraoperative ultrasound as pancreatic parenchyma is divided.

POSTOPERATIVE MANAGEMENT AFTER INSULINOMA RESECTION

- After excision of the entire insulinoma, patients recover almost instantaneously in terms of their glucose metabolism. Typically, blood sugars may rise to between 150 and 200 mg/dL or higher in the recovery room and for the first 24 to 48 hours, patients should be placed on appropriate sliding scale of insulin. It is certainly possible and has been reported that resection of an insulinoma may unmask a patient who has developed diabetes but the majority of these patients correct and normalize their glucose metabolism within 2 to 3 days.[22,23]
- The major postoperative complication from either a distal pancreatectomy or enucleation, either laparoscopic or open, is a pancreatic fistula.[24] The standard practice is to leave a closed suction drain adjacent to the enucleation site or the staple line and to leave that in until the patient is eating at least a low-fat diet. The color and character of the drain fluid can be monitored. If it is a serosanguineous color, it is likely to have a low pancreatic amylase content. Pancreatic fistulas normally present with a dishwater-gray discoloration and can be confirmed by measuring drain content amylase levels. Standard maneuvers to decrease pancreas secretion including nonfat diets or even using total parenteral nutrition should decrease pancreatic fistula outputs.

OUTCOMES AND ALTERNATIVES TREATMENT TO SURGERY FOR TREATMENT OF INSULINOMA

- In virtually all of the surgical series resecting insulinoma, there is uniformly a 100% long-term cure rate after excision of these small benign lesions.[3,4,25] The only exception would be inability to identify an occult insulinoma resulting in immediate operative failure. Because the vast majority of patients are cured by surgery, there has been no impetus to use nonsurgical treatments. Two percutaneous or endoscopic techniques have been reported.
- Ethanol injection to ablate insulinomas[26] and radiofrequency ablation[27] of lesions may provide nonsurgical resolution of hypoglycemic symptoms. Only for very selected patients who are poor surgical candidates should these ablative techniques be offered.

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Chapter 52 Surgery for Glucagonoma

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DEFINITION

- Glucagonomas are pancreatic neuroendocrine tumors (PNETs) that arise from the glucagon-secreting alpha islet cells of the pancreas. They are very rare with an estimated incidence of 1/20,000,000 individuals.[1] Most are sporadic but 10% are associated with multiple endocrine neoplasia type 1 (MEN-1) syndrome.[2] Most glucagonomas are large (>5 cm) at diagnosis, with 70% to 90% of patients presenting with metastatic disease.[3] Operative treatment of a glucagonoma involves resection of the primary tumor as well as metastatic disease for cure when possible or to palliate hormonal or local symptoms.

PATIENT HISTORY AND PHYSICAL FINDINGS

- Glucagonoma is classically associated with the 4 "Ds": dermatitis, diabetes, depression, and deep vein thrombosis.
- The skin lesions associated with a glucagonoma are termed necrolytic migratory erythema and are pathognomonic for glucagonoma. It is a pruritic rash that occurs in the lower abdomen, lower extremities, perineum, perioral area, and feet (**FIGS 1** and **2**). It is seen in approximately 70% of patients and may be the initial presentation of the tumor.[4]
- Glucose intolerance is often mild and insulin administration usually is not required.
- Weight loss is often out of proportion to the amount of tumor burden and is due to the catabolic effect of excess glucagon.
- Stomatitis, glossitis, and diarrhea are other frequent findings.
- Psychiatric manifestations may include depression, anxiety, and psychoses.
- Glucagonoma creates a hypercoagulable state, and 30% of patients will experience a thromboembolic event.[5]
- A thorough personal and family history should be taken, with particular interest in other endocrinopathies because glucagonomas may be associated with MEN-1. Glucagonomas may also secrete secondary hormones, which may lead to Zollinger-Ellison syndrome in up to 10% of patients. Less commonly, they may secrete vasoactive intestinal polypeptide (VIP), pancreatic polypeptide, somatostatin, or adrenocorticotropic hormone (ACTH).[6]

DIAGNOSIS

- Diagnosis is confirmed by high levels of fasting serum glucagon (>1,000 pg/mL; normal, <150 pg/mL). Other conditions that cause hyperglucagonemia include hepatic insufficiency, stress, sepsis, and starvation, but levels rarely reach beyond 500 pg/mL.

IMAGING

- Glucagonomas are typically greater than 5 cm at time of diagnosis and are easier to localize preoperatively than most PNETs. Most glucagonomas are located in the body or tail of the pancreas. Rarely, they may be located outside the pancreas in the duodenal wall, accessory pancreatic tissue, or the kidney.
- Triple-phase computed tomography (CT) scan is the first-line localization study. Somatostatin receptor scintigraphy (SRS) can also be used and can identify extraabdominal spread to lymph nodes and liver.
- Endoscopic ultrasound (EUS), visceral angiography, and portal venous sampling may be required for glucagonomas that are difficult to identify, but this is very unusual.

FIG 1 ● Necrolytic migratory erythema of the lower extremity.

FIG 2 ● Necrolytic migratory erythema of the lower extremity.

SURGICAL MANAGEMENT

- The goal of operative management of glucagonoma is an R0 resection including the primary tumor and all metastases. Patients who cannot undergo R0 resection benefit from tumor debulking because it can palliate symptoms due to excess glucagon by decreasing the levels of circulating hormone.
- If the tumor is limited to the pancreas, surgical resection can completely reverse all clinical manifestations of a glucagonoma. This demands a formal pancreatic resection due to the large size of the tumors, usually a distal pancreatectomy with or without splenectomy. Pancreaticoduodenectomy is required for tumors in the head of the gland. Resection should include peripancreatic lymph node dissection. Although smaller tumors may be technically amenable to enucleation, the high malignant potential of these tumors suggests caution with this approach (**FIG 3**).
- All nodal and hepatic metastases that can be safely removed should be excised. Hepatic metastases may be managed by either wedge resection or formal hepatic resection.
- Tumor debulking leads to a dramatic improvement in symptoms and the hormonal manifestations of glucagonoma may be diminished for years. Repeat debulking of recurrent disease may also prolong survival.
- In patients with MEN-1, consideration must be given to the presence of other functional and nonfunctional PNETs. If hyperparathyroidism is present as a component of the MEN-1 syndrome, it should be treated before addressing the pancreatic tumor to avoid problems with postoperative hypercalcemia.

Preoperative Planning

- Preoperative management is focused on treating the metabolic effects of excess glucagon and preventing or treating venous thromboembolism.

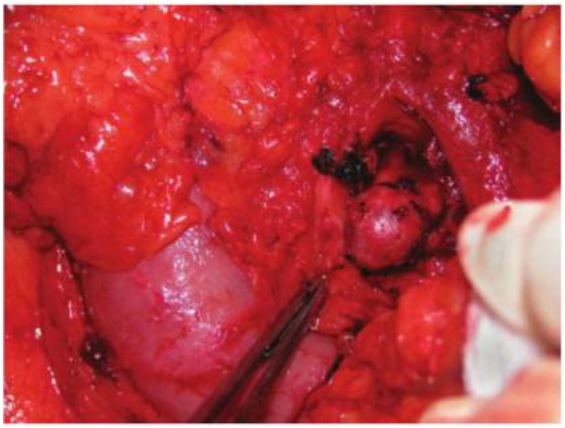

FIG 3 ● Small glucagonomas (<2 cm) with no malignant features can be enucleated from the pancreas using cautery or an energy device to control bleeding. Intraoperative ultrasound should be used to avoid injury to the pancreatic duct.

- Somatostatin analogue therapy with octreotide is titrated to symptomatic improvement. Total parenteral nutrition (TPN) may be needed if marked cachexia is present and may also help ameliorate necrolytic migratory erythema.
- Hyperglycemia and diabetes, when present, should be controlled.
- Patients should receive anticoagulation with Coumadin or low-molecular-weight heparin at the time of diagnosis. Preoperative placement of an inferior vena cava (IVC) filter may be necessary in patients with a history of thrombosis.

TECHNIQUES

POSITIONING

- As most patients present with metastatic disease and may require both pancreatic and hepatic resection, an open approach is preferred. For tumors confined to the pancreas, a laparoscopic approach may be possible. The open approach will be first described here.
- The patient is placed supine with arms either extended laterally or tucked according to surgeon preference.

INCISION

- Midline laparotomy, extended left subcostal, chevron, or a combination of these are all acceptable approaches to the abdomen and should be chosen based on surgeon preference and experience, the body habitus of the patient, and the possible need for hepatic or other organ resection.

DISTAL PANCREATECTOMY WITHOUT SPLENECTOMY

- After the abdomen has been explored, the lesser sac is entered by separating the greater omentum from the transverse colon. The short gastric vessels must be preserved to provide blood flow to the spleen.
- Mobilize the posterior wall of the stomach off the anterior surface of the pancreas and retract the stomach cephalad. The stomach may be held in place with retractors or stay sutures. The anterior body and tail of the pancreas should now be fully exposed (**FIG 4**).
- Incise the peritoneum along the inferior border of the pancreas along the length of the body and tail.

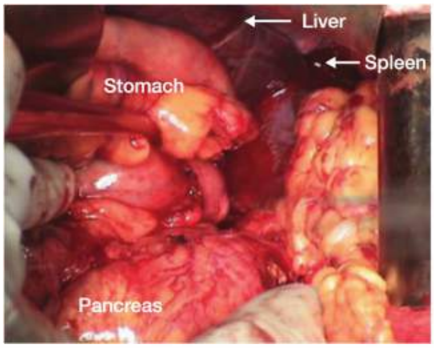

FIG 4 ● The anterior surface of the body and tail of the pancreas is exposed by entering the lesser sac thru the gastrocolic omentum and retracting the stomach cephalad.

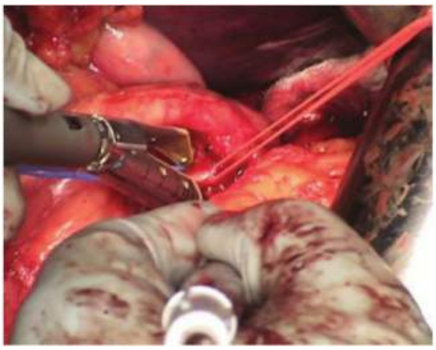

FIG 6 ● The splenic artery and vein are ligated with a vascular stapler as shown. Ligatures or suture ligatures may also be used according to surgeon preference.

Gently elevate the pancreas off the retroperitoneum using blunt dissection along the avascular plane.

- The splenic artery and vein, which run along the superior border of the pancreas (the vein runs posterior to the artery), will be elevated along with the rest of the pancreas.
- Determine the point of transection for the pancreas. This should be just to the left of the superior mesenteric vein in the pancreatic neck.
- Bluntly develop a plane between the splenic vessels and the pancreas at the point of transection. Place vessel loops around the splenic vessels to facilitate retraction and provide vascular control (**FIG 5**).
- Ligate the splenic artery and vein individually—ligatures, suture ligatures, or a vascular stapler (as shown) can be used according to surgeon preference (**FIG 6**).
- Divide the pancreas using a stapler with a vascular load. Multiple firings may be required (**FIG 7**). If there is bleeding from the staple line, place 2-0 sutures in a figure-of-eight pattern at the superior and inferior borders of the pancreas to secure the gastropancreatic arteries.
- Ligate, clip, or use an energy device to control the numerous small, short vessels connecting the splenic vessels to the pancreas along the entire body and tail. Control any bleeding that occurs on the splenic artery or vein with fine Prolene sutures.
- As the splenic vessels approach the hilum, they will branch into multiple tributaries. Care must be taken to avoid injury to these branches along the tail of the pancreas. The hilum of the spleen may be directly abutting or within 1 cm of the tail of the pancreas. Once fully dissected off the vessels, the specimen may be removed.
- Check the surgical bed for hemostasis. Omentum may be placed over the pancreatic stump. Placement of a closed suction drain is our preference.

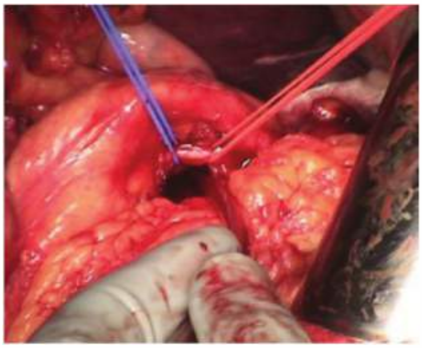

FIG 5 ● A plane is developed between the superior border of the pancreas and the splenic flexure at the point of transaction. Vessel loops are placed around the splenic vessels for retraction and vascular control.

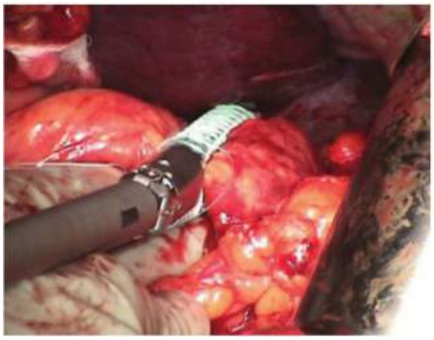

FIG 7 ● The pancreas is divided using a stapler with a vascular load.

DISTAL PANCREATECTOMY WITH SPLENECTOMY

- The exposure and mobilization of the pancreas proceed as described earlier.
- Divide the short gastric vessels.
- Mobilize the splenic flexure of the colon and retract it inferiorly.
- Divide the splenophrenic and splenocolic ligaments, and reflect the spleen and pancreatic body and tail up from the retroperitoneum.
- Once the point of transection of the pancreas has been determined, carefully isolate the splenic artery and vein and ligate them individually.
- Mobilize the splenic vessels along with the superior border of the pancreas.
- Divide the pancreas using a stapler with a vascular load. Multiple firings may be required. If there is bleeding from the staple line, place 2-0 sutures in a figure-of-eight pattern at the superior and inferior borders of the pancreas to secure the gastropancreatic arteries.
- The pancreas and spleen are then removed as specimen (**FIG 8**).
- Check the surgical bed for hemostasis. Omentum may be placed over the pancreatic stump. Placement of a closed suction drain is our preference.

FIG 8 ● The body and tail of the pancreas have been removed en bloc. The instrument points to the tumor.

LAPAROSCOPIC DISTAL PANCREATECTOMY

Positioning and Port Placement

- Laparoscopic distal pancreatectomy is a suitable approach for patients with localized disease confined to the pancreas.
- The patient is placed supine.
- A 5- to 12-mm port is placed infraumbilically.
- A diagnostic laparoscopy is performed and so is a laparoscopic ultrasound of the liver.
- Any suspicious lesions are biopsied and sent for frozen section analysis. If metastatic disease or invasion into surrounding organs is identified, conversion to an open operation should be considered.
- Additional trocars are as shown in the figure (**FIG 9**).
- The anterior wall of the stomach is elevated and the lesser sac is entered through the gastrocolic ligament using an energy device.

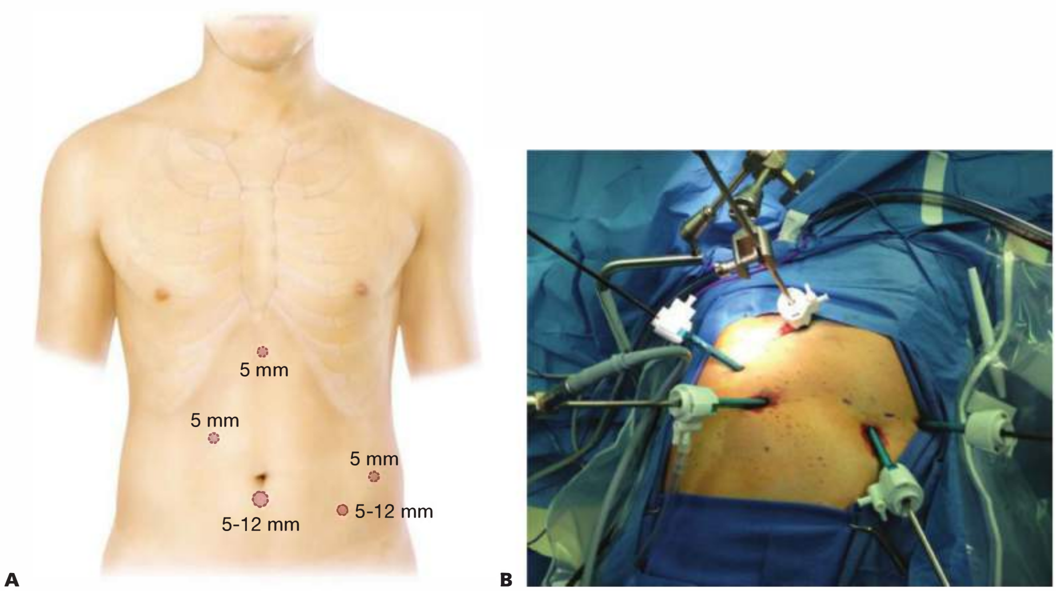

FIG 9 ● **A,B.** The position of the trocars for laparoscopic distal pancreatectomy is shown. A 5- to 12-mm trocar is placed at the umbilicus. A 5-mm trocar is placed subxiphoid for retraction. An optional assistant working port (5 mm) is placed in the right upper quadrant. Two working trocars, a 5- to 12-mm and another 5-mm, are placed in the left abdomen as shown. Trocar placement may be individualized for the patient.

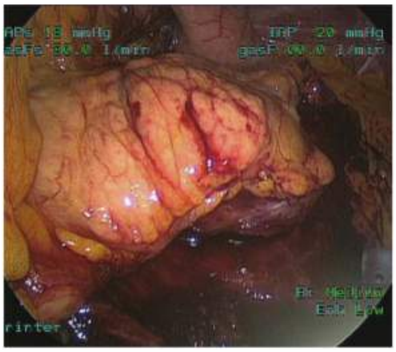

FIG 10 ● After entering the lesser sac through the gastrocolic ligament, the stomach is retracted superiorly and the transverse colon is mobilized inferiorly to expose the anterior surface of the pancreas.

FIG 12 ● When the specimen has been completely dissected free, it is elevated and placed in a plastic retrieval bag.

- The splenic flexure of the colon is mobilized inferiorly and the transverse mesocolon is dissected away from the inferior border of the pancreas, allowing visualization of the anterior surface of the pancreas and the splenic artery (**FIG 10**).
- Laparoscopic ultrasound is used to delineate the extent of the tumor and the proximal position for transecting the pancreas. In the medial to lateral technique, the splenic vessels are isolated and circumferentially dissected at the proposed transaction site.
- The splenic artery and splenic vein are individually divided using an endoscopic stapler with a 2- to 2.5-mm cartridge as determined by the vessel size. The splenic vein may need to be transected with the pancreatic parenchyma.
- The peritoneum on the inferior edge of the pancreas is incised and dorsal dissection of the pancreas is done to create a window for placement of the stapler.
- The pancreas is then divided with a linear stapler cutter with a vascular cartridge sized to the thickness of the pancreas (**FIG 11**). The pancreas and spleen are then mobilized in a retrograde fashion from left to right.
- The specimen is placed in a plastic retrieval bag and the umbilical port incision is extended to allow its removal (**FIG 12**).
- This incision is closed and the abdominal cavity is reinsufflated and irrigated and hemostasis confirmed.
- A closed suction drain is placed through the most lateral port in the left upper quadrant down to the pancreatic sump and fixed to the skin with sutures.
- The trocars are removed under direct vision and all port sites are closed with absorbable sutures.

Management of Hepatic Metastases

- Both curative intent resection and palliative intent resection are recommended for malignant glucagonoma (**FIG 13**). Other treatment options include hepatic artery occlusion or embolization, radiofrequency ablation, and cryoablation.
- Regional lymphadenectomy should be done because lymph node metastases are common.

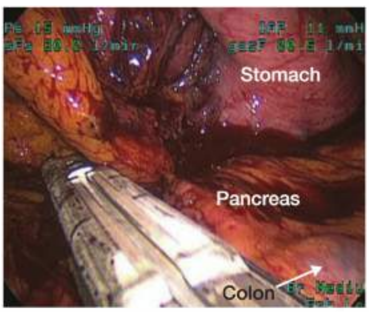

FIG 11 ● The pancreas is then divided with a linear stapler cutter with a vascular cartridge sized to the thickness of the pancreas. If the splenic vein could not be separated from the pancreas and individually ligated, it can be included with the pancreas transection.

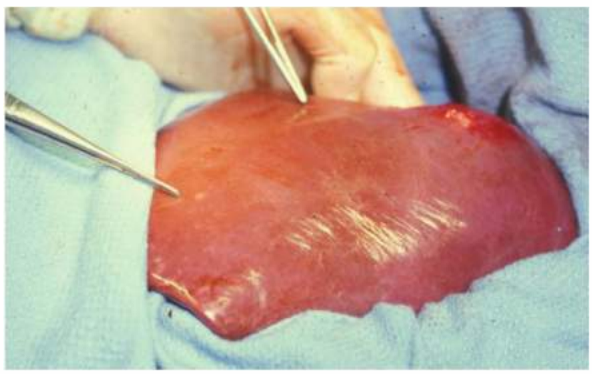

FIG 13 ● Glucagonoma metastases to the liver.

PEARLS AND PITFALLS

- MEN-1 patients with glucagonomas should have hyperparathyroidism addressed before surgical treatment for glucagonoma. Failure to do so may lead to uncontrolled hypercalcemia postoperatively.
- Although some tumors may be amenable to enucleation, formal pancreatic resection is preferred due to the high malignant potential of glucagonomas.
- Glucagonomas are associated with hypercoagulability and 30% of patients will have a deep vein thrombosis (DVT). Anticoagulation is recommended and serious consideration should be given to IVC filter placement preoperatively.
- Even if an R0 resection is not possible, patients may benefit tremendously from extensive debulking for palliation of symptoms.
- When performing a spleen-preserving distal pancreatectomy, care must be taken to avoid trauma to branches off the splenic vessels as you approach the tail of the pancreas. Remember, if extensive bleeding is encountered, the procedure can be changed to a distal pancreatectomy with splenectomy.
- Large tumors in the body of the pancreas may involve the splenic vein. In this situation, it may be helpful to divide the pancreatic neck early to better visualize the splenoportal confluence. If necessary, the splenic vein may be ligated flush with the superior mesenteric vein (SMV).
- The left adrenal may be located more superiorly than expected and may be injured by excessive medial retraction of the pancreas and spleen.
- Laparoscopic pancreatectomy without laparoscopic ultrasound is not recommended. Failure to use a laparoscopic ultrasound may result in a specimen that lacks part or all of the tumor.
- Pancreatic stump leak/fistula is one of the most common postoperative complications and may occur in up to 30% of patients. Consider octreotide for patients who do not respond to closed suction drainage or have high-output fistula. However, routine use of perioperative octreotide will not reduce the rate of fistula.

POSTOPERATIVE CARE

- Admission to the intensive care unit (ICU) is not mandatory and should be decided on a patient-by-patient basis. Management of pain, nasogastric intubation, and diet is similar to most major abdominal resections.
- Closed suction drain output should be tested for amylase and lipase before removal.
- Streptozocin is somewhat effective chemotherapy for both malignant tumors that are incompletely removed and their biochemical effects. Tumor regression is seen in 50% of patients and reduction in serum glucagon levels in over 60% of patients. Dacarbazine (DTIC) has also been used with some efficacy.
- Continued symptoms of excess glucagon after the operation should be treated with a somatostatin analog. However, routine perioperative use of octreotide therapy is not necessary and will not reduce the rate of pancreatic fistula.

OUTCOMES

- There is a paucity of outcomes data for glucagonoma. According to one study of MEN-1 patients, 10-year survival is approximately 50%.[7] In another, 5-year survival is approximately 50% following operative resection and adjuvant chemotherapy.[8]

COMPLICATIONS

- Patients may experience any postoperative complication associated with laparotomy such as superficial or deep wound infection, urinary tract infection, pneumonia, and cardiac dysrhythmia or ischemia.
- The risk of venous thromboembolism is elevated in patients with glucagonoma and the physician should remain vigilant about detection and treatment of thromboembolic events.
- Pancreatic leakage and fistula occur in up to 30% of patients undergoing distal pancreatectomy. This is managed by continued closed suction drainage in the stable patient. In a patient showing signs of infection, a CT scan should be obtained to look for abscess or inadequately controlled fistula. This can usually be treated with an additional percutaneous drain placed with image guidance. Consider octreotide therapy for persistent high-output fistulas. Operative drainage, endoscopic sphincterotomy, or stent placement may be necessary in patients not responding to percutaneous drainage.

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Part 6 Operative Techniques in Vascular Surgery

Chapter 1

Arch and Great Vessel Reconstruction with Debranching Techniques

W. Anthony Lee Alexander Kulik

DEFINITION

- An aortic arch aneurysm is defined as dilation of the aortic arch to greater than 5 cm in diameter. Rarely occurring in isolation, aneurysms of the aortic arch are often extensions of aneurysms present in the ascending or descending aorta. Causes of aortic arch aneurysms included atherosclerotic degeneration, cystic medial degeneration, aortic dissection, congenital aortopathy (i.e., bicuspid aortic valve), penetrating aortic ulcer, previous traumatic transection (chronic pseudoaneurysm), and previously repaired aortic coarctation (postsurgical pseudoaneurysm). Aortic arch aneurysms have traditionally been repaired with graft replacement of the aorta, with or without an elephant trunk, using cardiopulmonary bypass and deep hypothermic circulatory arrest. With the advent of thoracic endovascular aortic repair (TEVAR), debranching of the brachiocephalic vessels is a recently developed technique that takes advantage of the reduced surgical trauma associated with stent grafting.[1] Debranching functionally extends the proximal landing zone by repositioning the inflow of the brachiocephalic arteries toward the proximal ascending aorta. This facilitates endovascular stent graft repair of the aortic aneurysm by allowing stent coverage across the ostia of the arch vessels, producing a stable and fixed proximal landing zone in the ascending aorta.

PATIENT HISTORY AND PHYSICAL FINDINGS

- Aortic arch aneurysms are usually diagnosed as incidental findings noted on imaging studies, such as a chest x-ray or computed tomography (CT) scan, to evaluate other concurrent medical conditions.
- Most patients have no symptoms from their aneurysms. Symptoms, if they exist, may include chest or back pain from aneurysmal growth or those associated with compression of adjacent structures (i.e., trachea, esophagus). Hoarseness may develop from stretching of the left recurrent laryngeal nerve (Ortner's syndrome). Acute chest or back pain, with or without signs of shock, should raise the suspicion of impending aortic rupture and/or acute aortic dissection. Additional details regarding a patient's past medical history should be gathered, including a history of previous coronary intervention, previous cardiac surgery, known valvular heart disease, previous aneurysm surgery, or a family history of aortopathy.
- The physical examination is often unremarkable. However, attention should be directed to the presence of aortic valve insufficiency (diastolic murmur, widened pulse pressure), previous surgical incisions, and the presence of concomitant peripheral vascular disease.

IMAGING AND OTHER DIAGNOSTIC STUDIES

- Although a routine chest x-ray may be the first imaging test to note an aortic arch abnormality, further imaging is necessary, including a CT scan of the aorta (**FIG 1**) and an echocardiogram.
- An arterial phase CT angiogram should evaluate the entire length of the aorta, from the level of the skull base proximally to the femoral heads distally, to ensure visualization of the vertebral and iliofemoral arteries, respectively. The CT images are then processed using 3D imaging software for case planning and device selection. A magnetic resonance imaging (MRI) or a noncontrast CT scan will not suffice.
- A transthoracic (2D) echocardiogram should be performed to assess left and right ventricular function and to exclude the presence of significant valvular heart disease.
- Strong consideration should be given to evaluating the anatomy of the coronary arteries in the preoperative period. A CT coronary angiogram may be an option for younger patients or those with complex proximal aortic dissection. However, if there is a strong suspicion of coronary disease, then a preoperative conventional coronary angiogram should be performed, including those patients older than 40 years of age and those with a history of smoking.

SURGICAL MANAGEMENT

Preoperative Planning

- Indications for repair of an aortic arch aneurysm include large aneurysmal size (>5.5 cm), rapid growth (>0.5 cm per year), the presence of chest pain or back pain unexplained by other causes, and compression of adjacent organs (esophagus, trachea, or left main bronchus).[2]
- More aggressive size criteria may be applied for patients with Marfan's syndrome (repair at 4.5 to 5 cm). However, stent graft outcomes appear less favorable in patients with

FIG 1 ● Preoperative computed tomography (CT) angiogram of an aortic arch aneurysm.

connective tissue disease, and therefore, alternative surgical techniques (such as conventional aortic replacement surgery) should be considered.[2]

- The presence of significant concurrent cardiac disease may alter the surgical approach. Should significant coronary artery or valvular heart disease be identified in the preoperative period, consideration may be given to performing concomitant coronary artery bypass grafting (CABG) or valve replacement at the time of the aortic debranching procedure.
- During the second stage of the arch repair, stent graft deployment in the distal ascending aorta may require the placement of a guidewire across the aortic valve into the left ventricular cavity. The presence of a mechanical aortic prosthetic valve, through which a guidewire and the delivery system cannot safely be placed, may require a single-stage approach with deployment of the stent graft at the time of debranching (see endovascular second stage). A bioprosthetic valve in the aortic position may allow for careful transvalvular introduction of devices, with preference to bovine pericardial valves over porcine valves.
- Selection of the ideal treatment strategy for repair of an aortic arch aneurysm remains controversial and is dictated by surgical experience and local area expertise. Aortic arch debranching and stent graft completion is an appealing repair option that avoids a thoracotomy incision and may avert the use of cardiopulmonary bypass and circulatory arrest. These types of hybrid procedures may be performed either as single- or two-stage repairs. However, conventional open replacement of the entire aortic arch,[3,4] or replacement of the ascending aorta and proximal arch with the creation of an elephant trunk followed by stent graft completion,[1,5] should be considered as clinically indicated.
- Debranching of the aortic arch off the ascending aorta may not be applicable for a patient with an aortic arch aneurysm who has previously undergone cardiac surgery and who is too high-risk for consideration of redo sternotomy. In this case, an alternative option would include extra-anatomic debranching of the aortic arch (carotid–carotid, carotid–subclavian) followed by stent graft repair of the arch, with or without innominate artery chimney (snorkel) stenting.[6]
- The preoperative CT scan requires careful review before undertaking an aortic arch debranching operation. Arch branch anatomy and appropriate landing zones need to be identified proximal and distal to the arch aneurysm, with criteria similar to those that apply for stent graft repair of a descending thoracic aortic aneurysm. Anatomic variations of the aortic arch anatomy may require modification of the debranching procedure. These include a bovine aortic arch (common trunk of the innominate and left common carotid), arch origin of left vertebral artery, and an aberrant right subclavian artery.
- The ascending aorta is typically 6 to 7 cm in length from the sinotubular junction to the innominate artery. Placement of the proximal inflow anastomosis as low as possible on the ascending aorta (just distal to the sinotubular junction) will result in an optimal 3- to 4-cm proximal landing zone for the stent graft repair. The largest currently available thoracic stent grafts are 42 to 46 mm in diameter. To provide a safe and durable proximal landing zone and avoid a proximal type I endoleak, we recommend replacement of an ascending aorta that is extremely short or if its diameter is 36 mm or larger. Open replacement of the ascending aorta would be performed at the time of the arch debranching procedure, with implantation of an aortic graft 34 mm or smaller.
- The size of the iliofemoral arteries is worth noting on the preoperative CT study. The external iliac arteries need to be larger than 7 mm in diameter to provide adequate vascular access to deliver the stent graft devices during the second stage. An iliac artery conduit may be needed if the iliofemoral arteries are extremely small or in the presence of severe calcification and occlusive disease. Alternatively, a single-stage antegrade introduction of the stent graft from the ascending aorta may be performed (see endovascular second stage) to avoid access problems from a retrograde iliofemoral approach.
- The diameters of the brachiocephalic arteries are measured on the preoperative CT scan to determine the interposition graft sizes for the debranching procedure. Most frequently, the size of the graft chosen for the innominate artery branch is 10 to 14 mm, with 6- to 8-mm grafts usually used for the left carotid and left subclavian arteries.
- Cerebral oximetry monitoring may be helpful for the aortic debranching procedure to monitor brain perfusion before and after clamping of the brachiocephalic arteries. For the second-stage endovascular procedure, cerebrospinal fluid (CSF) drains are placed preoperatively to reduce the risk of spinal cord ischemia if a significant length of the descending thoracic aorta is to be covered.

Positioning

- For the arch debranching procedure, patients are positioned supine just as they are during standard cardiac surgical operations. Prepping is performed from the neck to the knees, with draping higher than usual to strategically provide access to the lower neck. The head may be turned slightly to the right to facilitate extension of the sternotomy incision proximally along the left sternocleidomastoid muscle.

AORTIC ARCH DEBRANCHING

- Although some advocate the use of a right thoracotomy incision or upper hemisternotomy, we prefer to expose the ascending aorta through a conventional sternotomy incision. This provides optimal visualization and control. The pericardium is incised and retracted.
- The ascending aorta is carefully mobilized to facilitate later placement of a proximally positioned side-biting clamp. The space between the left side of the aorta and the pulmonary artery is dissected, with small vessels cauterized or clipped and divided. The ascending aorta is mobilized proximally down to the level of the aortic root (sinotubular junction) to enable identification (and avoid injury) to the right coronary artery.
- The brachiocephalic arteries are circumferentially exposed. The innominate vein is mobilized and retracted

with an umbilical tape to facilitate exposure of the arch vessels (**FIG 2**). Uncommonly, the innominate vein requires ligation and division to aid in arch exposure. The left subclavian artery is often more posterior than expected, and exposure of this artery may be difficult. In these circumstances, the sternotomy incision may be extended superiorly and leftward along the sternocleidomastoid muscle. Alternatively, innominate and left carotid debranching may be combined with a left carotid-subclavian bypass/transposition procedure, through a standard supraclavicular approach, obviating the need to expose the left subclavian artery through the sternotomy.

- Although a preformed bifurcated or multilimb graft may be used, these occupy a large footprint and reduce the length available for the ascending aortic landing zone. Instead, we prefer to construct a Y-graft by sewing a beveled smaller Dacron graft end-to-side to larger Dacron graft (**FIG 3**). The graft sizes are selected based on the measured diameters from the preoperative CT scan. Typically, a 10- or 12-mm graft is used for the innominate artery, and a 6- or 8-mm graft is used for the left carotid artery.
- Heparin is administered to achieve an activated clotting time (ACT) of 200 seconds. The blood pressure is lowered to 90 mmHg systolic, and an aortic side-biting clamp is placed on the right anterolateral side (convexity) of the ascending aorta, as low as possible, with care not to compromise the right coronary artery.

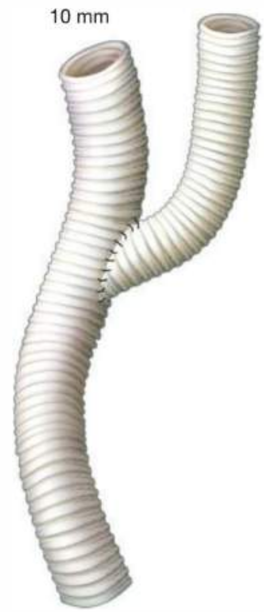

FIG 3 ● A Y-graft is constructed by sewing a beveled smaller Dacron graft (6 to 8 mm) end-to-side to larger Dacron graft (10 to 12 mm).

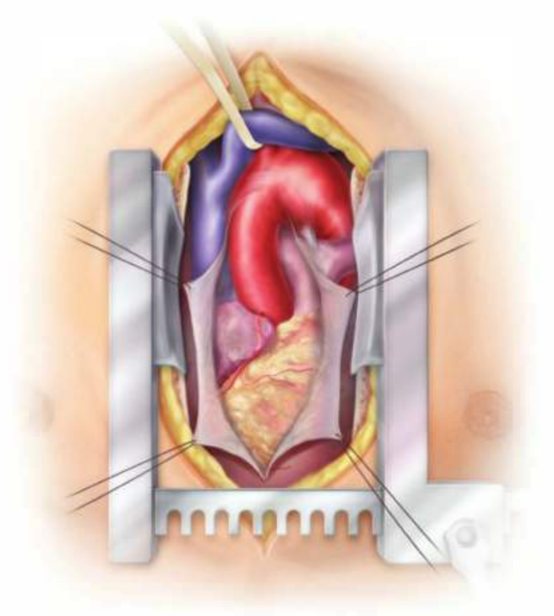

FIG 2 ● After sternotomy, the pericardium is incised and retracted. The ascending aorta is mobilized, and the brachiocephalic arteries are circumferentially exposed. The innominate vein is mobilized and retracted with an umbilical tape to facilitate exposure of the arch vessels.

A retraction suture in the right atrial appendage may be needed to facilitate proximal aortic exposure. Consideration may be given to performing this and subsequent steps in the operation with cardiopulmonary bypass to provide optimal hemodynamic control during clamp application and removal and to improve brain protection with systemic cooling in the range of 32°C to 34°C.

- The proximal end of the larger (10 or 12 mm) graft is cut to the appropriate length so the Y-graft easily reaches the arch vessels. The graft is beveled and sewn end-to-side to the ascending aorta with a running 3-0 or 4-0 polypropylene suture (**FIG 4**). BioGlue may be applied to further support the anastomosis. The aortic clamp is gently released. A large clip may be placed across the heel of the anastomosis. This will help visualize the origin of the debranching graft from the ascending aorta and precisely define the proximal landing zone without the need for contrast during the second-stage endovascular procedure.
- The innominate artery is transected, and the proximal end is oversewn with two layers of 4-0 polypropylene. The distal large end of the Y-graft is then tunneled underneath the innominate vein and sewn end-to-end to the innominate artery with running 5-0 polypropylene (**FIG 5**).
- Next, the left common carotid artery is transected, and the proximal end of the carotid artery is oversewn with 4-0 polypropylene. The distal smaller end of the Y-graft is tunneled underneath the innominate vein and sewn

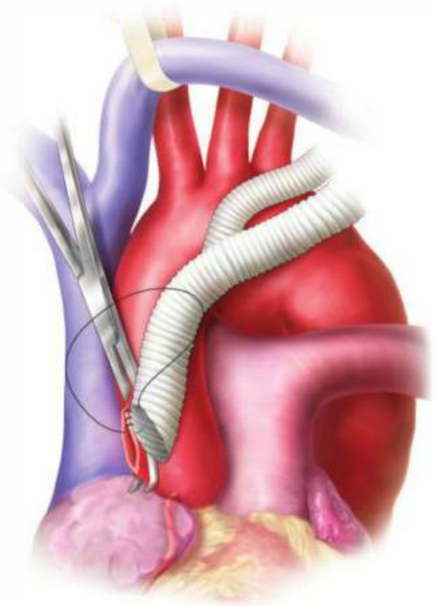

FIG 4 ● An aortic side-biting clamp is placed on the right anterolateral side (convexity) of the ascending aorta, as low as possible. The proximal end of the larger (10 or 12 mm) graft is beveled and sewn end-to-side to the ascending aorta with a running 3-0 or 4-0 polypropylene suture.

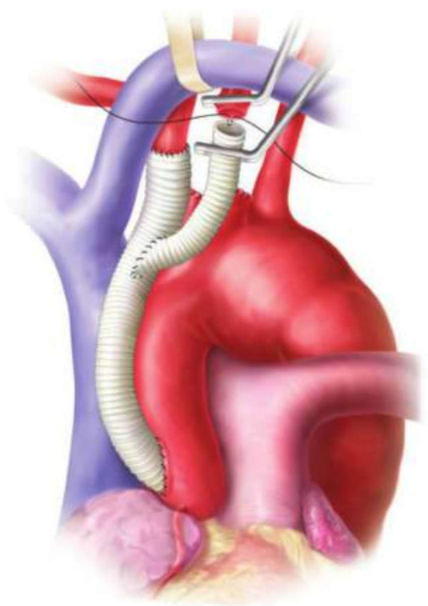

FIG 6 ● The left common carotid artery is transected, and the proximal end of the carotid artery is oversewn with 4-0 polypropylene. The distal smaller end of the Y-graft is tunneled underneath the innominate vein and sewn end-to-end to the carotid artery with running 5-0 polypropylene.

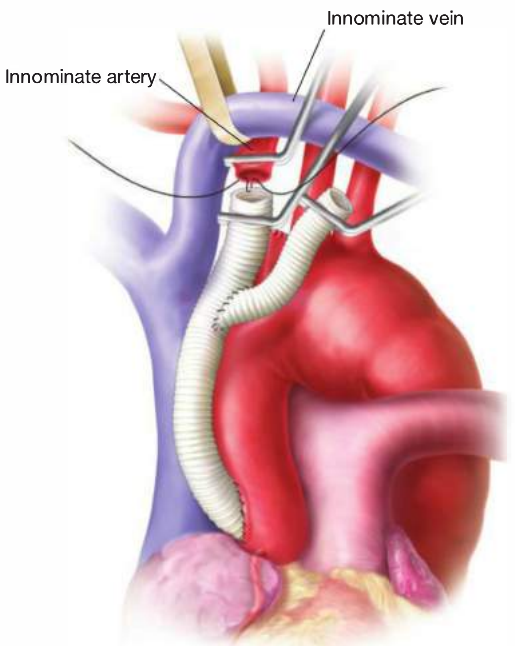

FIG 5 ● The innominate artery is transected, and the proximal end is oversewn 4-0 polypropylene. The distal large end of the Y-graft is then tunneled underneath the innominate vein and sewn end-to-end to the innominate artery with running 5-0 polypropylene.

end-to-end to the carotid artery with running 5-0 polypropylene (**FIG 6**).

- At this point, a decision needs to be made regarding the debranching strategy for the left subclavian artery. Indications for left subclavian revascularization are controversial. Routine versus selective strategies may be adopted.[7] If the left subclavian artery needs to be revascularized but cannot safely be exposed, a carotid–subclavian bypass can be performed as previously mentioned. If the subclavian artery can be exposed, the distal anastomosis is created first using a 6- or 8-mm Dacron graft anastomosed either end-to-end to the transected artery or end-to-side (functional end-to-end) followed by ligation of the proximal artery in continuity. A side-biting clamp is then placed along the carotid graft, and the subclavian graft is sutured end-to-side to the carotid graft with 5-0 polypropylene suture (**FIG 7**).
- Protamine is administered to reverse the heparin, and hemostasis is ensured. The grafts should lie tension free within the mediastinum. The pericardium may be partially closed over the grafts, with care to avoid compression of the graft branches. Chest tubes are positioned, and the sternum is closed routinely. After the sternum is closed, the blood pressure should be assessed in each arm and cerebral oximetry monitored to confirm adequate perfusion through the graft branches and the absence of graft compression.

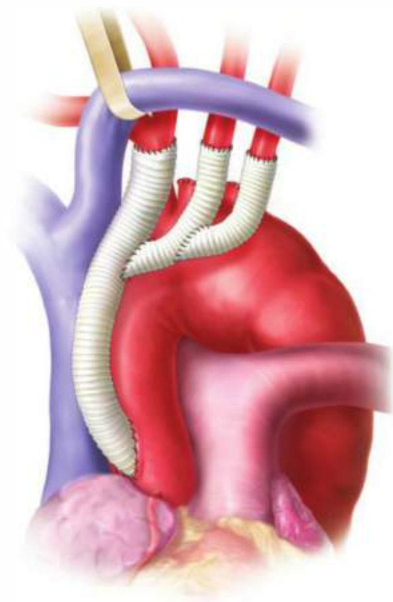

FIG 7 ● If the subclavian artery can be exposed, the distal anastomosis is created first using a 6- or 8-mm Dacron graft anastomosed end-to-end to the transected artery. The subclavian graft is then sutured end-to-side to the carotid graft with 5-0 polypropylene suture.

ENDOVASCULAR SECOND STAGE

- The endovascular second stage of the arch repair is conducted in a fairly similar manner to that of stent graft repair of a descending thoracic aortic aneurysm, as described in Part 6, Chapter 13 (Thoracic Endografting).
- The timing of the endovascular repair as a single versus staged approach remains controversial. We prefer to delay the second stage depending on the clinical scenario. It can range from a few days (same hospitalization) to several weeks (separate admission) to allow the patient to recover from the first procedure. This reduces the overall physiologic stress on the patient.
- Although we favor delivery of the stent graft in a retrograde manner from the iliofemoral arteries, in cases of a mechanical aortic valve or severe iliofemoral occlusive disease, single-stage antegrade deployment should be considered. The technical variations for these less common situations are beyond the scope of the present chapter.
- The site of insertion of the endovascular graft delivery system is decided based on the size and quality of the access vessels. In general, the grafts are delivered through the common femoral artery, whereas an iliac conduit may be required for very small or diseased iliofemoral arteries.
- The delivery guidewire is placed in the left ventricle during the endovascular procedure to provide sufficient proximal rail support for the endovascular graft.
- The proximal stent graft is deployed in the ascending aorta just distal to the origin of the debranching graft. During deployment, it is useful to lower the blood pressure using one of a variety of pharmacologic, ventricular pacing or atrial inflow occlusion techniques.[8]

PEARLS AND PITFALLS

Indications	■ The preoperative CT angiogram should be reviewed in detail to ensure the patient is a suitable candidate for aortic arch repair with debranching and stent grafting, including appropriate landing zones proximally and distally and adequate vascular access.
Proximal type I endoleak	■ To optimize the length of the proximal landing zone and prevent a type I endoleak, the debranching graft should be placed as low as possible on the ascending aorta. Preemptive replacement of the ascending aorta should be performed if it is extremely short or its diameter is $>$34 mm.
Mechanical aortic prosthesis	■ After aortic debranching, the endovascular graft delivery system may have to cross the aortic valve. Although transvalvular placement of a large sheath is relatively safe for native and bioprosthetic valves, it is contraindicated for a mechanical aortic valve. Antegrade stent graft deployment at the time of debranching should be considered in the presence of a mechanical prosthesis.
Injury to right coronary artery	■ Care should be taken when applying the side-biting clamp low on the ascending aorta to avoid occlusion or injury to the right coronary artery.

Ascending aortic dissection	■ The systolic blood pressure should be lowered to <90 mmHg when applying the side-biting clamp on the ascending aorta to prevent injury and dissection of an already fragile and diseased aorta.
Left subclavian artery	■ If the left subclavian artery is not easily accessible via the sternotomy incision (large rotated aortic arch aneurysm), then debranching of this artery can be performed via carotid–subclavian bypass.
Compression and kinking of debranching grafts	■ Ideally, the main debranching graft should lie along the right side of the ascending aorta to avoid compression by the sternum after chest closure. The graft branches should lie tension free, with care taken to avoid kinking at the time of pericardial and chest wall closure.

POSTOPERATIVE CARE

- Following the debranching procedure, patients are monitored in a cardiovascular surgical intensive care unit for 48 hours, with a focus on neurologic status, applying standard postoperative cardiac surgery protocols.
- Chest tubes are typically removed 2 days after the debranching operation.
- If a patient is recovering well after debranching without complication and has stable renal function, then the stent graft completion can be performed 3 to 5 days postoperatively. In the event of a major complication requiring extended recovery, the patient may be discharged to a rehabilitation center. The stent graft procedure can be delayed for a few weeks. However, up to 25% of patients may not return for their second stage.
- Following the second-stage stent graft procedure, the blood pressure is augmented with fluid and vasopressor support to achieve a target systolic blood pressure of 140 to 160 mmHg for 48 hours to optimize spinal cord perfusion.
- CSF drains are left open for 24 hours following stent grafting. Drainage is limited to less than 15 mL per hour or less than 350 mL per day to avoid the potential risk of subdural hemorrhage. In the absence of spinal cord injury, CSF drains are then clamped for 12 hours and subsequently removed.
- Follow-up CT angiograms of the aorta are performed at 1 and 6 months after the stent graft procedure, and then yearly thereafter.

OUTCOMES

- In the authors' experience of 37 aortic arch debranching procedures,[1] rates of spinal cord injury, stroke, and 30-day mortality were 0%, 10.8%, and 16.2%, respectively. The incidence of proximal type I endoleak was 3.7% at 1 and 12 months. Survival at 1 and 12 months was 86.5±5.6% and 71.6±8.5%, respectively. Freedom from undergoing any secondary surgical procedure after stent graft completion at 1 and 12 months was 71.0±7.8% and 52.8±10%, respectively.
- A recent systematic review of aortic arch debranching summarized the clinical outcomes of 27 published studies including a total of 642 patients.[9] Reporting results similar to those of the authors' experience[1]; the review noted rates of spinal cord injury, stroke, and 30-day mortality of 4.3%, 7.3%, and 11.9%, respectively. In this review, a trend existed between higher surgical volume and lower neurologic complications, with stroke rates of 9.6% and 6.5% in low-volume and high-volume case series, respectively.[9]
- In another review article that included 18 studies and data from 195 patients, the technical success rate following aortic arch debranching and stent graft repair was reported at 86%. The most common reason for technical failure was endoleak (9%).[10]

COMPLICATIONS

- Reopening for bleeding
- Stroke or transient ischemic attack (TIA)
- Spinal cord ischemic injury
- Ascending aortic dissection
- Endoleak
- Iliofemoral artery injury
- Mortality

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Chapter 2

Extrathoracic Revascularization (Carotid–Carotid, Carotid–Subclavian Bypass and Transposition)

Edward Y. Woo Scott M. Damrauer

DEFINITION

- Extrathoracic revascularization, including carotid–subclavian and carotid–carotid bypass, involves the bypass of the proximal great vessels outside of the chest. Initially described for treatment of cerebrovascular and upper extremity occlusive disease, these procedures are commonly now employed to create a proximal seal zone for endovascular treatment of thoracic aortic disease by "debranching" the aortic arch.
- Carotid–subclavian bypass is accomplished by inserting a graft conduit between the mid-common carotid artery to the ipsilateral subclavian artery.
- Subclavian artery transposition is a potential alternative to carotid–subclavian bypass requiring division of the subclavian artery proximal to the vertebral artery and transposing it to the ipsilateral common carotid artery. It is an efficient way to revascularize the subclavian artery without the use of prosthetic conduit.[1]
- Carotid–carotid bypass provides flow from one common carotid artery to the contralateral common carotid artery.
- When carotid–carotid bypass is performed in a right-to-left manner and in conjunction with carotid–subclavian bypass, the blood flow to the left brain can be preserved while allowing for extension of the proximal thoracic endovascular aortic repair (TEVAR) seal zone to cover the left common carotid artery.

PATIENT HISTORY AND PHYSICAL FINDINGS

- The history should focus on neurologic symptoms that may indicate the presence of symptomatic cerebrovascular disease. Previous head and neck or carotid surgery should be noted, as well as a history of head, neck, or upper chest region external beam radiation therapy, as these may significantly increase the complexity of the procedure.
- The directed physical exam should be focused on detection of underlying vascular disease that may complicate planned intervention. Bilateral upper extremity blood pressures should be obtained; a difference of greater than 10 mmHg indicates the potential presence of preexisting occlusive disease. Likewise, the presence of carotid bruits, delayed carotid upstrokes, or abnormal upper extremity pulses suggests arterial occlusive disease that should be delineated prior to extrathoracic reconstruction or bypass of the great vessels.
- Special attention should be directed toward the cranial nerves and voice, especially in patients with prior cervical surgical procedures. Indirect laryngoscopy should be performed preoperatively in patients with hoarseness or in whom a preexisting vocal cord or cranial nerve deficit has been noted.
- Neck mobility and the presence of cervical spinal disease should be assessed, as neck extension and rotation is essential for adequate operative exposure. Patients with relative neck immobility may be poorly suited for these procedures.

IMAGING AND OTHER DIAGNOSTIC STUDIES

- Carotid duplex scanning should be used to identify patients with carotid artery stenosis prior to planned bypass procedures. Failure to identify and address stenoses at the carotid bifurcation may lead to postoperative steal phenomenon and neurologic sequelae. Manipulation of the diseased carotid artery may also increase the risk of periprocedural stroke. In these circumstances, concomitant or staged carotid intervention may be warranted.
- Computed tomographic (CT) angiography of the aortic arch and proximal carotid arteries provides the anatomic detail necessary to safely perform carotid–subclavian bypass, subclavian artery transposition, or carotid–carotid bypass. This study is complementary to duplex scanning, as it provides anatomic rather than hemodynamic assessment and images vessels equally well inside and outside the chest. CT scanning also visualizes the course of the subclavian artery in relationship to the clavicle, as its course may also be distorted by a large arch aneurysm.

SURGICAL MANAGEMENT

Preoperative Planning

- Neuromonitoring is a useful adjunct to ensure adequacy of cerebral perfusion from the contralateral cerebral circulation when the ipsilateral common carotid artery is clamped. Numerous modalities exist for neuromonitoring, including electroencephalography (EEG), transcranial Doppler, near-infrared spectroscopy, and stump pressure measurement. An indwelling carotid shunt may be placed to improve ipsilateral blood flow when monitoring indicates cerebral perfusion is inadequate. This problem occurs infrequently, as only the common carotid is occluded, but preparations should be made for shunting procedures when indicated. Alternatively, as with carotid endarterectomy (CEA), in the absence of neuromonitoring, shunts may be placed prophylactically to preserve carotid flow in all cases.
- Invasive continuous arterial pressure monitoring is routinely employed, with line placement dictated by the laterality of the procedure. Keeping in mind the potential need to occlude the subclavian artery for the reconstruction, the arterial line should be placed in the contralateral limb or in a femoral artery.

Positioning

- The patient is positioned supine with the head rotated away from the operative side. A pneumatic pillow is placed under the shoulders to allow for neck extension. Careful attention must be paid to achieve maximum neck extension while still supporting the occiput. The bed is placed in a semi-Fowler's position to reduce venous pressure and minimize bleeding.
- For carotid–carotid bypass, the head is positioned midline to facilitate bilateral dissection.

CAROTID–SUBCLAVIAN BYPASS

Exposure of the Subclavian Artery

- The incision is extended from the lateral aspect of the clavicular head of the sternocleidomastoid (SCM) muscle laterally across the supraclavicular fossa. This is further developed through the subcutaneous tissue and platysma with electrocautery. If the external jugular vein is encountered, it should be ligated and divided.
- Sufficient clavicular head of the SCM is divided to allow for adequate medial exposure. Up to one-half of the sternal head of the SCM can also be divided if also needed, but this is rarely necessary. The scalene fat pad is then visualized and divided. It is preferable to divide this near its inferior border so that most of the fat pad can be preserved and reclosed to cover the reconstruction. Care must be taken to identify and preserve the phrenic nerve as it courses over the anterior scalene muscle deep to the fat pad. The thoracic duct is easily identified. If it is injured or in the way, it should be ligated to prevent significant morbidity from a postoperative lymphatic leak.
- Once the fat pad has been mobilized, the anterior scalene muscle is divided to reveal the underlying subclavian artery (**FIG 1**). It is best to divide the muscle slowly and in layers to prevent injury to the underlying vessel. The subclavian artery is dissected circumferentially and controlled with vessel loops. Care must be taken when manipulating this vessel, as the subclavian artery is significantly more fragile and prone to injury than lower extremity arteries of comparable diameter (e.g., femoral or popliteal). Depending on the method of reconstruction and location of the planned anastomosis, the thyrocervical trunk, inferior mammary, and vertebral arteries may need to be controlled separately (**FIG 2**).

FIG 2 ● The subclavian artery and its branches are circumferentially dissected and controlled with vessel loops.

Exposure of Carotid Artery

- In the medial aspect of the wound, the lateral border of the internal jugular vein is identified and sharply defined. The vein is retracted posteriorly and the carotid sheath is entered from the lateral posterior margin. Care must be taken to identify the vagus nerve early, as its usual posterior position places it immediately in the field of dissection as the sheath is opened from this approach.

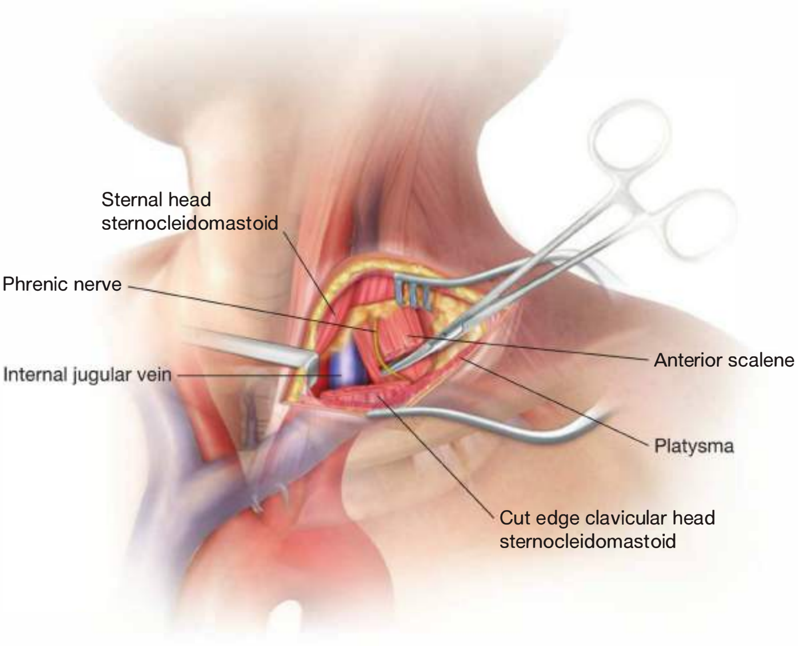

FIG 1 ● The skin incision is placed in the supraclavicular fossa over the clavicular head of the SCM muscle. The subclavian artery lies directly beneath the anterior scalene muscle. Care must be taken to identify and preserve the phrenic nerve when dividing the anterior scalene muscle.

FIG 3 ● The carotid artery is dissected circumferentially after entering the carotid sheath from its posterior lateral margin. The internal jugular vein can be seen retracted out of the way. The vagus nerve is running parallel to the artery between it and the nerve.

- The common carotid artery is dissected circumferentially (**FIG 3**). Only 5 cm of artery needs to be isolated in order to obtain control and perform the anastomosis. The dissection should stay proximal to the carotid bulb, which minimizes risk of cerebral embolization and injury to more proximal nerves.

Bypass

- Either Dacron or polytetrafluoroethylene (PTFE) can be used as conduits for extrathoracic bypass with no difference in outcomes.[2] Autogenous vein grafts should be avoided, however, as their long-term patency is inferior to prosthetic in this location.[3] We favor Dacron given the size ranges available and the relative resistance of the graft to kinking over the short distance of the reconstruction.
- Prior to arterial clamping, systemic anticoagulation is achieved with intravenous heparin administration. The activated clotting time (ACT) should be monitored and additional heparin administered throughout the procedure to maintain adequate anticoagulation.
- The subclavian anastomosis is performed first. Arterial control (vessel loops or clamps) is obtained and the vessel is opened with a longitudinal arteriotomy. The anastomosis should be fashioned in the position most favorable to the planned graft. The graft is beveled and trimmed so that the graft lies at an approximately 60-degree angle to the artery. A running Prolene suture is used to perform the anastomosis with completion of the back wall first. Once the anastomosis is complete, the graft is clamped and flow restored to the arm by unclamping the subclavian artery. It is useful to flush through the graft to remove any debris prior to opening to the arm. The graft should also be flushed with heparinized saline and clamped near the anastomosis to avoid any thrombosis of the stagnant blood column within the graft. If repairs are needed, control is restored and pledgeted sutures are used to avoid injury to the fragile artery.
- The graft is tailored to the appropriate length to prevent redundancy and kinking, and beveled so that the heel of the anastomosis will lie proximally on the carotid artery. As the common carotid artery is clamped, special attention must be directed to neuromonitoring; significantly diminished cerebral perfusion, although very uncommon, mandates shunt placement at this stage of the procedure. A longitudinal arteriotomy is performed and the proximal anastomosis completed with running Prolene suture, again starting with the back wall (**FIGS 4 and 5**).

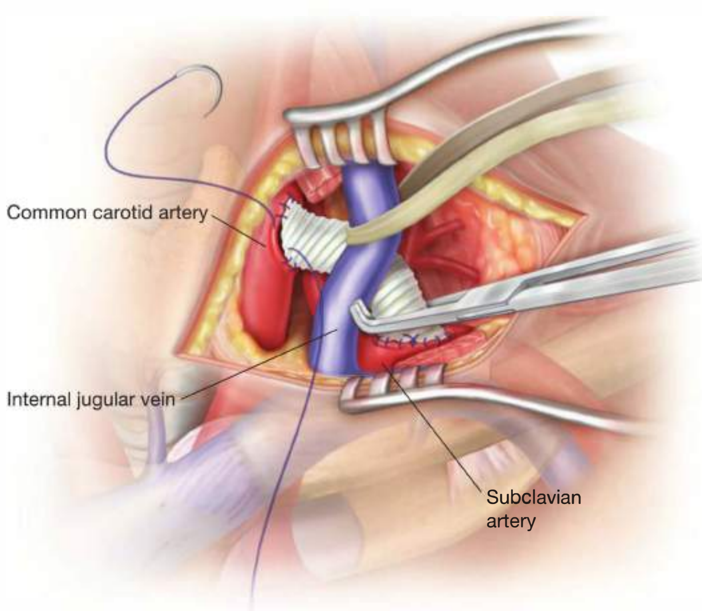

FIG 4 ● After completing the distal anastomosis, the graft and the subclavian artery are all controlled and the proximal anastomosis is performed in a running fashion. The graft can be tunneled superficial or deep to the internal jugular vein depending on patient anatomy and surgeon preference.

FIG 5 ● The completed bypass graft can course anterior or posterior to the internal jugular vein. The phrenic nerve is seen in the lower field.

- The final sequence of clamp removal is important to prevent embolism to the brain. Proximal subclavian artery control is again obtained, and the clamp is removed from the graft. The proximal carotid clamp is then removed to allow "flushing" down the arm rather than to the brain. After a few cardiac cycles, the distal carotid clamp is also removed. The proximal subclavian artery is then released as well.
- When performed in anticipation of thoracic aortic stent grafting, the subclavian artery must be ligated proximal to the origin of the vertebral artery. This can involve dissection deep into the mediastinum and carries an inherent risk of catastrophic bleeding. Alternatively, the proximal subclavian artery can be controlled by placement of an intraarterial occlusion device (e.g., Amplatzer), either during the carotid–subclavian bypass or at the time of subsequent stent graft placement via a left brachial approach.[4]

Closure

- If a pneumatic pillow was used to provide exposure, it is deflated prior to wound closure in order to reduce neck extension and assist in allowing the wound to be closed without tension.
- A closed suction drain is left in the deep wound and brought out through a separate stab incision.
- In order to provide coverage for the graft, the scalene fat pad is returned to its anatomic location and sutured in place. The SCM is reapproximated with running absorbable sutures.
- The platysma and subcutaneous tissues are closed in separate layers in a running fashion and the skin is reapproximated with a running dermal suture.

SUBCLAVIAN ARTERY TRANSPOSITION

Exposure

- The subclavian artery is exposed, as described in the previous section, for carotid–subclavian bypass. The dissection must be carried proximal to the vertebral artery and enough artery must be exposed proximally to allow sufficient length for the anastomosis as well as control the proximal stump. This can often be difficult as an aortic aneurysm can occupy a significant portion of the mediastinum limiting vessel manipulation.
- The carotid artery is exposed in the same manner as described in the previous section.

Division of the Subclavian Artery

- Systemic heparin is administered, and maximum arterial length is obtained by advancing a Cooley clamp as deeply as possible into the mediastinum along the subclavian artery. A distal atraumatic clamp is then applied, typically in the midsubclavian artery, with the more proximal branches individually controlled with vessel loops. There must be adequate distance between the proximal clamp and the vertebral artery to allow for proximal control, transposition, and anastomosis. Prior to transection, pledgeted 5-0 Prolene stay sutures are placed on each side of the proximal artery to ensure that if clamp control is lost for any reason, the open artery does not retract into the mediastinum (FIG 6).
- The proximal subclavian artery is oversewn by extending the stay sutures across the stump. Hemostasis is confirmed by slowly releasing clamp control while maintaining traction on the stay sutures. Only once hemostasis is rigorously ensured are the sutures divided and the proximal subclavian artery allowed to retract into the mediastinum.

Carotid–Subclavian Anastomosis

- The subclavian artery, having been freed circumferentially, is then mobilized toward the carotid artery. It may be tunneled anterior or posterior to the internal jugular vein depending on the length of the artery and patient-specific anatomy. The carotid artery is then clamped proximally and distally and the anastomosis performed in the standard running fashion. Prior control of the subclavian artery is maintained (FIG 7). As the anastomosis is completed, the unclamping sequence should be repeated as described in the preceding section to prevent inadvertent air or particulate embolization to the brain.

Closure

- As described in the section on carotid–subclavian bypass, the wound is closed in multiple layers over a closed suction drain placed through a separate stab incision.

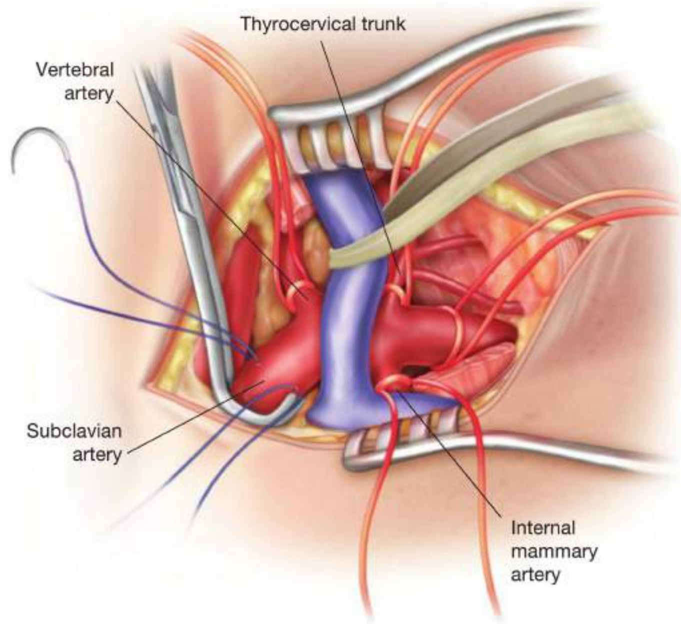

FIG 6 ● The subclavian artery and its branches are controlled individually with vessel loops and clamps. A Cooley clamp is used proximally on the subclavian artery. Stay sutures of 5-0 Prolene are placed in both ends of the subclavian artery proximal to the transection line.

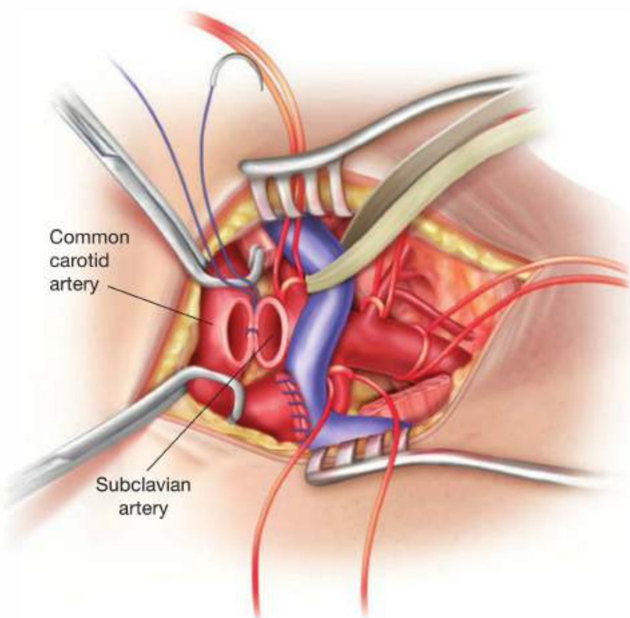

FIG 7 ● The subclavian artery is mobilized so that it may reach to the carotid artery and the end-to-side anastomosis is performed in the standard running fashion, starting along the back wall. The thyrocervical trunk may be divided if necessary to facilitate mobilization.

CAROTID–CAROTID BYPASS

Exposure of the Bilateral Carotid Arteries

- Bilateral incisions are made over the anterior border of the SCM at the base of the neck. The subcutaneous tissues and platysma are divided and the anterior border of the SCM is identified.
- The SCM is mobilized laterally by carrying the dissection down toward the internal jugular vein; this exposes the carotid sheath. Any bridging veins encountered can be divided; however, the entire dissection should be below the level of the facial vein, as this marks the carotid bifurcation. For this procedure, there is no need to risk injury to adjacent structures by

exposing the carotid bifurcation. To obtain sufficient proximal exposure, the omohyoid muscle may need to be divided bilaterally.

- The carotid sheath is entered sharply on its anterior surface. The vagus nerve must be identified within the carotid sheath and protected as the common carotid artery is exposed and controlled.

Graft Tunneling and Anastomosis

- Once the bilateral common carotid arteries are sufficiently exposed and controlled, the appropriate graft tunnel can be created. Tunneling is achieved via blunt finger dissection from both sides of the neck. The graft may be tunneled either between the trachea and esophagus or behind the esophagus, depending on patient habitus and surgeon preference (**FIG 8**). Care must obviously be taken to avoid injuries to these critical structures. Placement of an orogastric or nasogastric tube prior to creation of the dissection plane can be helpful for identifying the esophagus.
- Once the tunnel has been developed, the graft is passed and patient systemically anticoagulated with intravenous heparin administration.
- The anastomoses are performed in the standard running fashion; either one may be performed first. Careful attention must be paid to neuromonitoring as the carotid artery is clamped.
- Once the first anastomosis is complete, the graft is clamped and carotid artery flow restored on that side. Prior to removing the distal carotid artery clamp, the distal artery can be back-bled and the proximal artery flushed out the open graft. As with the subclavian artery, the graft should be flushed with heparinized saline and clamped close to the anastomosis to avoid a long stagnant column of blood within the prosthetic graft.
- The contralateral anastomosis is then performed in the same fashion (**FIG 9**). The graft should be flushed with heparinized saline and the graft, proximal carotid artery, and distal carotid artery should be vigorously flushed prior to completion.

Closure

- Hemostasis is obtained. The neck wounds are closed in layers, first taking care to reapproximate the SCM in its anatomic position with interrupted absorbable sutures.
- A closed suction drain is left in each wound.
- The platysma and subcutaneous tissues are closed with running absorbable sutures and the skin reapproximated with a running deep dermal suture.

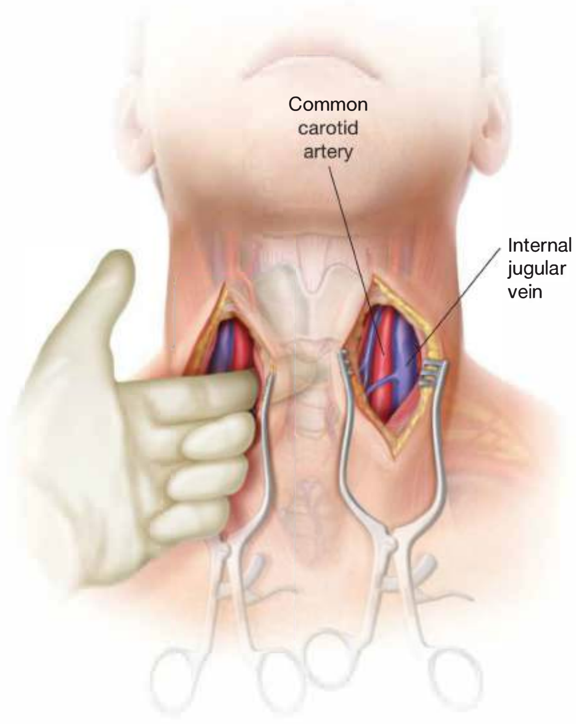

FIG 8 ● After isolating both common carotid arteries, a retropharyngeal tunnel is fashioned using blunt finger dissection. The placement of a nasogastric or orogastric tube allows for easy identification and protection of the esophagus.

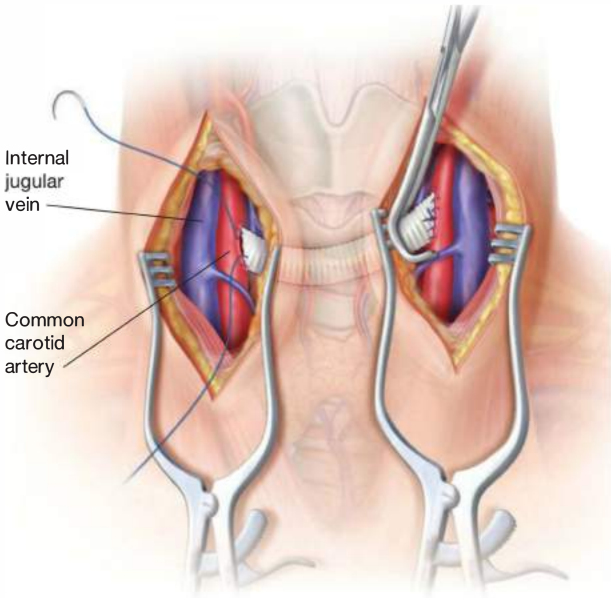

FIG 9 ● The distal anastomosis is performed in the standard running fashion starting with the back wall. Prior to completing the anastomosis, the carotid arteries and graft should be back-bled and flushed with heparinized saline.

PEARLS AND PITFALLS

Positioning	■ When inflating the pneumatic pillow, care must be taken to ensure that the occiput is adequately supported. Failure to adequately support the head may result in cervical spine and neurologic injuries.
Thoracic duct	■ Great care must be taken to avoid injuring the thoracic duct when exposing the subclavian artery. All lymphatic tissue encountered should be ligated before being divided as the ensuing lymphatic leak can be quite troublesome for the patient and the surgeon.
Subclavian artery control	■ The subclavian artery can be controlled either with vessel loops or with atraumatic vascular clamps, depending on which helps to better deliver the artery into the wound without undue tension.
Subclavian artery anastomosis	■ The subclavian artery is exceedingly friable and should be handled carefully. Given the exposure, it may be easier to parachute the anastomosis rather than fix the suture line at the heel of the anastomosis.
Positioning vis-à-vis the internal jugular vein	■ Depending on the habitus of the individual patient, the graft may lie better tunneled either above or below the internal jugular vein. It is prudent to explore both options prior to creating and completing the carotid anastomosis.
Proximal subclavian control during transposition	■ The use of stay sutures on the proximal subclavian artery in subclavian artery transposition is crucial. Once the stay suture on the proximal end of the artery is released, the artery retracts deep into the mediastinum and is not retrievable. Uncontrolled bleeding may be disastrous and lead to fatal complications. As such, the proximal oversewed subclavian artery must be hemostatic prior to release of the stay sutures. Stay suture safety is ensured by placement of pledgeted sutures at either end of the subclavian closure.
Common carotid artery exposure	■ It is not necessary and not advisable to expose or manipulate the carotid bulb or bifurcation in performing any of these reconstructions unless a concomitant CEA is necessary or the bifurcation is situated low in the neck. These procedures are performed on the common carotid artery, and exposing the bifurcation only increases the risk of cranial nerve injury and stroke.
Closure	■ The pneumatic pillow should be deflated prior to closure to assist in bringing the tissue together without tension.

POSTOPERATIVE CARE

- Careful attention should be paid to both systolic and mean arterial blood pressure in the postoperative period. Invasive arterial monitoring is usually maintained for the first 24 hours. When carotid–subclavian bypass or subclavian artery transposition is performed, blood pressure should be monitored in the contralateral arm.
- Neurologic status and distal pulses should be followed closely in the postoperative period. Any pulse changes need to be rigorously investigated as they may indicate the presence of either graft occlusion or distal embolization.
- When carotid–subclavian bypass, where the proximal subclavian artery is not ligated, is performed as a debranching procedure prior to thoracic aortic stent grafting, the timing of the endovascular procedure is important. In these patients who tend not to have concomitant occlusive disease, there is competitive flow via the native circulation, putting the newly placed graft at risk of thrombosis. In the absence of complications or other mitigating circumstances, the endovascular aortic procedure should be performed within 3 to 5 days of the debranching bypass.
- Patients should be placed on aspirin therapy and followed at regular intervals with duplex ultrasonography.

OUTCOMES

- Recent review of the American College of Surgeons National Surgical Quality Improvement Program (ACS-NSQIP) database from 2005 to 2010 demonstrates that extrathoracic revascularization carries a 3.5% risk of stroke and 3.3% risk of death in the immediate perioperative period.[5] Over this time period, 918 procedures were performed, with 10% of them as part of a staged approach to thoracic aortic stent grafting.
- Carotid–subclavian bypass has excellent durability. In a series of 284 consecutive patients, Takach and colleagues[2] reported 5-, 10-, and 15-year primary patency rates of 94%, 88%, and 86%, respectively. These results have subsequently been replicated by other large, multiple-decade series.[6] Subclavian artery transposition has similarly outstanding long-term patency, with rates as high as 99% reported at 5 years.[6,7]
- Symptom-free survival following revascularization is likewise excellent, with long-term results approaching 88% to 99% at 5 years.[6,7]

COMPLICATIONS

- The thoracic duct lies at the medial aspect of the field of dissection when dissecting in the supraclavicular fossa. This can be easily injured and remain undetected during the course of the operation. Continued or milky drainage is a clear sign of duct injury. The oral administration of cream can be used to promote chyle flow, and if a leak is present, will promptly increase drain output. When this occurs, the closed suction drain should be left in place, the patient kept fasting, and parenteral nutrition instituted. With conservative management, some of these injuries may close without further intervention. The complete management of this complication is beyond the scope of this text; however, it should be mentioned that reexploration of the wound in the early period is relatively straightforward and may represent the best way to resolve the problem. Late reexploration can be fraught with difficulty finding the leak as the tissue becomes fixed. A muscle flap may then be needed to close the space. The main concern with a persistent leak is the potential for graft infection. Unfortunately, early wound reexploration significantly increases the risk of prosthetic graft infection as well.
- The vagus, phrenic, and recurrent laryngeal nerves, as well as the brachial plexus, can all be injured as a result of carotid and subclavian artery exposure. Most injuries are due to traction rather than transection, and conservative therapy will generally resolve symptoms over the course of months to a year. In the case of a staged bilateral subclavian revascularization, it is important to ensure that any vagus or phrenic nerve injury has resolved prior to contralateral intervention, as bilateral injuries can lead to tracheal obstruction and acute respiratory failure.
- Although uncommon, significant bleeding from the wound should mandate reexploration. More commonly, minor wound hematomas may develop that can be observed. Judgment regarding the need for reexploration of a neck hematoma is similar to that required during any other neck procedure.
- Infection of the wound can be devastating if prosthetic is involved. Local cellulitis should be treated aggressively with early institution of antibiotics in order to prevent deeper infection. Upon removal of the drain, it is important that the drain site does not continue to leak, as continued leakage may act as an entry point for bacterial contamination. Simple suture closure should resolve this. Prosthetic graft infection necessitates graft removal, which is extremely difficult and beyond the scope of this chapter.
- Although uncommon, stroke is a complication of any carotid procedure. Taking the precautions outlined previously in this chapter should minimize these risks.

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Chapter 3

Carotid Surgery: Interposition/Endarterectomy (Including Eversion)/Ligation

Vinit N. Varu Wei Zhou

DEFINITION

- Stroke is the leading cause of disability in the United States and Western Europe and the third leading cause of death behind coronary artery disease and cancer.
- Pivotal studies have shown the efficacy of carotid endarterectomy (CEA) in stroke prevention in both symptomatic and asymptomatic patients with internal carotid artery (ICA) stenosis versus medical therapy alone.[1,2]
- CEA is defined as the surgical excision of atherosclerotic lesions of the intima and tunica media of the carotid artery.
- Occasionally, ICA ligation and/or interposition bypass may be indicated for stroke prevention.

PATIENT HISTORY AND PHYSICAL FINDINGS

- Patients may be entirely asymptomatic and still benefit from carotid intervention to prevent long-term stroke. In the United States, most CEA procedures are performed on asymptomatic patients. Symptoms of cerebroembolic disease originating from the carotid bifurcation, when present, may include dysarthria, dysphasia, aphasia, hemiparesis, or hemisensory deficit or amaurosis fugax. Symptoms that resolve within 24 hours are defined as transient ischemic attacks (TIAs) regardless of severity; symptoms that persist past the first day constitute a stroke.
- For patients at risk for cerebroembolic disease, a thorough vascular history is obtained including modifiable risk factors such as smoking, hyperlipidemia, hypertension, and diabetes management. Prior to surgery, single-agent antiplatelet therapy is initiated and continued indefinitely following intervention. Blood pressure control at or below 140 mmHg systolic and 90 mmHg diastolic is the single most important medical intervention to reduce stroke risk.[3] Sufficient β-blockade to stabilize resting heart rate at 60 bpm is also instituted prior to surgery to limit perioperative myocardial oxygen demand unless contraindicated.[4]
- Cervical auscultation is performed in both the supraclavicular and mandibular regions. Bruits appreciated at the mandibular angle usually indicate ICA or bifurcation disease. More proximal bruits may indicate common carotid artery (CCA) disease or radiating heart sounds.
- A full neurologic assessment including mental status, speech, facial symmetry, and extremity strength must be obtained and documented prior to surgery.

IMAGING AND OTHER DIAGNOSTIC STUDIES

- All patients exhibiting symptoms of carotid territory ischemia need appropriate vascular imaging studies. Screening is not recommended to detect asymptomatic disease in the general population; patients with appropriate risk factors, or those with a bruit on physical exam should be evaluated when clinical circumstances warrant.
- Carotid duplex ultrasound provides a reliable and accurate noninvasive tool to identify predicted stenosis and is the initial diagnostic study of choice. Peak systolic velocity (PSV) higher than 125 cm per second predicts angiographic stenosis more than 50% and higher than 230 cm per second predicts more than 70% stenosis. However, a combination of PSV, end diastolic velocity, and the PSV ratio of ICA to CCA is more accurate in estimating significant carotid stenosis. In general, end diastolic velocity higher than100 cm per second correlates to more than 80% carotid stenosis.
- When duplex imaging is not definitive, as is the case in the setting of extensive carotid bifurcation calcification, additional cross-sectional imaging (computed tomography angiography [CTA] or magnetic resonance angiography [MRA]) may be necessary to quantify the degree of stenosis. When accurate velocity information is obtainable, duplex imaging provides the most accurate and physiologically relevant estimates of percent diameter reduction.

SURGICAL MANAGEMENT

Indications

Endarterectomy

- The Society for Vascular Surgery recommends that neurologically symptomatic patients with greater than 50% stenosis or asymptomatic patients with greater than 60% stenosis should be offered CEA to reduce risk of recurrent or initial stroke, respectively. Endarterectomy is appropriate for patients with at least a 3- to 5-year life expectancy with perioperative stroke/death rates less than 3%. In all other circumstances, optimal medical therapy is preferred.[5]
- Surgical endarterectomy is the procedure of choice for good-risk surgical patients with normal cervical anatomy. For selected high-risk patients, such as those with tracheal stoma, previously radiated neck, prior cranial nerve injury, or lesions proximal to the clavicle or distal to C2 vertebral body, transcatheter angioplasty and stenting is generally the preferred approach.[5] Indications and technical guidelines for carotid angioplasty and stenting procedures are discussed in Part 6, Chapter 4.

Carotid Artery Interposition Bypass

- Reconstruction for extensive bifurcation disease, injury to the bifurcation during endarterectomy, or aggressive restenosis following previous intervention (endarterectomy or stent placement) is best accomplished by carotid resection and interposition grafting. Other indications include the following:

- Significant diffuse CCA and ICA disease
- Radiation-induced stenosis or other forms of arteritis involving long arterial segments
- Aneurysms (degenerative or traumatic) and invasive carotid body tumors.

Ligation

- Ligation and resection of the proximal ICA may be indicated in the setting of carotid stump syndrome, when persistent distal embolization from the "cul-de-sac" of the occluded ICA may reflux into collateral pathways, such as through the ophthalmic artery into the distal ICA.

Preoperative Planning

- Similar outcomes are achieved with general anesthesia or regional anesthesia.
- Use of shunt during CEA is dependent on operator preference. Most surgeons either shunt selectively or use a shunt for all cases. Some surgeons never shunt.[6] Surgeons should develop the methods they feel most comfortable with to optimize outcome. Objective measures that may influence shunt usage include stump pressure measurement, electroencephalographic monitoring, and transcranial Doppler assessment. Data supporting use of these adjuvants is inconsistent, and none is considered standard of care nationally.
- Optimal neck extension is obtained by placing a towel or gel roll behind the scapula. The head is rotated contralateral to the operative side. In older patients, often with limited neck movement or prior cervical fusions, padding and shay positioning must be sufficient to support the neck to prevent hyperextension injury. The chin, angle of the mandible, lower earlobe, and sternal angle are prepped and preliminarily draped within the operative field. The bed itself can be flexed with the head in relative extension to aid in positioning (**FIG 1**).

FIG 1 ● Recommended patient position for a CEA procedure.

- Arterial blood pressure monitoring is necessary for optimal anesthetic management. Bladder catheterization is performed if the procedure is expected to extend beyond 2 hours. If endarterectomy is performed with regional anesthesia, an audible squeeze device is placed in the patient's contralateral hand for indirect neurologic monitoring. Preoperative antibiotics are administered routinely.
- Aspirin therapy is initiated well in advance of surgery and continued throughout the perioperative period. Evidence suggests that statin therapy, initiated preoperatively, reduces postoperative neurologic events and mortality.[7]

CAROTID ENDARTERECTOMY—PATCH ANGIOPLASTY

Incision

- The skin incision is optimally placed along the anterior border of the sternocleidomastoid muscle. This should be curved posterolaterally near the angle of the mandible to avoid dissection into the parotid gland.
- Alternatively, a more transverse incision can be made at the level of the carotid bifurcation. Although providing an improved cosmetic result, exposure of the distal ICA may be compromised with this approach (**FIG 2**).

Carotid Exposure and Control

- As the incision is extended through the platysma muscle, the anterior border of the sternocleidomastoid muscle is visualized and retracted posterolaterally. The greater auricular nerve should be identified and protected at the superior extent of the incision.
- Following fascial incision, the facial vein is identified and securely ligated. This vein usually transverses the CCA near the bifurcation. Failure to adequately secure this vein may lead to bleeding and airway compromise during postoperative cough spells or Valsalva maneuvers.
- Within the carotid sheath, the vagus nerve usually extends posterior to, and parallel with, the artery and vein. However, this position relative to the other contents of the carotid sheath may vary, and the vagus should always be identified and protected in the course of the dissection. The ansa cervicalis nerve is commonly much smaller than the vagus and runs anterior to the carotid bifurcation. When completely isolated, the proximal ansa arises from the ipsilateral hypoglossal (XII) cranial nerve. The ansa cervicalis can be divided to improve exposure if necessary or mobilized sufficiently to be gently retracted out of the operative field.
- The CCA is circumferentially dissected from surrounding structures in sufficient length to provide adequate exposure for proximal clamping and control. The CCA is

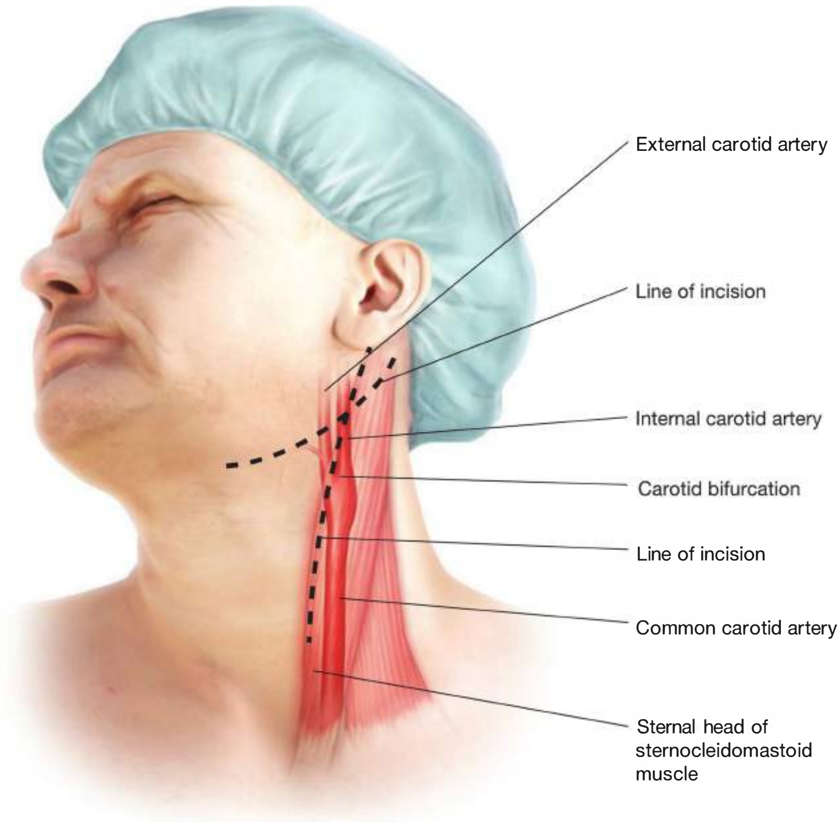

FIG 2 ● The incision along the anterior border of sternocleidomastoid (SCM) muscle is the most commonly used incision for a CEA procedure. A transverse incision along a skin crease in the vicinity of the carotid bifurcation is an alternative incision for a better cosmetic result. CCA, common carotid artery; ICA, internal carotid artery; ECA, external carotid artery.

optimally controlled by placement of an appropriately sized, atraumatic vascular clamp such as a Gregory profunda clamp. The ratchet should be engaged only to the minimal amount necessary to control bleeding to prevent intimal injury and dissection at the site of clamp placement.

- Following common carotid control, the dissection is extended cranially and posteriorly along the posterolateral border of the ICA. Development of the dissection plane posterolaterally along the proximal ICA minimizes risk of hypoglossal nerve injury. This dissection is also performed with minimal displacement and instrumentation of the ICA to reduce intraoperative embolization risk (**FIG 3**).
- To complete the necessary exposure, the external carotid artery (ECA) is dissected and mobilized to at least the level of the superior thyroidal artery. The superior laryngeal nerve may also be encountered posterior to the carotid bifurcation in this area.
- Following dissection, and prior to clamp placement, sufficient unfractionated heparin is administered intravenously to obtain an activated clotting time (ACT) of more than 200 seconds. With normal circulation times, this is usually accomplished within 2 or 3 minutes of injection.
- Clamping of ICA is performed first, followed by control of the external and common carotid arteries. This sequence is followed to minimize embolization risk associated with clamping. When necessary, measurement of ICA stump pressure is obtained at this juncture by cannulation of the carotid bifurcation and selective removal of the internal carotid clamp.

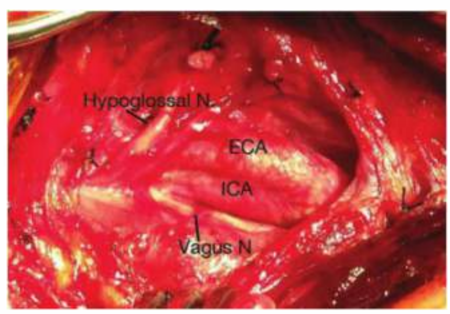

FIG 3 ● Exposure of carotid bifurcation. Vagus nerve and hypoglossal nerve are most commonly encountered nerves during carotid dissection.

Conventional Endarterectomy

- The arteriotomy is initiated in a soft, uninvolved proximal segment of the CCA and extended cephalad with Potts scissors. It should be positioned on the anterior-lateral surface of the ICA to avoid the flow divider. (**FIG 4A**).
- When an indwelling shunt is indicated or required, the distal tapered end is carefully inserted into the ICA under direct vision. We prefer the Pruitt-Inahara shunt, which has pilot balloons at both ends to maintain shunt position and hemostasis. Once the distal end is inserted, the distal balloon is inflated with less than 1 mL of air until the "pop-off" balloon inflates on the pilot tube. Familiarity with this shunt prior to insertion is essential; if the inflation override cuff covers the "pop-off" balloon on the pilot tube, overinflation may injure or rupture the distal ICA. Following distal ICA cannulation and balloon inflation, the shunt is back-bled to confirm luminal placement and decant air. With the shunt actively back-bleeding, the proximal end is inserted into the CCA followed by proximal clamp removal into the unobstructed lumen. The proximal pilot tube is inflated with the provided syringe until the cuff is palpable in the CCA, after which a prepositioned Rumel tourniquet is gently cinched around the artery. When performed quickly, with concurrent digital control of the CCA following clamp removal and prior to shunt insertion, minimal bleeding ensues. When saline is applied to the shunt tubing, pulsatile flow is appreciable with handheld Doppler insonation.
- At the site of maximal atherosclerotic disease in the CCA, the Penfield knife is employed to identify and develop the appropriate endarterectomy plane within the medial layer. When the correct plane is identified, the plaque is easily and rapidly elevated from the underlying adventitia. In areas containing intraplaque hemorrhage, inflammation may increase adherence of the plaque to the adventitia, and care should be taken not to extend the dissection plane into the adventitia itself.
- At the distal extent plaque, sufficient exposure should be present to create a defined endpoint, allowing placement of tacking sutures if necessary, ensuring that no further potentially mobile plaque remains. It is essential to "feather" the plaque at the distal endpoint to minimize risk for distal dissection or thrombus accumulation. If the plaque extends past the point where feathering is feasible, a distal endpoint should be determined and created sharply with scissors or a no. 15 blade (**FIG 4B**). Tacking sutures, placed circumferentially, can control distal plaque at the transection site. Care should be taken, however, to place the minimal number of sutures necessary to prevent dissection, or consider extending the arteriotomy and endarterectomy to identify a more suitable termination site. Successful suture placement requires circumferential dissection and optimal visualization.
- Once the distal endpoint is determined, residual plaque is removed from the ECA by eversion into the CCA and circumferential dissection and traction. Sufficient back-bleeding is performed to remove any luminal debris within the ECA.
- Direct visualization of the endarterectomy bed following plaque removal commonly identifies loosely attached residual medial elements. These are best removed with fine forceps under magnification. Complete removal is facilitated by continuous irrigation to identify mobile medial elements. Integrity of the distal and proximal endpoints is also verified using this technique.

Patch Placement

- An appropriately sized bovine pericardial or Finesse Dacron knitted polyester patch is selected and trimmed as necessary for closure-assisted angioplasty. Both bovine pericardial and polyester patches have chirality considerations; one surface is preferred for luminal apposition. Please consult the accompanying instructions for use prior to implantation. Closure is secured with running 6-0 polypropylene suture initiated at the cephalad extent of the arteriotomy and continued proximally along the long axis of the patch.
- After 90% or more of the circumference of the patch is secured, flushing is accomplished by sequential clamp removal and luminal irrigation with heparinized saline. Closure is then completed prior to restoration of flow.
- The declamping sequence is of critical importance. The CCA is released first, followed by the ECA clamp. After several cardiac cycles have ensued, the distal ICA is released (**FIG 4C**).
- We perform intraoperative completion duplex imaging of the endarterectomy site as well as the proximal and distal carotid arteries, with purpose-designed, miniaturized 7 MHz probes. Completion duplex scanning is quick, efficient, highly reproducible, and effective at identifying significant residual luminal defects. Detailed description of the characteristics of significant luminal defects identified by completion ultrasonography are beyond the scope of this chapter. Intraoperative insonation is not possible through extruded polytetrafluoroethylene (ePTFE) patches and should not be attempted.

Closure

- Following adequate duplex imaging and endpoint determination, anticoagulation is reversed with protamine sulfate. Some practitioners are reluctant to reverse anticoagulation due to uncertainty regarding thrombogenicity at the endarterectomy site. In our experience, technical issues at the endarterectomy site are most predictive of postoperative neurologic events, and these are efficiently identified and corrected, when present, with completion ultrasonography. Following reversal, the entire wound is inspected for venous or arterial bleeding. The entirety of the patch angioplasty suture line is reinspected for periodicity of suture placement and potential leaks. Reinforcing sutures are applied liberally as needed to ensure hemostasis, but with experience and even suture spacing, the need for additional sutures should be rare. Bleeding lymph nodes should be sutured and removed from the operative field. Confirmation of hemostasis, the platysma is reapproximated with running absorbable suture followed by skin closure. We usually also perform a Valsalva maneuver to identify occult venous injuries that may not be apparent with positive pressure ventilation prior to closure.

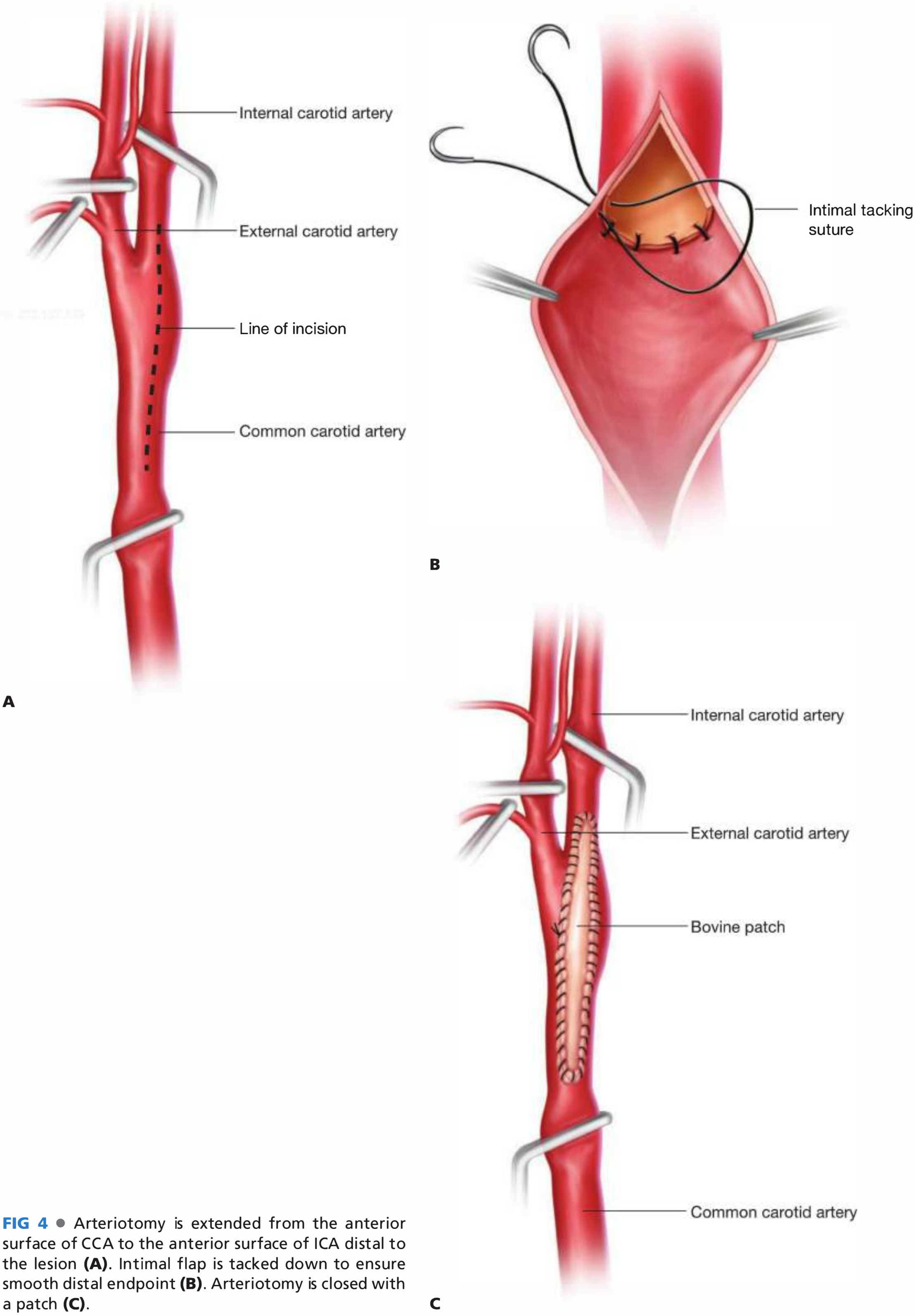

FIG 4 ● Arteriotomy is extended from the anterior surface of CCA to the anterior surface of ICA distal to the lesion **(A)**. Intimal flap is tacked down to ensure smooth distal endpoint **(B)**. Arteriotomy is closed with a patch **(C)**.

CAROTID ENDARTERECTOMY—EVERSION

Incision

- See section under Carotid Endarterectomy—Patch Angioplasty.

Dissection and Control of the Carotid Artery

- See section under Carotid Endarterectomy—Patch Angioplasty.

Eversion endarterectomy

- An oblique or circumferential incision is made at the junction of the bulbous portion of the ICA and CCA (**FIG 5A**).
- The ICA adventitia is grasped with fine forceps and everted away, as gentle traction is placed on the plaque within the artery. This maneuver is extended distally until the feathered endpoint identifies itself. Tacking sutures are not possible using this approach, which can be a deterrent to adoption by surgeons trained with conventional endarterectomy. Common and external carotid plaque is subsequently removed by the Penfield knife as indicated. The proximal CCA arteriotomy may be extended as needed to ensure complete removal.
- Common and external carotid plaque is subsequently removed by the Penfield knife as indicated. The proximal CCA arteriotomy may be extended as possible to ensure complete removal (**FIG 5B**).

Anastomosis

- The ICA is reverted and anastomosed end-to-end to the proximal CCA (**FIG 5C**).
- If redundant residual ICA is present following plaque removal, the ICA spatulation is extended, as is the CCA arteriotomy, and the two ends are further advanced over each other prior to closure. Alternatively, a portion of the redundant ICA may also be excised.

Closure

- See section under Carotid Endarterectomy—Patch Angioplasty.

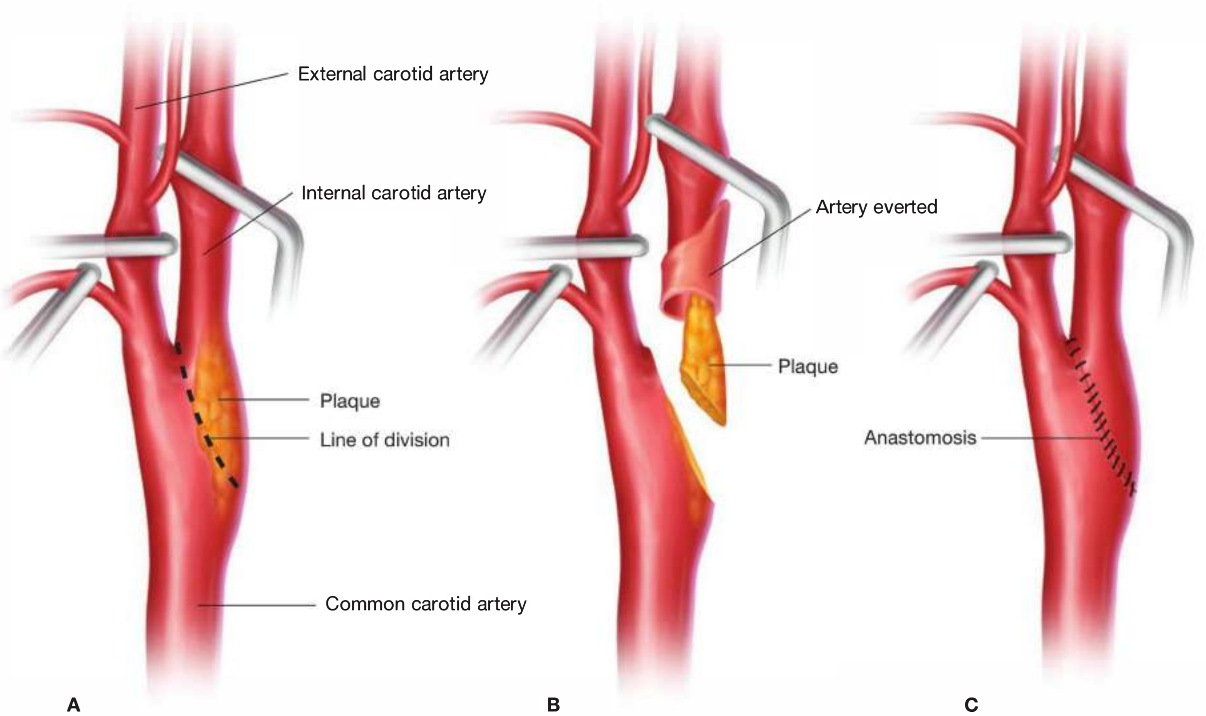

FIG 5 ● Carotid eversion endarterectomy. The ICA is divided from the CCA in an oblique line **(A)**. The divided ICA is everted on itself until the plaque endpoint is encountered and the plaque is removed from the ICA **(B)**. Following endarterectomy, the ICA is reverted and reattached to the CCA **(C)**.

CAROTID ARTERY INTERPOSITION BYPASS

Incision

- See section under Carotid Endarterectomy—Patch Angioplasty.

Dissection and Control of the Carotid Artery

- See section under Carotid Endarterectomy—Patch Angioplasty.
- Although reversed autogenous vein is the preferred conduit, when available, ePTFE provides a suitable alternative when necessary.[8]

Anastomosis

- The diseased segment of the carotid artery is resected. Commonly, the ECA is oversewn as well.
- End-to-end anastomoses are performed in standard fashion. Prior to completion, flushing maneuvers are done to evacuate particular matter or residual air (**FIG 6**).

Closure

- See section under Carotid Endarterectomy—Patch Angioplasty.

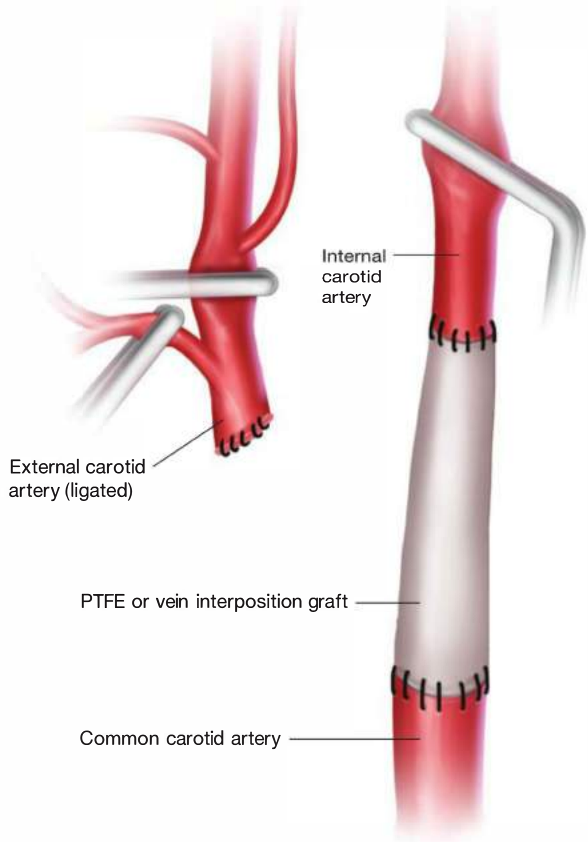

FIG 6 ● Carotid interposition graft. Following resection of the diseased segment, a prosthetic graft or a segment of reversed greater saphenous vein is used to bridge the CCA and ICA in an end-to-end fashion.

CAROTID ARTERY LIGATION (CAROTID STUMP SYNDROME)

Incision

- See section under Carotid Endarterectomy—Patch Angioplasty.

Dissection and Control of the Carotid Artery

- See section under Carotid Endarterectomy—Patch Angioplasty.

Endarterectomy

- The technique is similar to that for standard ICA endarterectomy, the difference being the arteriotomy being carried out on the distal CCA into the ECA (**FIG 7A**).
- The thrombosed ICA is resected, ideally in line with the common and external carotid arteriotomies. Closure is accomplished via patch angioplasty (**FIG 7B,C**).

Closure

- See section under Carotid Endarterectomy—Patch Angioplasty.

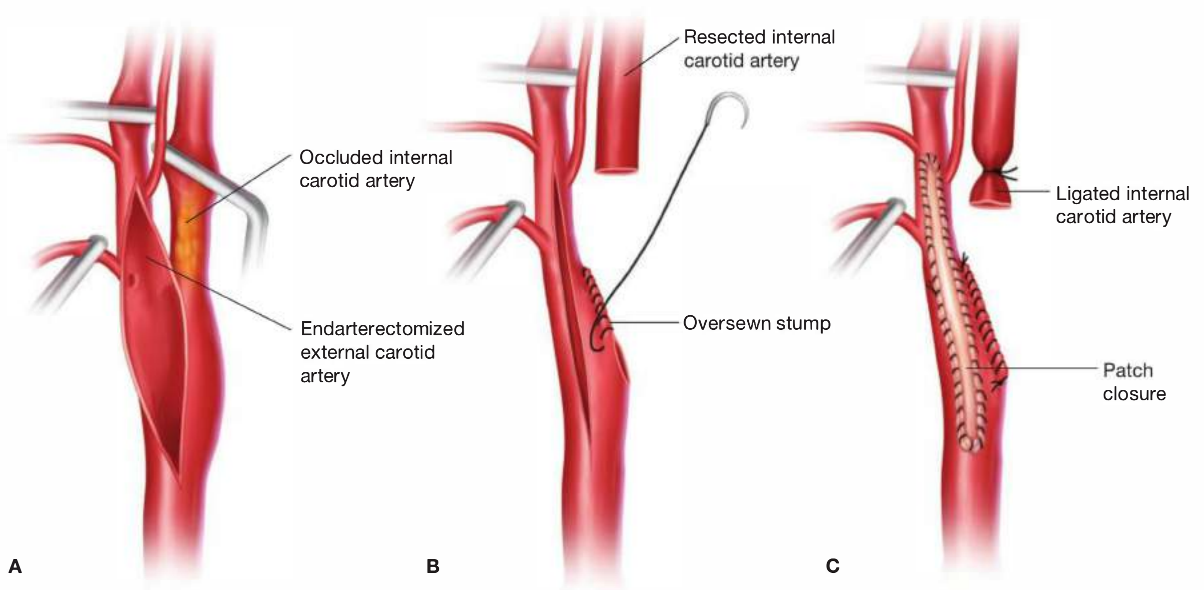

FIG 7 ● Carotid ligation. The occluded ICA is amputated and removed **(A)**, and the ICA stump is oversewn **(B)**. The plaque in the CCA and ECA is removed, and the arteriotomy is closed with a patch **(C)**.

PEARLS AND PITFALLS

Incision	▪ On table duplex scanning optimizes incision placement, particularly for transverse exposure.
Identifying the vagus nerve and hypoglossal nerve	▪ Vagus nerve is located posterolateral to the carotid artery, within the carotid sheath and between carotid artery and internal jugular vein. Hypoglossal nerve typically crosses ICA anteroinferiorly to posterosuperiorly. Following the ansa cervicalis will lead to hypoglossal nerve.
Clamping	▪ A "robin blue" hue is often seen in the distal ICA, which signifies a soft area for safe clamp placement.
Shunting	▪ Be prepared in all cases for potential shunt placement. This should be flushed and prepared on the back table prior to performing the arteriotomy.
Conventional endarterectomy	▪ Lavage the arterial lumen with heparinized saline to identify and remove luminal debris.
Eversion endarterectomy	▪ Use caution in patients with high bifurcation (difficulty visualizing and securing distal endpoint), those who require a shunt, or those with a small ICA. These procedures are best suited for patients with redundant ICAs.
Interposition bypass	▪ Use the anastomotic suture line to tack down distal residual plaque as necessary to prevent antegrade dissection.
Ensuring technical perfection	▪ A completion imaging study, either an on-table angiogram or a carotid duplex study, can help to ensure technical perfection prior to skin closure.
Closure	▪ If a closed suction drain is placed, it should be removed on postoperative day 1.

POSTOPERATIVE CARE

- Patients should be placed on continuous monitoring to assess for blood pressure lability. Patients generally are discharged on postoperative day 1 or 2.
- A postoperative duplex should be obtained within 30 days of intervention to assess the reconstruction, provide a new baseline for long-term surveillance, and monitor wound healing and plaque incorporation. Serial ultrasounds should be obtained to identify and manage restenosis, which most commonly occurs in the first 2 years following endarterectomy.

OUTCOMES

- The North American Symptomatic Carotid Endarterectomy Trial (NASCET) demonstrated the 30-day CEA stroke and death rate of 5.5% for symptomatic patients.[1]

- The Asymptomatic Carotid Atherosclerosis Study (ACAS) demonstrated a combined 30-day CEA stroke and death rate of 2.3%.[2]
- More recently, the Carotid Revascularization Endarterectomy versus Stenting Trial (CREST) demonstrated the 30-day stroke, death, or rate of myocardial infarction (MI) to be 5.4% in symptomatic patients and 3.6% in asymptomatic patients, and the 30-day death and stroke rates were found to be 3.2% in symptomatic patients and 1.4% in asymptomatic patients undergoing CEA. In the periprocedural period, there is a lower rate of stroke with CEA versus stenting (2.3% vs. 4.1%) but a higher rate of MI (2.3% vs. 1.1%). Mortality rates are similar.[9]

COMPLICATIONS

- Cervical hematoma
- Hemodynamic instability
- Cerebral hyperperfusion syndrome manifested by severe headache
- Cranial nerve palsy
- Stroke/MI
- Thrombosis (early)
- Recurrent stenosis (late)

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Chapter 4

Carotid Surgery: Bifurcation Stenting with Distal Protection

Zhen S. Huang   Darren B. Schneider

DEFINITION

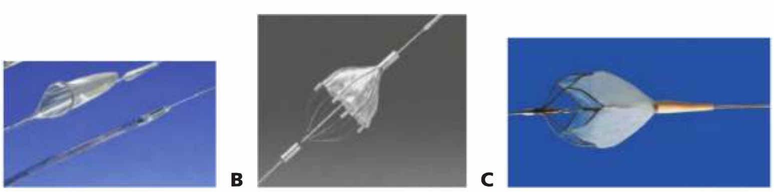
- Carotid artery stenosis was first successfully treated via percutaneous balloon angioplasty in 1977 by Mathias and colleagues.[1,2] This technique has evolved over time to include use of self-expanding nitinol stents and distal embolic protection devices (EPD). Carotid angioplasty and stenting (CAS) is indicated as an alternative to open carotid endarterectomy (CEA) in certain clinical scenarios where the patient's anatomy and/or physiology pose a greater risk for complications with CEA. However, these specific clinical conditions are not absolute and must be weighed against risks for endovascular intervention.
- Distal EPD
  - According to the 2011 ASA/ACCF/AHA/AANN/AANS/ACR/ASNR/CNS/SAIP/SCAI/SIR/SNIS/SVM/SVS guideline on the management of patients with extracranial carotid and vertebral artery disease, "EPD deployment during CAS can be beneficial to reduce the risk of stroke when the risk of vascular injury is low."[3]
  - A distal filter is placed in the internal carotid artery (ICA) distal to the lesion but below the skull base, with the purpose of capturing debris to prevent distal embolization during CAS (**FIG 1**). The target lesion must be crossed by the filter before deployment but this system allows for cerebral protection with maintenance of blood flow to the brain during subsequent steps of the procedure. The filter is mounted on the same wire used to perform CAS and after successful CAS, the filter is retrieved along with any captured debris.

PATIENT HISTORY AND PHYSICAL FINDINGS

- A thorough history should be obtained prior to intervention and should include a detailed description of, if present, symptoms (quality, duration, etc.) that may be indicative of transient ischemic attacks (TIA) or prior stroke, past medical/surgical history (e.g., prior cerebrovascular disease/interventions), current medications (e.g., antiplatelet or anticoagulation medications), and social history (e.g., tobacco use).
- A comprehensive physical exam is mandatory and should include a complete vascular and neurologic/stroke evaluation. Vascular exam should note the presence of palpable femoral and distal lower extremity pulses and carotid bruits.

IMAGING AND OTHER DIAGNOSTIC STUDIES

- Initial carotid duplex ultrasound is obtained to evaluate the degree of stenosis and plaque morphology. Studies have highlighted a higher potential for embolism during CAS with hypoechoic lipid-containing plaque.[4]
- Angiographic imaging of the aortic arch and carotid and cerebral arterial vasculature must be obtained to aid in proper patient selection and procedural planning. This is accomplished through computed tomographic arteriography (CTA) (**FIG 2**), magnetic resonance arteriography (MRA), or catheter-based contrast arteriography.
  - Arch anatomy
    - Aortic arch morphology is variable and can change with advancing age. The arch anatomy can be divided into three types, dictated by the position of the innominate artery origin relative to two horizontal lines drawn across the apices of the outer and inner aortic arch curvatures (**FIG 3**).
    - Type I—the innominate origin arises at or above the horizontal plane of the outer arch curvature (**FIG 3A**)
    - Type II—the innominate origin arises in between the two horizontal planes of the outer and inner arch curvatures (**FIG 3B**)
    - Type III—the innominate origin lies below the horizontal plane of the inner arch curvature (**FIG 3C**)
    - The difficulty in gaining access to the carotid arteries increases from types I to III. There is an increase in angle acuity of the great vessel origins off the arch with increasing arch types that make wire/catheter guidance/exchange more difficult.
    - Bovine arch—congenital arch variations where the left common carotid artery (CCA) shares a common origin with the innominate artery (more frequent) or the left CCA branches off the innominate artery. In a pure bovine arch (extremely rare), the right subclavian, common carotid—both right and left—and left subclavian all derive from one common arterial trunk off the aortic arch.



A B C

FIG 1 ● Distal EPD. **A.** FilterWire EZ, Boston Scientific. **B.** Angioguard, Cordis Endovascular. **C.** RX Accunet, Abbot Vascular.

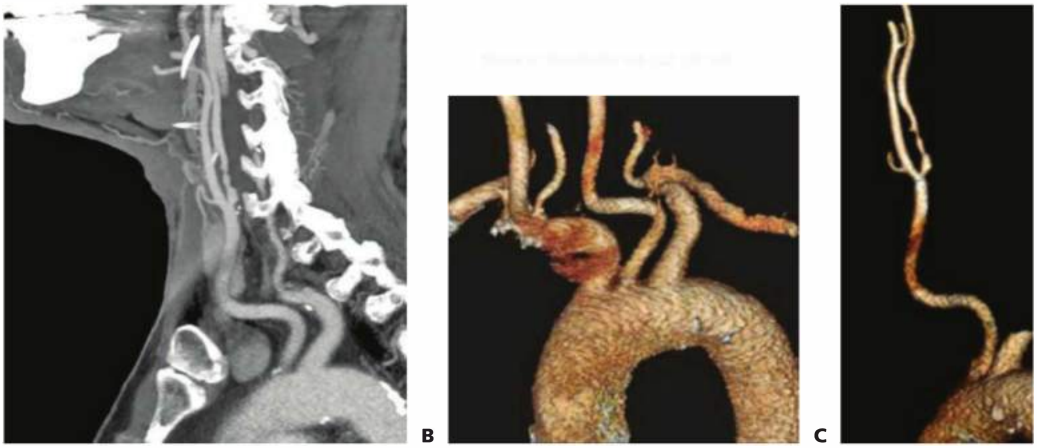


FIG 2 • CTA imaging of aortic arch and great vessels demonstrating a left ICA stenosis. **A.** Sagittal image. 3-D image reconstructions from the CTA images of the aortic arch **(B)** and cervical left carotid artery, demonstrating the left ICA stenosis **(C)**.

  - Shaggy aorta—when extensive aortic wall irregularities exist, there is a high risk for significant atheroembolism and thus, this may be a contraindication to CAS.
  - Eggshell aorta—with severe aortic wall calcification, there is increased risk of intimal disruption and difficulty of wire/catheter manipulation/advancement.
- Cerebral flow to both hemispheres is assessed to determine cerebral reserve.
- Carotid vessel size, tortuosity, and calcification—carotid artery diameter should be assessed to aid in determining device sizes. In addition, severe carotid circumferential calcification and vessel tortuosity may negatively impact procedural success (e.g., difficulty with inserting stent, placement of EPD in distal ICA) and may represent a contraindication to CAS.
- Preoperative brain imaging with computed tomography (CT) or magnetic resonance imaging (MRI) is needed for symptomatic patients to document prior infarcts and to rule out preexisting hemorrhagic stroke prior to the initiation of the procedure.

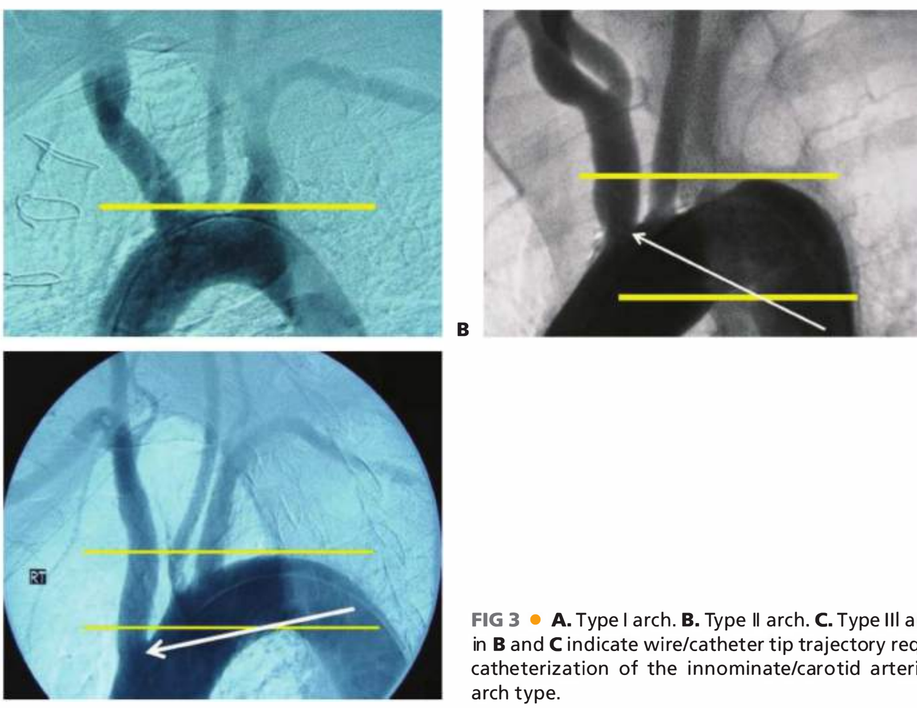


FIG 3 • **A.** Type I arch. **B.** Type II arch. **C.** Type III arch. (*White arrows* in **B** and **C** indicate wire/catheter tip trajectory required for selective catheterization of the innominate/carotid arteries within specific arch type.

SURGICAL MANAGEMENT

- The indications for any surgical intervention for carotid disease depend on the patient's clinical status (i.e., symptomatic or asymptomatic) and the characteristics of the carotid lesion.
- It has been widely accepted that appropriate candidates for CEA are symptomatic patients with carotid stenosis of 70% to 99% on noninvasive imaging and an anticipated perioperative risk of stroke or mortality of less than 6%. Benefit of intervention for symptomatic patients with lesser degrees of stenosis (50% to 69%) has also been shown but not for symptomatic patients with less than 50% carotid stenosis. CAS is an alternative to CEA for symptomatic patients meeting similar criteria along with anatomic and/or physiologic factors unfavorable for CEA (Table 1).[3,5]
- The recommendations/indications for CAS in asymptomatic patients are still issues for debate and no consensus exists. CAS may be considered for patients with asymptomatic ICA stenosis between 70% and 99%, but there are insufficient data to recommend CAS for primary therapy in asymptomatic patients. Therefore, these patients need to be addressed on a case-by-case basis with consideration of patient comorbidities and risks of CAS.
- The contraindications for CAS are predominantly related to aortic arch and carotid artery anatomic factors (Table 2).

Table 1: Anatomic and Physiologic Factors Favoring Carotid Angioplasty and Stenting

Anatomic Factor	Physiologic Factor
Reoperative neck (e.g., prior CEA, prior radical neck dissection)	Unstable angina
History of cervical radiation	Recent MI (<30 days)
High carotid lesion (above C2)	CHF with EF less than 30%
History of contralateral CEA with associated cranial nerve injury	Severe COPD (FEV_1 <30%)
Tracheostomy	
Contralateral carotid occlusion	

CEA, carotid endarterectomy; CHF, congestive heart failure; EF, ejection fraction; COPD, chronic obstructive pulmonary disease; FEV_1, forced expiratory volume in 1 second.

Preoperative Planning

- Patients are initiated on antiplatelet therapy with aspirin 325 mg per day and clopidogrel 75 mg per day for 5 days prior to intervention. Alternatively, a clopidogrel loading dose of 300 mg can be administered 4 to 6 hours prior to the intervention.
- Antihypertensive medications can be held off the day of intervention to prevent contribution to the possible periprocedural hypotension.

Positioning

- The patient is placed in the supine position with adequate monitoring throughout the peri- and postprocedural period. Minimal monitoring includes continuous electrocardiogram (EKG), intraarterial blood pressure, and pulse oximetry. The patient's neurologic status must be frequently evaluated during the procedure via answering of simple questions and squeezing a plastic sound toy (e.g., rubber duck squeaky toy) in the contralateral hand.
- Intraarterial blood pressure monitoring is established usually via a radial arterial line.
- In order to maintain patient cooperation/comfort and frequent neurologic monitoring, minimal or no sedation is administered and only local anesthesia is infiltrated for the access site.

Table 2: Anatomic and Physiologic Factors Unfavorable for Carotid Angioplasty and Stenting

Anatomic Factor	Physiologic Factor
Severely angulated aortic arch (type III)	Ages 80 years and older
Shaggy/eggshell aorta	Contraindication to antiplatelet therapy
Severe aortoiliac occlusive disease	Severe renal dysfunction
Severe ICA calcification/tortuosity	
Severe carotid stenosis/string sign	
Unstable carotid plaque	
Fresh carotid thrombus	
Decreased cerebral reserve	

ICA, internal carotid artery.

PERCUTANEOUS RETROGRADE FEMORAL ARTERY ACCESS

- Obtain retrograde access via the common femoral artery (CFA) using a percutaneous micropuncture (21-gauge needle) system under ultrasound guidance. The CFA should be accessed immediately proximal to the femoral bifurcation in an area with minimal disease. The right CFA is the most convenient site for right-handed operators. The left CFA and brachial and radial arteries are alternative access sites. Ultimately, the safest and simplest access site to the target lesion should be employed.
- The micropuncture sheath is then exchanged for a 5-Fr introducer sheath over the 0.035-in access wire.

ARCH AORTOGRAPHY

- A guidewire is advanced into the aortic arch followed by a pigtail catheter. The pigtail catheter is positioned in the mid-ascending aorta and arch aortography is performed in a 45- to 60-degree left anterior oblique projection in order to adequately visualize the origin of the great vessels (**FIG 4**).

FIG 4 ● Arch aortography with pigtail catheter in midascending aorta.

SELECTIVE COMMON CAROTID CATHETERIZATION

- Before further manipulation of wires/catheters in the arch and great vessel origins, the patient is administered systemic heparin at 70 to 100 U/kg intravenously (IV) with a goal activated clotting time of 250 to 300 seconds.
- While maintaining the left anterior oblique (LAO) projection that allows for optimal visualization of the great vessels origins, a road map image is used to assist in selective catheterization of the CCA. The pigtail catheter is exchanged for the operator's catheter of choice.
- Multiple curved catheters are available (**FIG 5**), each with unique features that may be beneficial in different anatomies. However, frequently, selective common carotid catheterization can be accomplished with a combination of an angled or simple curved catheter and a floppy angled Glidewire™.

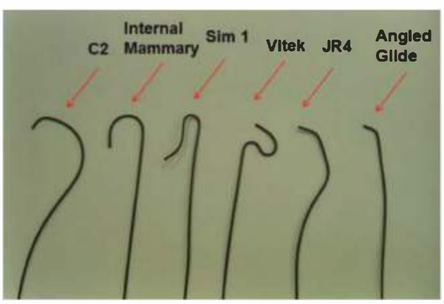


FIG 5 ● Various catheters can be used for selective catheterization of the common carotid.

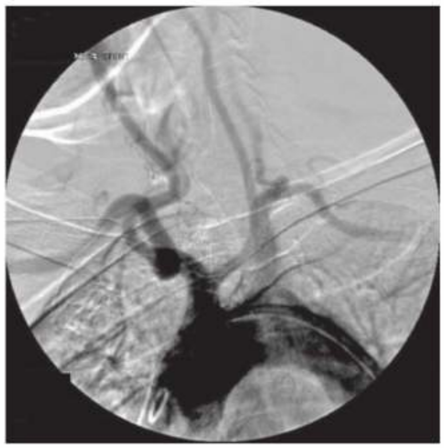


FIG 6 ● Type I arch with bovine configuration.

- However, a retroflexed or complex curved catheter (e.g., SIM or Vitek) may be necessary with a difficult arch anatomy such as type III arch or bovine configuration (**FIG 6**).
- After the Glidewire™ has accessed the common carotid (but taking extreme care not to advance past the bifurcation), the selective catheter is advanced over the Glidewire™ into the common carotid. Common carotid–selective angiograms are then performed typically in the anteroposterior, lateral, and oblique projections (more views are performed as needed) (**FIG 7**). Contralateral carotid arteriogram can be performed as well if necessary, but this usually is not performed during CAS of a unilateral lesion.
- Cerebral vessel angiography is then performed, typically in anteroposterior and lateral views (**FIG 8**). Additional views can be done if necessary.

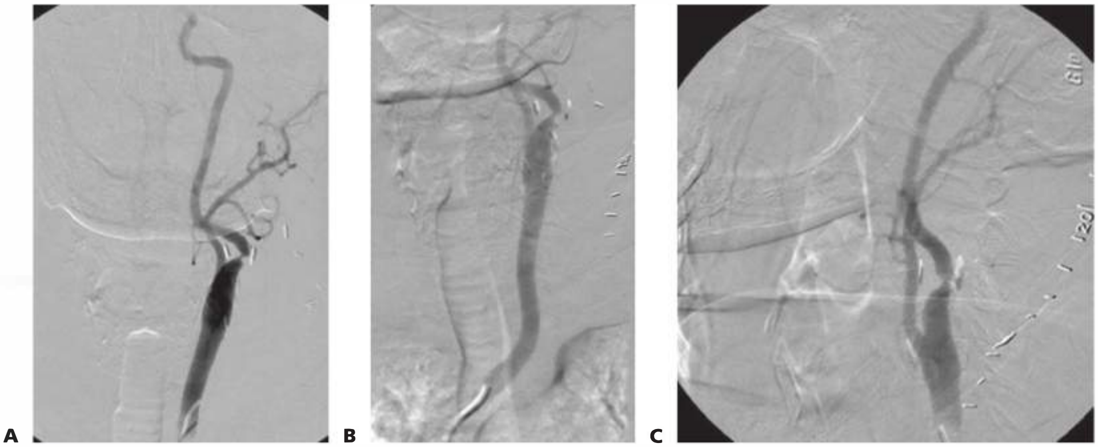


FIG 7 ● **A.** Selective left common carotid angiography, craniocaudal anteroposterior projection. **B.** Selective left common carotid angiography, oblique projection. **C.** Selective left common carotid angiography, lateral projection.

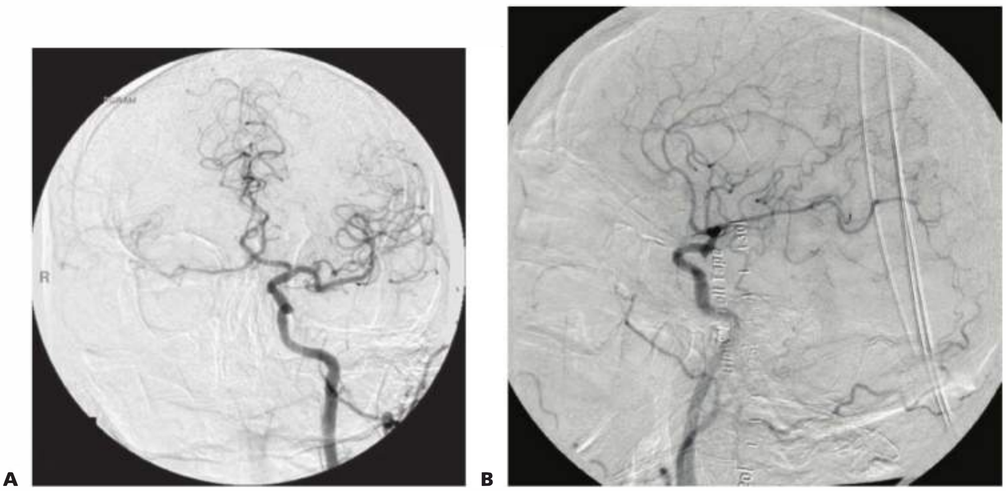


FIG 8 ● **A.** Cerebral vessel angiography via left CCA, craniocaudal anteroposterior (AP) projection. **B.** Cerebral vessel angiography via left CCA, lateral projection.

PLACEMENT OF GUIDING SHEATH

- After common carotid angiography is complete, it is recommended that the appropriate necessary equipment to complete the procedure is selected prior to further selective cannulation of the carotid vessels (e.g., access sheaths, wires, catheters, filter and filter retrieval system, pre- and postdilatation balloons, stent).
- In order to advance a sheath into the proximal common carotid, adequate exchange support is needed with a stiff guidewire. To achieve this, the selective catheter is carefully advanced over the floppy Glidewire™ into a branch of the external carotid artery (ECA). The floppy Glidewire™ is then exchanged for a stiff guidewire (e.g., long Amplatz™ Superstiff wire with floppy tip). Caution needs to be exercised to ensure the stiff wire tip does not inadvertently advance and potentially perforate the ECA branch. The catheter is then removed leaving the stiff wire in place in the ECA (FIG 9). If there is significant atherosclerotic stenosis involving the carotid bifurcation, or if the ECA is severely stenotic/occluded that prevents safe ECA access, an Amplatz™ wire with a 1-cm floppy tip may be left in the distal CCA.
- Once the supportive wire is in place, the groin introducer sheath is exchanged for a 6-Fr 90-cm sheath. The sheath is tracked over the stiff wire and placed into the distal CCA proximal to the bifurcation. It is imperative that sheath advancement is performed on live fluoroscopy, especially when negotiating the turn at the common carotid origin, to ensure the sheath is advancing appropriately.

FIG 9 ● Stiff wire within ECA to allow guiding sheath advancement into common carotid.

CROSSING THE LESION WITH DISTAL EMBOLIC PROTECTION DEVICES

- With the sheath in place and using a road map image, the ICA lesion is crossed with the 0.014-in wire component of the distal EPD. The distal EPD should be deployed in a straight portion of the distal ICA proximal to the petrous portion at skull base (**FIG 10**). It is important not to allow inadvertent migration of the EPD further distally for risk of injury to the intracranial ICA.

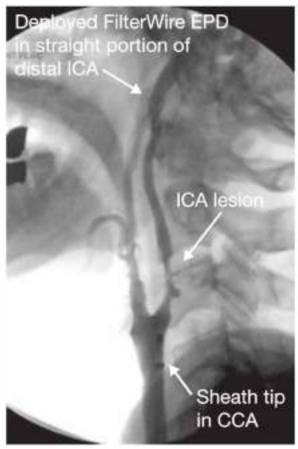


FIG 10 ● Distal EPD deployed in the distal ICA proximal to the petrous portion at skull base.

PREDILATATION WITH ANGIOPLASTY BALLOON

- After the distal EPD is in position, the carotid lesion is predilated with a 3- or 4-mm coronary angioplasty balloon up to nominal pressure (**FIG 11**). A higher inflation pressure may be required for heavily calcified lesions. Using a balloon length of 4 cm should help to minimize the risk of the balloon slipping ("watermelon seeding") during inflation. In addition, it is important to be extra vigilant in monitoring the patient's heart rate for possible bradycardia (or even asystole) during lesion predilatation and atropine must be readily available for administration before predilatation.

FIG 11 ● Left ICA lesion predilatation with 3-mm coronary balloon.

STENTING AND POSTDILATATION

- Following predilatation, a channel is created that will accommodate the advancement of the stent system. A self-expanding stent compatible with the distal EPD system is advanced over the wire and deployed under a road map. The distal and proximal stent landing zones must be at areas of normal vessel wall and this will frequently necessitate stenting across the ECA origin with the proximal landing zone in the distal CCA (**FIG 13**). After stent deployment, it is postdilated (usually using a 5 to 6 mm × 2 cm balloon), treating only the stented portions of the ICA to minimize injury to the native vessel wall (**FIG 12**) and over postdilatation is strictly avoided to reduce risks of embolization. During postdilatation, the patient's heart rate must be closely monitored for any changes and atropine should still be readily available.

FIG 12 ● Stent postdilatation with a 5 mm × 2 cm balloon.

EMBOLIC PROTECTION DEVICE RETRIEVAL AND COMPLETION ANGIOGRAM

- Completion angiography is performed to assess stent placement and poststent carotid antegrade flow before the distal EPD is removed (**FIG 13**). With normal flow through the stent and no filling defects present, the filter is retrieved. Slow flow and/or filling defects at the filter can be secondary to significant debris and this must be aspirated prior to retrieval. The EPD retrieval system is advanced carefully past the stent without engaging/catching on the stent. With extensive debris present in the filter, it is important not to fully recapture the filter in the retrieval catheter as this can extrude debris from the filter and cause distal embolization. Distal ICA vasospasm can be present as well and it is usually secondary to migration of EPD during the procedure. Typically, this is managed conservatively but with significant ICA spasm, nitroglycerin (50 to 200 μg) can be administered in small doses directly intraarterially in the ICA.

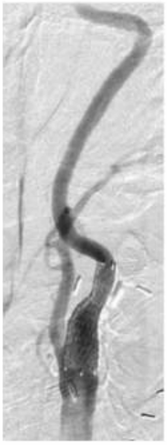


FIG 13 ● Completion angiography is performed to assess stent placement and poststent carotid antegrade flow. Note that this stent is placed across the ECA origin.

ACCESS HEMOSTASIS

- The femoral access arterial puncture can be closed using standard techniques either with a closure device or by direct manual compression. We prefer to use a closure device and do not routinely reverse heparin anticoagulation with protamine. For brachial artery access, direct manual compression is the preferred method for achieving hemostasis.

PEARLS AND PITFALLS

Selective common carotid catherization	■ Tortuous aortic arch/great vessel anatomy may require additional manipulation with various retroflexed catheters in order to select the common carotid. However, with increasing manipulation, there is a greater risk of embolization/aortic injury. Therefore, aortic arch/great vessel anatomy should be analyzed preoperatively and, when indicated, suitable alternative plans should be prepared if the initial method proves unsuccessful. ■ An extremely diseased aortic arch may be a relative contraindication to CAS.
Placement of guiding sheath	■ When the ECA is occluded, a supportive guidewire cannot be placed to allow tracking of the sheath and an alternative method is needed. Alternatively, an Amplatz guidewire with a 1-cm floppy tip in the distal CCA may provide sufficient support for sheath placement. Shuttle systems that permit telescoping the sheath into the CCA over a guidewire and catheter assembly are another alternative.
Crossing the lesion with EPD	■ Difficulty crossing the lesion can be addressed by changing the shape of the crossing wire tip or using a directional catheter. Additionally, changing the patient's head/neck position may make a vessel less angulated. ■ Certain EPD such as the Nav-6 (Abbott Vascular, Abbott Park, IL) and Spider (Covidien, Plymouth, MN) are introduced over a wire that is introduced independently before the filter. Introduction of the independent wire may facilitate subsequent introduction of the filter across a tightly stenotic lesion or a lesion with an acute entry angle. ■ A "buddy wire" (additional 0.014-in wire) can also be used to provide extra support and facilitate crossing a difficult lesion. ■ If the crossing profile of the EPD is too large to cross the stenotic lesion, the stenotic lesion can also be predilated with a 2.5-mm balloon in order to create a channel large enough for EPD. However, dilating the lesion without an EPD in place increases the risk of distal embolization.
Distal ICA spasm	■ Usually caused by distal EPD and resolves after EPD and wire are removed. ■ Small doses of nitroglycerin administered directly to carotid may aid in resolution.
Occlusion of flow proximal to EPD after stent placement	■ Distal ICA filter may be full of debris causing slow flow or ICA occlusion. The debris should be aspirated from the filter using an aspiration catheter and repeat angiogram is performed after to confirm return of flow prior to EPD retrieval. ■ If it is determined that occlusion is due to acute stent thrombosis then immediate conversion to open exploration, stent removal, and formal CEA may be necessary. Preparations for carotid stenting should always include this possibility.
Distal embolization with neurologic symptoms and/or intracranial arterial occlusion	■ Neurorescue techniques are used to treat distal embolization or thrombosis, including the following: ■ Catheter-directed thrombolysis with tissue plasminogen activator (tPA) ■ Mechanical thrombolysis with aspiration ■ Glycoprotein (GP) IIa/IIIb inhibitor administration ■ Direct removal with snare (intraarterial) ■ Direct balloon angioplasty to restore a lumen Note: Intracranial neurorescue techniques should be performed by physicians with appropriate experience and training.

POSTOPERATIVE CARE

- Neurologic status is immediately evaluated after completion of the procedure and continuous invasive blood pressure monitoring and pulse oximetry are maintained. Typically, CAS patients are observed in a monitored step-down unit overnight.
- Goal systolic blood pressures should be based on preoperative measurements. Vasopressor and/or inotropic support may be required to compensate for hypotension and/or bradycardia likely due to carotid sinus distension related to the procedure until the carotid sinus adapts to the presence of the stent. Other causes of hypotension need to be excluded prior to attributing the cause to angioplasty/stenting alone. Conversely, antihypertensives should be used as needed to prevent hypertension and potential cerebral hyperperfusion.
- The patient needs to remain on bed rest in the supine position for 4 to 6 hours after access site hemostasis is achieved. The head of the bed can be inclined to a maximum 30 degrees to promote patient comfort and respiratory function. Afterward, the patient can ambulate as tolerated.
- Immediate head and neck imaging along with neurology consultation are mandatory if the patient experiences a postoperative neurologic event.
- Antiplatelet therapy with clopidogrel should be continued for at least 1 month post-CAS, whereas aspirin is continued indefinitely.

OUTCOMES

- Studies prior to year 2000 failed to define the role of CAS in treating carotid artery disease due to numerous factors. More recent randomized controlled trials (RCTs) were performed in order to elucidate CAS' role in carotid disease, namely as a noninferior alternative to CEA.

- The Stenting and Angioplasty with Protection in Patients at High Risk for Endarterectomy (SAPPHIRE) trial[6] randomized symptomatic patients with 50% or greater carotid stenosis or asymptomatic patients with 80% or greater stenosis with comorbidities that increased their risk of surgery to receive either CEA or CAS. For the CAS patients, they all had self-expandable nitinol stents (S.M.A.R.T. or PRECISE; Cordis, Miami Lakes, FL) placed with EPD (Angioguard or Angioguard XP; Cordis, Miami Lakes, FL). The primary endpoint was composite incidence of death, stroke, or myocardial infarction (MI) within 30 days postprocedure or death or ipsilateral stroke between 31 days and 1 year. Only 334 patients were randomized—167 to CEA and 167 to CAS (trial stopped early due to poor enrollment). No significant difference in the primary composite endpoint rate was detected in the periprocedural period (30 days) for CAS compared to CEA. However, 1-year primary composite endpoint rate was lower in CAS compared to CEA (12.2% vs. 20.1%; *P* = .004) with a more pronounced difference in asymptomatic (9.9% in CAS vs. 21.5% in CEA; *P* = .02) than in symptomatic patients (16.8% in CAS versus 16.5% in CEA; *P* = .95). This difference vanished in long-term follow-up and at 3 years, the major secondary endpoint (primary endpoint plus death or ipsilateral stroke 1 to 3 years) cumulative incidences were 24.6% for CAS vs. 26.9% for CEA; *P* = .71.[7] Thus, the SAPPHIRE authors concluded that CAS with EPD was not inferior to CEA in patients with severe carotid artery stenosis and increased surgical risk.
- However, these results were not mirrored in two large European multicenter RCTs—Stent-Supported Percutaneous Angioplasty of the Carotid Artery versus Endarterectomy (SPACE)[8] and Endarterectomy Versus Angioplasty in Patients with Symptomatic Severe Carotid Stenosis (EVA-3S)[9] trials. Both of these studies failed to show noninferiority of CAS compared to CEA in their respective study populations. In SPACE, the primary endpoint (rate of death or ipsilateral ischemic stroke 30 days postprocedure) was 6.84% in CAS and 6.34% in CEA (absolute difference 0.51%, 90% CI −1.89% to 2.91%; noninferiority *P* = .09). In EVA-3S, the results demonstrated greater rates of stroke and death in the CAS group as compared to the CEA group: 30-day incidence of stroke or death was 9.6% in CAS (95% CI, 6.4 to 14.0) and 3.9% in CEA (95% CI, 2.0 to 7.2); the relative risk of any stroke or death after CAS as compared with CEA was 2.5 (95% CI, 1.2 to 5.1). At 6 months, the incidence of any stroke or death was 11.7% after CAS and 6.1% after CEA (*P* = .02). However, long-term data at 4 years from EVA-3S did not demonstrate significant differences in the risk of any stroke or death in between both CAS and CEA; the hazard ratio (HR) was 1.39 (0.96 to 2.00; *P* = .08).[10] The authors interpreted these results to "suggest that carotid stenting is as effective as carotid endarterectomy for middle-term prevention of ipsilateral stroke, but the safety of carotid stenting needs to be improved before it can be used as an alternative to carotid endarterectomy in patients with symptomatic carotid stenosis."
- A more recent international multicenter RCT, the International Carotid Stenting Study (ICSS), demonstrated that CEA was safer than CAS as treatment for patients with symptomatic carotid stenosis of 50% or greater (enrolled 1,713 patients; CAS, n = 855; CEA, n = 858).[11] The primary composite endpoint, 120-day incidence of stroke, death, or MI was higher in CAS compared to CEA (8.5% vs. 5.2%; HR, 1.69; 95% CI, 0.16 to 2.45; *P* = .006). The adverse events occurring with the 30-day postprocedure period accounted for the majority observed at 120 days where the cumulative incidence of stroke, death, and MI was 7.4% in CAS compared to 4.0% in CEA (*P* = .003). The authors concluded that CEA should remain the treatment of choice for symptomatic carotid stenosis patients that are suitable for surgery while awaiting the long-term follow-up data of ICSS.
- The Carotid Revascularization Endarterectomy versus Stenting Trial (CREST) is a U.S. trial that is the most recent and largest RCT to compare the efficacy between CAS and CEA in standard-risk patients.[12] Two thousand and five hundred two patients with asymptomatic carotid stenosis of 70% or greater (based on ultrasound criteria) or symptomatic carotid stenosis of 50% or greater (based on angiographic North American Symptomatic Carotid Endarterectomy Trial criteria) were randomized to either CAS (n = 1,262; RX Acculink stent; Carotid Stent System, Abbott Vascular, Abbott Park, IL) and a distal EPD (RX Accunet Embolic Protection System, Abbott Vascular, Abbott Park, IL) or CEA (n = 1,240). The primary composite endpoint was stroke, death, or MI during the periprocedural period or any ipsilateral stroke within 4 years. During the periprocedural period, the primary endpoint incidence was similar with CAS and CEA (5.2% and 4.5%, respectively; HR for stenting 1.18; 95% CI, 0.82 to 1.68; *P* = .38). However, the rates of individual endpoints differed between CAS and CEA: greater risk of stroke in CAS (4.1% vs. 2.3%, respectively; *P* = .01), greater risk of MI in CEA (1.1% vs. 2.3%, respectively; *P* = .03), no difference in death (0.7% vs. 0.3%, respectively; *P* = .18). The periprocedural risk of stroke or death was higher after CAS for symptomatic patients (6.0% vs. 3.2%; *P* = .02). There was no significant difference in the estimated 4-year rate of the primary endpoint between CAS and CEA (7.2% vs. 6.8%, respectively; HR, 1.11; *P* = .51; 95% CI, 0.81 to 1.51). CREST also demonstrated an interaction between age and treatment efficacy (*P* = .02) where CAS tended to show greater efficacy at younger than 70 years of age and CEA at older than 70 years of age.
- Overall, CAS as a noninferior or equivalent alternative treatment compared to CEA has not been definitively established and further studies are needed.

COMPLICATIONS

- Postoperative complications
  - Stroke—the incidence of stroke is higher with CAS than CEA.[11] Risk factors include advanced age, symptomatic carotid stenosis, and complex anatomy. Postoperative stroke needs to be addressed immediately with full neurologic evaluation and potential intervention.
  - Hypotension—frequently observed post-CAS; however, it usually will resolve spontaneously. Patients may require transient blood pressure support with vasopressors/volume.

- Cerebral hyperperfusion syndrome—may occur within the first week post-CAS and is usually associated with poorly managed underlying hypertension. It presents as a unilateral headache and can progress to seizures, intracranial hemorrhage, and/or coma. Head CT is obtained and focal cerebral edema may be observed. The treatment is aggressive blood pressure management.
- MI—cardiac complications, namely MI, may occur during the periprocedural period for CAS. This is likely due to the typically high-risk patient population selected for CAS given that most are poor candidates for CEA.
- Access site complications—the most common access site complications that are inherent to endovascular procedures are hematoma, pseudoaneurysm, retroperitoneal hematoma, and arteriovenous fistula. To minimize the risk for these complications, we recommend direct visualization of the access vessel under ultrasound and using a micropuncture access system. In addition, proper use of vessel arteriotomy closure devices and/or manual vessel compression is mandatory to reduce the risk for these complications.
- Stent restenosis—restenosis will occur in any current stent placed in the body and can be managed with reintervention as needed.

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Chapter 5

Carotid Surgery: Distal Exposure and Control Techniques and Complication Management

Cheong J. Lee

DEFINITION

- The carotid artery typically bifurcates at the level of the C3-C4 cervical spine. High carotid bifurcations and lesions that extend to the C1-C2 level pose technical challenges that may increase perioperative risk of stroke and cranial nerve injury. Ideally, the need for high access in carotid surgery should be anticipated preoperatively, with familiarity of the anatomy and exposure necessary for distal carotid control.

PATIENT HISTORY AND PHYSICAL FINDINGS

- As with any medical therapy, the clinician must first clearly define the goals of treatment and thoroughly review the operative risk with the patient.
- Optimal medical therapy must be instituted prior to intervention (e.g., antiplatelet agent, statin, beta-blocker).
- Patients with hostile neck anatomy, such as those with history of high-dose neck radiation or severe systemic comorbidities contraindicating general or cervical block anesthesia, should be offered carotid angioplasty and stenting (CAS) as an alternative procedure.
- Patients with prior contralateral carotid revascularization procedures should have laryngeal, hypoglossal, and glossopharyngeal nerve function documented prior to ipsilateral dissection and exposure. When evidence of prior injury to CN IX, X, or XII is evident, CAS should be considered as an alternative. If CAS is not feasible under these circumstances, the potential need for tracheostomy to manage postoperative airway obstruction should be reviewed with the patient.
- Although duplex scanning provides accurate and reproducible assessment of the presence and severity of carotid stenosis, precise anatomic detail required for surgical planning is optimally obtained from computed tomographic angiography (CTA) or magnetic resonance arteriography (MRA). Localization of the carotid bifurcation in regard to cervical landmarks, as well as the distal extent of internal carotid artery (ICA) disease, is best assessed by CTA or MRA (**FIG 1**).

IMAGING AND OTHER DIAGNOSTIC STUDIES

- Current indications for carotid endarterectomy were reviewed in Part 6, Chapter 3.[1–3]
- In recent years, CTA and MRA have assumed preeminent roles in carotid intervention planning. Improved resolution has enabled highly accurate characterization of plaque morphology, which may provide useful guidance regarding plaque vulnerability during operative manipulation.
- MRA and CTA also provide essential information regarding potential collateral arterial flow through the circle of Willis and the need for adjuvant maneuvers such as shunt placement during carotid revascularization (**FIG 2**).

SURGICAL MANAGEMENT

Preoperative Planning for Distal Cervical Carotid Exposure

- Knowledge of patient-specific cervical anatomy is essential to successful management of distal carotid disease. When recognized as necessary, specifying nasotracheal, rather than orotracheal, intubation for general endotracheal

FIG 1 ● Reformatted CTA of a carotid body tumor extending to the distal ICA at the C1 cervical spine level.

FIG 2 ● Rendered CTA demonstrating incompetency of the circle of Willis.

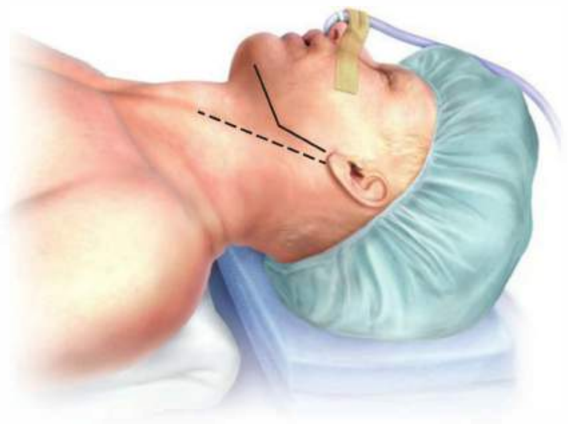

FIG 3 ● Nasotracheal intubation facilitates exposures of the distal ICA by opening the angle between the mastoid process and the mandible *(black lines)*.

anesthesia is a simple and highly effective maneuver to improve exposure. Nasotracheal intubation allows the mouth to stay closed during surgery, providing more room between the ramus of the mandible and mastoid process for distal dissection.

- Temporomandibular subluxation may further advantage carotid exposure cephalad to the C2 cervical spine. Subluxation of the ipsilateral mandibular condyle, performed via intraoral wiring, facilitates exposure from infratemporal ICA to the skull base. Subluxation is distinguished from dislocation, which is more injurious and can potentiate long-term temporomandibular joint pain syndromes.

Positioning

- The patient is positioned supine, with the head extended and rotated away from the operative site. Shoulder rolls and shays are placed to stabilize the neck and optimize extension. The nasotracheal tube is secured over the head (**FIG 3**).
- Arms are tucked to the patient's side to allow the operator and the assistant to maneuver and stand comfortably. This position also facilitates C-arm positioning when needed.
- The patient is placed in the "beach chair" position to limit venous hypertension (**FIG 4**).

FIG 4 ● Patient in the "beach chair" position.

TECHNIQUES

ANTERIOR APPROACH TO THE DISTAL INTERNAL CAROTID ARTERY

Incision

- A vertical, rather than transverse, cervical incision is recommended for optimal distal ICA access (**FIG 5**).
- Standard exposure of the carotid artery in the sheath was previously described in Part 6, Chapter 3.

FIG 5 ● Anatomic landmarks for carotid exposures include the mastoid process, the angle of the mandible, and the sternal notch. Skin incision for carotid exposures are placed anterior to the sternocleidomastoid muscle (SM) *(solid line)*. If distal exposure is anticipated, the incision can be carried in front of the ear *(dotted line)*.

Exposure of the Internal Carotid Artery Distal to the Bifurcation

- Key structures that lie superior to the carotid bifurcation are the posterior belly of the digastric muscle, the hypoglossal nerve, crossing veins from the sternocleidomastoid muscle to the internal jugular vein, and muscular arterioles of the posterior branches of the external carotid artery (ECA) (**FIG 6**).
- The hypoglossal nerve is identified safely using a posterolateral to anteromedial dissection of the ICA. Moving cephalad, the hypoglossal nerve is dissected free from the medial surface of the digastric muscle. Crossing artery and veins of the SCM often tether this nerve closer to the bifurcation. Meticulous identification and controlled division of these tethering vessels will enable mobilization of the nerve. Tracing the course of the descending branch of the ansa cervicalis back to the hypoglossal itself provides positive confirmation of the location and course of the nerve (**FIG 7**).
- The posterior digastric muscle belly may be retracted or divided as required for exposure, following release of the adherent hypoglossal nerve.
- Additional cephalad exposure at this juncture requires division of the occipital branch of the ECA. This further releases the hypoglossal nerve. This maneuver also requires division of the styloid musculature (styloglossus, stylopharyngeus).
- Continued cephalad dissection exposes the glossopharyngeal nerve, seen as a single or double trunk crossing the ICA anteriorly and coursing posterior to the external carotid. Care must be taken in separating the hypoglossal and glossopharyngeal nerves, as small motor

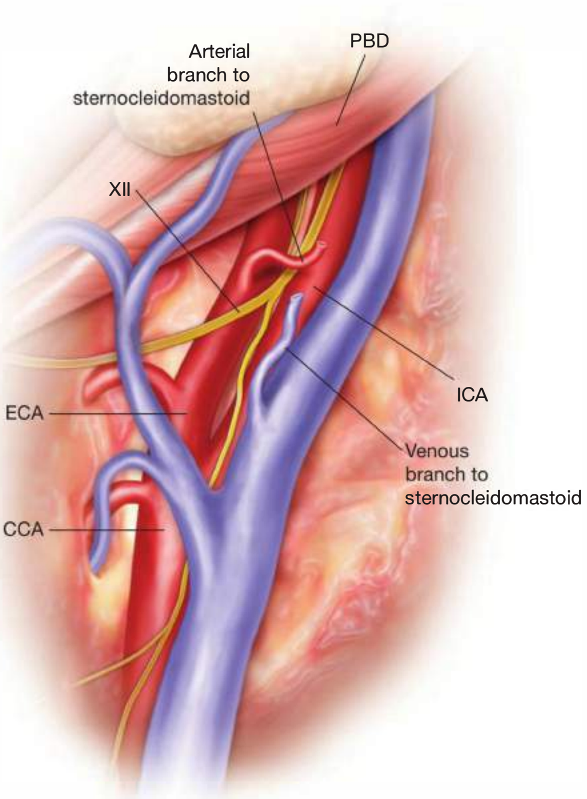

FIG 6 ● Once the carotid sheath is entered, exposure of the distal ICA from an anterior approach begins with identification and dissection of the hypoglossal nerve (XII), the posterior belly of the digastric muscle (PBD), and the crossing veins and arteries to the sternocleidomastoid muscle.

FIG 7 ● Following division of the digastric muscle and the crossing muscular vein and arteries to the sternocleidomastoid, the descending ansa cervicalis nerve (DAC) can be ligated to further mobilize the hypoglossal nerve (XII). To further facilitate hypoglossal mobilization, the occipital artery coming off the ECA has been ligated and divided.

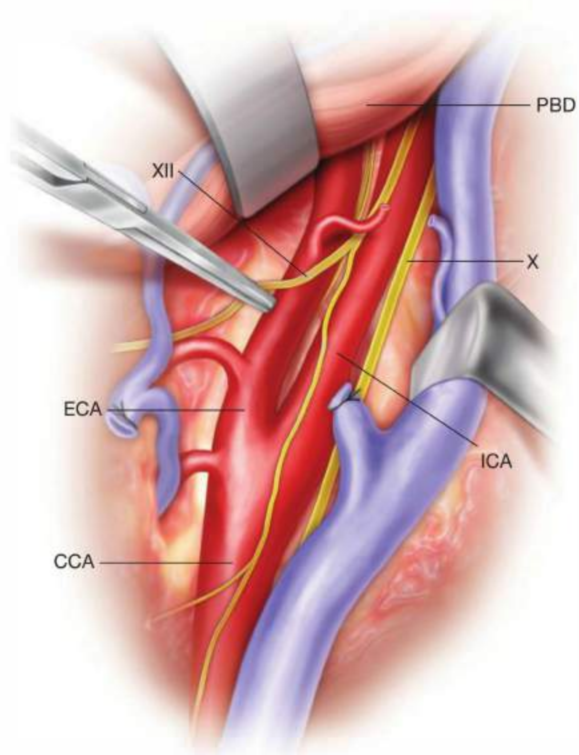

FIG 8 ● Mobilization of the hypoglossal nerve (XII) allows exposure of the distal ICA.

fibers exiting the vagus nerve also course in this plane. Damage to these nerves or the glossopharyngeal can cause swallowing dysfunction. Classically, injury to the glossopharyngeal nerve in this region may impair the ability of the soft palate to rise sufficiently with swallowing to prevent nasopharyngeal liquid reflux.

- When these steps are safely completed, the ICA may be adequately exposed for reconstruction up to the level of C2 (**FIG 8**). Further exposure to the level of C1 following this course requires styloidectomy and/or preoperative mandibular subluxation.
- Distal dissection may also be facilitated by mobilization of the parotid gland and facial nerve. This is most safely accomplished with assistance from otolaryngologists or craniomaxillofacial surgeon. To provide this method of exposure, the skin incision is carried cephalad anterior to the ear (**FIG 9**). This enables mobilization of the parotid gland superiorly and medially.
- The parotid fascia is entered and the branches of the facial nerve are dissected, identified, and protected before dividing the posterior belly of the digastric muscle.
- Care is again taken to identify the glossopharyngeal nerve and the motor fibers of the vagus nerve (**FIG 10**).
- Distal control of the ICA at high C1-C2 level may require specialized instrumentation. Small detachable occluding clamps (such as the Heifetz or Yasargil clips) may provide improved exposure compared to traditional "handled" vascular clamps in this region. When used, however,

FIG 9 ● If further exposure of the ICA is required and mandibular subluxation is not feasible, incision can be carried in front of the ear for mobilization of the parotid gland.

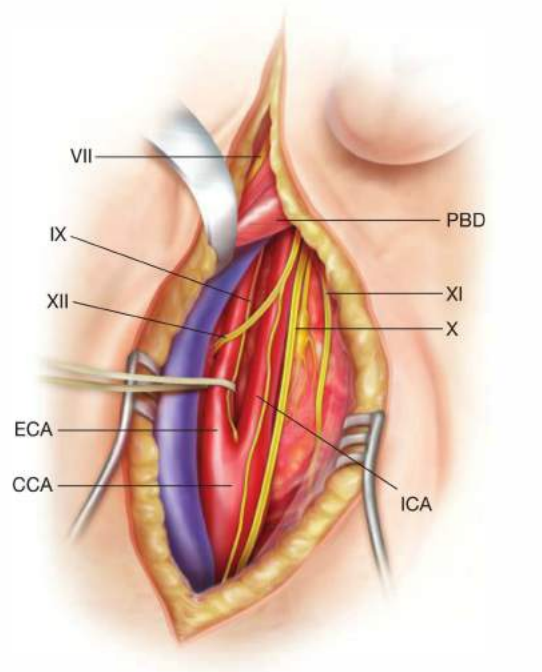

FIG 10 ● Once the parotid fascia is entered, the branches of the facial nerve (VII) are identified followed by the division of the posterior belly of the digastric muscle (PBD). Dissection is then carried anterior to the ICA from the hypoglossal nerve (XII) distally to identify the glossopharyngeal nerve (IX). Motor fibers from the vagus nerve (X) are carefully identified and preserved.

care must be taken to avoid clamp dislodgement in this crowded and moving field, which when it does happen usually does so at the maximally inconvenient time.

- As an alternative to distal clamp control, short occluding intraluminal catheters can be used, such as a #2 Fogarty embolectomy catheter with stopcock. Extreme care must be taken in positioning and deploying embolectomy balloons in this area, however, as inflation within the petrous portion or overinflation in any region may precipitate dissection, arterial rupture, or thrombosis. Only the lowest amount of inflation required to prevent back-bleeding should be used. The carotid artery is thin-walled at this level and easily traumatized by balloon inflation. Late complications also include pseudoaneurysm or arteriovenous fistula formation. The inflated catheter should be secured to prevent its migration. Stay sutures may be placed in the distal carotid to maintain access should control be lost due to reflux of the balloon from the distal artery or balloon puncture during suture closure of the anastomosis.

RETROJUGULAR APPROACH TO THE DISTAL INTERNAL CAROTID ARTERY

Retrojugular Dissection

- A third approach to the distal ICA is provided by retrojugular access. The internal jugular (IJ) vein angles anteriorly as it ascends from the base of the neck to the base of the skull and overlies the distal ICA as the artery approaches the transverse process of C1.
- Using the posterior approach, dissecting behind the IJ vein, obviates the need for hypoglossal exposure and relocation, as that nerve passes anteriorly over the ICA.

Identification of the Spinal Accessory Nerve

- The retrojugular dissection uses the same incisions as other approaches to the distal internal carotid, with the incision made vertically, anterior to the SCM muscle.
- Using this approach, it is essential to identify the spinal accessory nerve where it exits 2 to 3 cm below the edge of the mastoid process, anterior to the SCM. The SCM is fully mobilized to facilitate this exposure.
- Once the spinal accessory nerve is identified and isolated, the IJ vein is dissected along its posterior border. The vagus nerve is identified and reflected anteriorly. With the vein and vagus nerve mobilized anteriorly, the hypoglossal nerve remains anterior to the distal ICA (**FIG 11**).

Identification of the Superior Laryngeal Nerve

- In the retrojugular space, the ICA can be dissected along its posterior lateral wall superiorly whereupon the superior laryngeal nerve will be encountered exiting the vagus nerve and looping around the distal ICA. Often, the superior cervical ganglion can be identified just lateral to this looping point (**FIG 12**).
- For added exposure, the nerve is carefully lifted from the ICA adventitia.

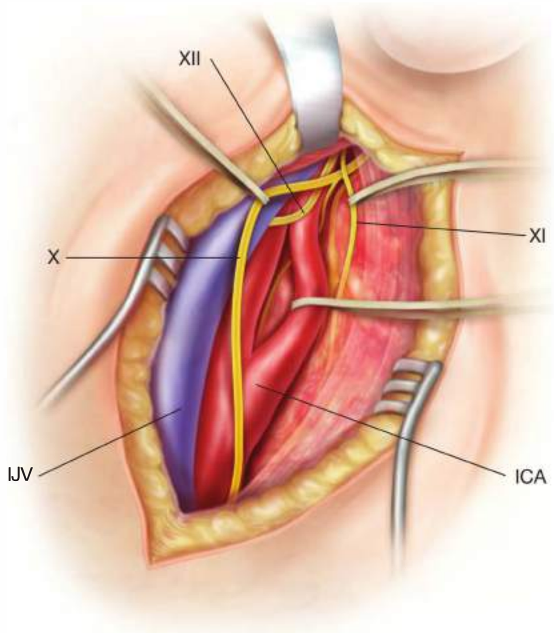

FIG 11 ● Retrojugular exposure of the ICA: Dissection is carried behind the IJ vein and the vagus nerve (X) mobilized anterior to the ICA. Care is taken in identifying the spinal accessory nerve (XI) at the superior aspect of the dissection. This approach avoids mobilization of the hypoglossal nerve (XII) as the plane of dissection remains posterior to the nerve.

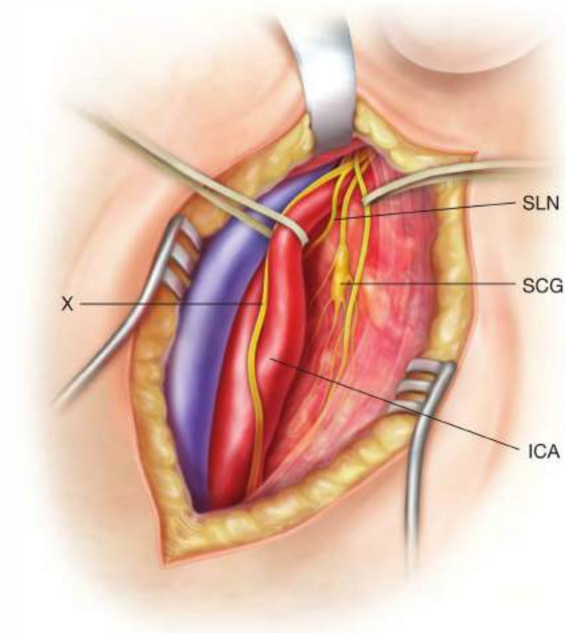

FIG 12 ● At the distal aspect of this retrojugular space, the ICA will be looped by the super laryngeal nerve (SLN) as it comes off the vagus nerve (X). Often, the superior cervical ganglion (SCG) serves as a landmark for where the SLN emanates.

PEARLS AND PITFALLS

Indications	■ Make note of significant radiation or surgery to the neck, which may inform the choice of procedure (surgery vs. stent). ■ Make certain the patient's cranial nerve status is documented, especially in the setting of prior neck operations.
Imaging	■ Although duplex imaging alone is sufficient to plan most routine carotid surgery, cross-sectional imaging (CTA/MRA) provides essential guidance for complex exposures and reconstructive techniques. ■ The status of the circle of Willis should be defined in the course of preoperative planning.
Technique	■ For lesions extending to the C1-C2 cervical spine, consider at a minimum nasotracheal intubation. ■ In extreme situations, mandibular subluxation may provide critical additional degrees of freedom. ■ Mandibular dislocation is not recommended and should not be performed to assist carotid surgery. ■ *Knowledge of cranial nerve anatomy is the most important determinant of success.* ■ Any neural tissue crossing anterior to the carotid bifurcation and the ICA should *not* be divided. ■ Mobilization of diseased arterial segments, including the carotid bifurcation, should be avoided or minimized prior to heparinization. ■ Anterior distal ICA exposure is dependent on the extent to which the hypoglossal nerve can be safely mobilized. ■ Posterior, retrojugular exposure requires early identification of the spinal accessory nerve and anterior reflection of the vagus nerves to visualize the superior laryngeal nerve encircling the distal internal carotid. ■ Balloon occlusion may facilitate far distal carotid control, but overadvancement and overinflation are real risks that must be considered. Placement of stay sutures will facilitate future control maneuvers should the catheter become dislodged.

POSTOPERATIVE CARE

- Following carotid revascularization, the immediate postoperative care is focused on close neurologic surveillance. Patients are recovered typically in an intensive care unit or monitored setting to facilitate ready identification of evolving neurologic deficits.
- Careful blood pressure monitoring and management is also essential. Following carotid revascularization, patients need to avoid the extremes of blood pressure, which may elicit hemodynamic stroke and intracerebral hemorrhage.
- Immediate postoperative (<24 hours) neurologic deficits should be assumed to be thromboembolic in nature, most commonly associated with a technical (surgical) error. Further imaging studies are unlikely to alter decision making and should not delay immediate reoperation. Neurologic deficits arising later in the postoperative period (>24 hours) may be due to intracranial hemorrhage; in these cases, computed tomography (CT) or magnetic resonance (MR) imaging may assist the decision-making process and should be considered when etiologic circumstances are less certain.
- Bleeding complications following carotid surgery are rare but potentially serious or fatal. These may occur during the first several hours after surgery or even later, particularly in patients resuming anticoagulation therapy for existing conditions early in the postoperative period. Recognition and expeditious control of the airway is of utmost importance as a wound hematoma develops, as cord and airway edema rapidly worsen in response to reduced venous and lymphatic drainage. Reopening a carotid incision prior to anesthetic induction may facilitate emergency endotracheal intubation; however, this dramatic maneuver is best performed in a controlled environment with resuscitation equipment available should complications ensue. Ideally, preparations are made for wound decompression as endotracheal intubation is being attempted, with the wound being opened as a last step maneuver prior to emergency cricothyroidotomy. Cord edema in these circumstances may be profound, however, and visualization may not improve sufficiently after hematoma evacuation to enable orotracheal or nasotracheal intubation. Therefore, cricothyroidotomy may become necessary in extreme circumstances, and all carotid surgeons should be facile in this maneuver as a matter of course.

OUTCOMES

- Although carotid endarterectomy is a well-established technique continually refined over several decades, good outcomes are not limited to regional centers of excellence. Data provided to the American Board of Surgery regarding surgical case experience in the 12 months preceding application for recertification in vascular surgery, carotid endarterectomy is recorded as one of the most common procedures performed by contemporary vascular surgeons. A recent query of the Nationwide Inpatient Sample (NIS) identified 259,080 carotid revascularization procedures performed during 2003 and 2004. Although the study examined and compared outcomes of both carotid endarterectomy and carotid artery stenting, endarterectomy outcomes alone demonstrated an impressive overall stroke rate of 0.88% and operative mortality rate of 0.39%.[4] Similarly, data prospectively obtained from National Surgical Quality Improvement Program (NSQIP) participation reviewed 13,622 carotid endarterectomies performed between 2000 and 2003 at 123 Veterans Affairs and 14 private sector academic medical centers demonstrated a combined stroke and death rate of 3.4%.[5]
- Data describing outcome of distal (base of skull) carotid revascularizations is based on more limited, institution-specific case series. In these circumstances, outcomes are more difficult to benchmark. One recent series reported that one of five patients requiring a distal ICA bypass for aneurysm repair suffered a stroke; 60% suffered varying degrees of cranial nerve deficit.[6] The largest experience reported to date is that of Sessa et al.,[7] who reported a 3% and 6% rate of perioperative stroke and restenosis at 1 year, respectively. When distal carotid/skull base exposure appears to be necessary to safely manage an occlusive lesion, consideration should again be given to CAS as a lower risk alternative technique to open endarterectomy or interposition grafting.

COMPLICATIONS

- Stroke
- Cranial nerve injury
- Horner's syndrome
- Seroma
- Infection

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Chapter 6

Vertebral Transposition Techniques and Stenting

Mark D. Morasch

DEFINITION

- Treatment for occlusive lesions involving the origin of the vertebral artery (V1 segment) is undertaken to relieve posterior brain circulation ischemia, otherwise known as vertebrobasilar insufficiency. Revascularization options include open surgical and endovascular techniques. The most common operation is a proximal vertebral to common carotid transposition. Endoluminal treatment includes balloon angioplasty and (typically) stenting.

DIFFERENTIAL DIAGNOSIS

- Other medical conditions mimicking posterior circulation ischemia include postural hypotension, cardiac arrhythmias, anemia, brain tumors, and benign vertiginous states. A thorough investigation consists of ruling out (1) inner ear pathology, (2) cardiac arrhythmias, (3) internal carotid artery stenosis/occlusion, and (4) complications of excessive blood pressure control (Table 1).
- Evaluation of patients with posterior circulation ischemia requires defining the precise circumstances that elicit symptoms. Vertigo, instability, and occasional loss of consciousness often accompany positional changes and standing in older individuals due to reduced sympathetic venous tone. This is particularly common in patients with diabetes. The presence of orthostatic hypotension should be evaluated as a common alternative cause for vertebrobasilar symptoms. Any decreases in basilar artery perfusion pressure may precipitate hemodynamic symptomatology, with or without concomitant vertebral occlusive disease.
- The next most common cause of brainstem ischemia is reduced cardiac output. When suspected, evaluation includes 24-hour Holter monitoring and echocardiography. In patients with vertebrobasilar insufficiency, palpitations may be noted with the onset of symptoms. Transesophageal echocardiography may be necessary to rule out structure heart issues.
- Inner ear pathology, including rare cerebellopontine angle tumors, produces symptoms suggestive of vertebrobasilar insufficiency. Benign vertiginous states should also be considered. Physical examination can alert the physician to the possibility of subclavian steal in patients with differences in brachial blood pressure greater than 25 mmHg or with diminished left upper extremity pulses. Reversed flow in the ipsilateral vertebral artery demonstrated on duplex scanning is pathognomonic for subclavian steal physiology and subclavian steal syndrome in patients with appropriate symptoms at rest or following exercise in the ipsilateral upper extremity.
- Patients may relate symptoms of vertebrobasilar insufficiency to positional changes, including turning or extending their head. These dynamic symptoms usually appear when turning the head to one side. In this circumstance, symptoms may be elicited by extrinsic compression of the dominant or sole vertebral artery (in the case of unilateral occlusion) by adjacent arthritic bone spurs.[1]

Table 1: Nonvascular and Cardiac Conditions that Mimic Vertebrobasilar Ischemia

Cardiac arrhythmia
Pacemaker malfunction
Cardioemboli
Antihypertensive medications
Labyrinthine dysfunction
Cerebellopontine angle tumors
Cerebellar degeneration
Myxedema
Electrolyte imbalance
Hypoglycemia

PATIENT HISTORY AND PHYSICAL FINDINGS

- In general, ischemic mechanisms in vertebrobasilar insufficiency can be categorized as hemodynamic or embolic. Symptoms of vertebrobasilar insufficiency include dizziness, vertigo, drop attacks, diplopia, perioral numbness, alternating paresthesia, tinnitus, dysphasia, dysarthria, and ataxia. When two or more of these symptoms are present, vertebrobasilar ischemia is more likely to be the inciting cause. Unlike other regions of the brain, strokes in the posterior circulation territory occur due to large artery occlusive diseases.
- Patients with "hemodynamic" ischemia experience transient vertebrobasilar symptoms due to inadequate vertebral artery inflow or collateral circulation. Symptoms are typically short lived, repetitive, somewhat predictable, and rarely result in stroke. Postural hypotension may precipitate serious traumatic injury, however, when patients lose their balance with standing.
- Embolic events may also precipitate vertebrobasilar ischemia as well as cerebellar and brainstem infarction. Microemboli from the heart, aortic arch, or any arteries leading directly to the basilar artery may arise from atherosclerotic lesions, intimal defects, repetitive trauma, fibromuscular dysplasia lesions, aneurysms, or dissections. Although much less common than hemodynamic vertebrobasilar insufficiency, when present, microemboli are much more likely to cause fatal events or debilitating infarcts.[2–4]
- Timing of the onset of symptoms following positional changes may help differentiate vertebrobasilar insufficiency from labyrinthine disorders. In the latter circumstance, rapid head movement invokes immediate symptoms. In the case of vertebrobasilar insufficiency, however, a short delay usually precedes the onset of symptoms, including nystagmus.

IMAGING AND OTHER DIAGNOSTIC STUDIES

Duplex ultrasound, an otherwise excellent tool for the assessment of extracranial cerebrovascular disease, has limitations in the diagnosis of vertebral artery pathology. Direct visualization of the second portion is obscured by the transverse processes of C2–C6. As previously mentioned, however, duplex imaging reliably identifies subclavian steal physiology, as well as detect proximal velocity increases consistent with orificial vertebral or proximal subclavian stenosis.[5]

- Magnetic resonance imaging (MRI) provides safe, noninvasive, and detailed evaluation of the aortic arch and great vessels, the extracranial and intracranial arterial vasculature, as well as the presence of mass lesions, fluid collections, or parenchymal defects in the posterior fossa. Contrast-enhanced magnetic resonance angiography (MRA), with three-dimensional reconstruction and maximum image intensity techniques, provides excellent image quality in high resolution (**FIG 1**). As in other applications, however, in low-flow circumstances, excessive signal dropout may result in overestimation of lesion severity based on signal intensity alone.
- In contrast to computed tomographic (CT) imaging, transaxial MRI readily diagnoses both acute and chronic brain infarctions in the posterior fossa. Brainstem infarctions are typically small and as such may be overlooked with noncontrast CT imaging. Brain MRI is performed in symptomatic patients prior to vertebral artery intervention to identify infarctions when they are present and provide baseline images for future comparison.
- Evaluation of vertebral anatomy via catheter-based, contrast arteriography requires acquisition of images in multiple projections to fully evaluate the entire extent of both vertebral arteries. Evaluation begins with the aortic arch to determine the origin of the bilateral vertebral arteries. Anomalous origin of the left vertebral artery, arising directly from the aorta proximal to the left subclavian, is present in 6% of patients. Much less frequently, the right vertebral artery originates from the innominate or right common carotid artery. This anomaly often accompanies an aberrant right subclavian artery, which itself may precipitate symptoms of dysphagia lusoria.
- Usually, right and left posterior oblique projections are sufficient to comprehensively evaluate the V1 (first) vertebral artery segment from the origin to the transverse process of C6. In most patients, the left artery is usually dominant, but a number of normal variants may be encountered, including congenital atresia of either vertebral artery.

FIG 1 ● Vertebral MRA (with the carotid image subtracted).

- The vertebral artery origin may not be visualized adequately with either duplex ultrasonography or MRA. Oblique projections are required during arteriography due to superimposition of the subclavian artery over the vertebral origin. Additional projections, including craniocaudal tube angulation, may also be required to optimize visualization. The presence of a poststenotic dilatation in the first centimeter of the vertebral artery is a clue that should prompt further projections to isolate the origin from the overlying subclavian artery.
- Dynamic arteriography, incorporating provocative positioning, may be required to assess the possibility of extrinsic vertebral artery compression. Finally, delayed imaging may demonstrate reconstitution of patent distal extracranial vertebral arteries through cervical collaterals when the origin initially appears occluded.

SURGICAL MANAGEMENT

- Some degree of vertebral artery orificial stenosis is present in 20% to 40% of patients with other manifestations of cerebrovascular disease.[2] A number of operative approaches will satisfactorily address V1 segment disease and orificial stenosis.[6,7] Vertebral transposition, or repositioning of the origin of the vertebral artery onto the adjacent common carotid artery is the most common. Endoluminal dilatation, with or without stenting, is also appropriate in selected circumstances.

Vertebral to Common Carotid Transposition

- General endotracheal anesthesia is preferred. Positioning supine, with the back of the table slightly elevated toward a chair position with the head rotated away from the planned incision site facilitates additional deep mediastinal exposure when required.
- Proximal vertebral artery exposure is similar to that required for subclavian-to-carotid transposition. One fingerbreadth above the clavicle, a transverse incision is created directly over the two heads of the sternocleidomastoid muscle (SCM). Between the SCM heads, the omohyoid muscle is identified and divided. Lateral retraction of the internal jugular vein and vagus nerve exposes the carotid sheath medially. Maximal proximal carotid artery exposure, facilitated by positioning of the primary operator at head of the patient, is necessary to ensure an optimal result (**FIG 2**).
- The sympathetic ganglia are identified running behind and parallel to the carotid artery. On the left side, the thoracic duct is divided between ligatures to minimize lymphatic leaks. The proximal end should be doubly ligated, avoiding transfixion sutures. Accessory lymph ducts—often seen on the right side—should also be ligated and divided when identified. The entire dissection is confined medial to the prescalene fat pad covering the scalenus anticus muscle and phrenic nerve. These latter structures are left unexposed lateral to the field. The inferior thyroid artery, running transversely across the field, is also ligated and divided.
- The vertebral vein is next identified emerging from the angle formed by the longus colli and scalenus anticus and

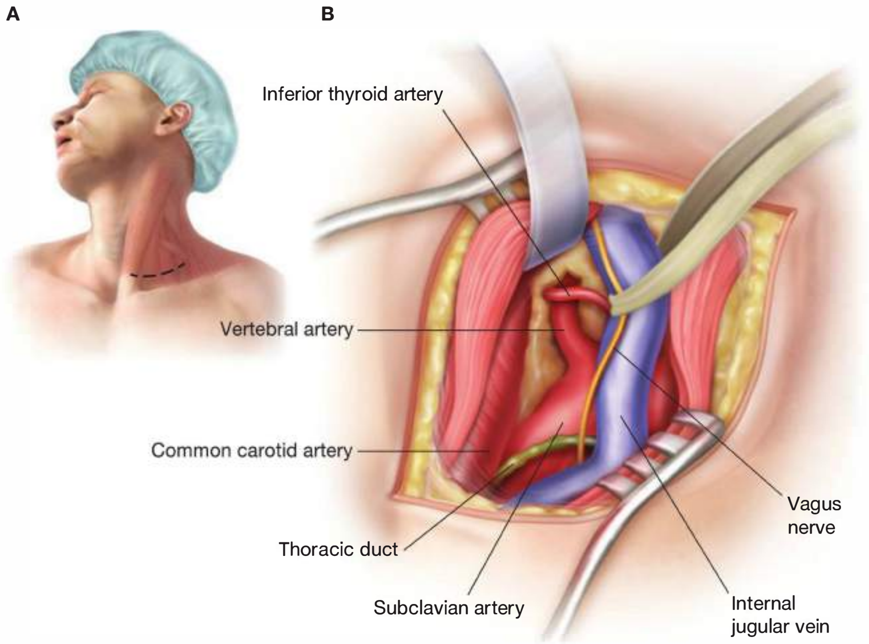

FIG 2 ● **A.** Access to the proximal vertebral artery between the sternocleidomastoid muscle bellies. **B.** Transposition of the proximal vertebral artery to the posterior wall of the common carotid artery.

overlying the vertebral artery and, at the bottom of the field, the subclavian artery. Unlike its sister artery, the vertebral vein has branches. It is ligated in continuity and divided. Below the vertebral vein lies the vertebral artery. It is important to identify and avoid injury to the adjacent sympathetic chain. The vertebral artery is dissected superiorly to the tendon of the longus colli and inferiorly to its origin in the subclavian artery. The vertebral artery is freed from the sympathetic trunk resting on its anterior surface without damaging the trunk or the ganglionic rami. Preserving the sympathetic trunks and the stellate or intermediate ganglia resting on the artery usually requires freeing the vertebral artery from these structures, and after dividing its origin, the latter is transposed anterior to the sympathetics.

- Once the artery is fully exposed, an appropriate site for reimplantation in the common carotid artery is selected. The patient is systemically anticoagulated with intravenous heparin. The distal portion of the V1 segment of the vertebral artery is clamped below the edge of the longus colli with a microclip placed vertically to indicate the orientation of the artery and to avoid axial twisting during its transposition. The proximal vertebral artery is closed by transfixion with 5-0 polypropylene suture immediately above the stenosis at its origin. The artery is divided at this level, and its proximal stump is further secured with a hemoclip. The artery is then brought to the common carotid artery and its free end is spatulated for anastomosis.
- The carotid artery is then cross-clamped. An elliptical 5- to 7-mm arteriotomy is created in the posterolateral wall of the common carotid artery with an aortic punch. The anastomosis is performed in open fashion with continuous 6-0 or 7-0 polypropylene suture while avoiding any tension on the vertebral artery, which tears easily. Before completion of the anastomosis, any slack in the suture is tightened appropriately with a nerve hook, standard flushing maneuvers are performed, and the suture is tied to reestablish flow (**FIG 3**).

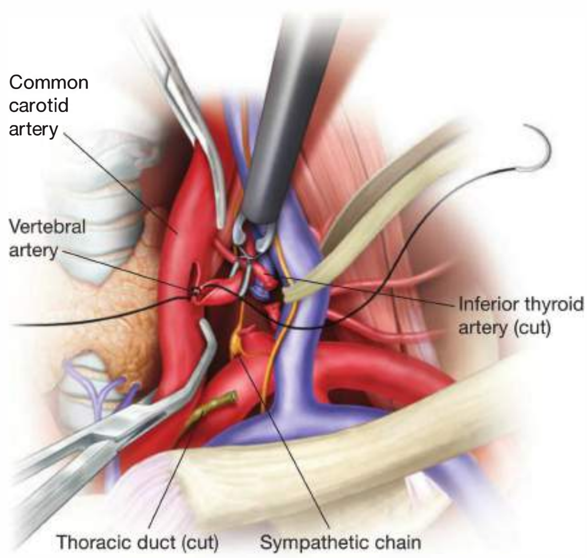

FIG 3 ● Proximal vertebral–to–common carotid transposition.

Vertebral Artery Angioplasty and Stent Placement

- In the past decade, endovascular treatment of vertebral artery disease has gained increasing acceptance. For endovascular intervention, patients are pretreated with dual antiplatelet therapy (aspirin and clopidogrel). The procedure is usually performed with local anesthesia and conscious sedation, enabling continuous neurologic monitoring of the patient. The patients are positioned supine and prepped to allow percutaneous entry into the chosen access vessel. Most cases are performed from a femoral approach (93%), although transbrachial (3%) and transradial (5%) access has also been used as noted in one recent review.[8] The stenotic lesions are crossed and then dilated with 0.014- or 0.018-in guidewires and small coronary-diameter balloons. If a stent is chosen, these are usually bare metal type, but drug elution has also been used. The same 0.014- or 0.018-in guidewires are used as platforms over which the stents are delivered and then deployed. Post-deployment angioplasty may be necessary in selected cases. Procedures can be performed with or without the assistance of embolic protection, although most vertebral arteries are too small to accommodate most distal protection devices.

PEARLS AND PITFALLS

Placement of incision	■ It is important to place the incision medially enough to dissect between the heads of the sternocleidomastoid. An approach lateral to this structure will make the transposition challenging, if not impossible, to complete.
Orientation	■ Enough of the V1 segment of the vertebral artery, up to near where it disappears into the transverse process of C6, needs to be mobilized. Also, plan ahead and see where on the carotid is best to reimplant the vertebral before creating the carotid arteriotomy.
Closure	■ A drain is usually helpful, especially on the left side where the thoracic duct crosses the exposure, just in case a tie comes off of a large lymphatic. The drain allows for early diagnosis of this complication.

POSTOPERATIVE CARE

- Following surgical transposition, absent significant lymphatic drainage from the wound, the patient may be safely discharged on the first or second postoperative day. Similarly, after endoluminal therapy, patients are kept overnight to ensure neurologic stability.

OUTCOMES

- After proximal vertebral–to–common carotid transposition, patency rates at 5 and 10 years equal or exceed 95% and 91%, respectively. When selected appropriately, more than 80% of patients will experience symptomatic relief following proximal surgical reconstruction.[9]
- Appropriate reconstruction and subsequent reperfusion of the brainstem in patients experiencing hemodynamic vertebrobasilar symptoms may also improve hypertension management.
- Overall, retrospective reviews suggest that endoluminal vertebral artery intervention is reasonably safe, although a selection bias exists. A 2005 Cochrane review identified 313 interventions for vertebral artery stenosis, with just over half using stent placement as part of the treatment. The technical success rate was 95%, and the 30-day stroke and death rate was 6.4%.[10]
- Despite high technical success rates, vertebral artery angioplasty alone, especially when used for the treatment of disease at the origin of the vessel, appears to have an unacceptably high rate of restenosis. Adjuvant stent placement adds to the clinical durability but adds potential morbidity such as malposition or potential fracture. In their series of 105 patients who underwent endovascular stenting for symptomatic vertebral artery disease, Jenkins et al.[11] achieved 100% radiographic improvement (residual stenosis ≤30%). The authors reported immediate (30-day) periprocedural risk of death of 1% and periprocedural complication rate of 4.8%. Complications included transient ischemic attack, flow-limiting dissection, hematoma, and catheter-access-site problems. At 1 year of follow-up, six patients had died and five had experienced a vertebrobasilar stroke, and at approximately 2.5 years of follow-up, 70% of patients remained symptom free, but 13% of patients had restenosis requiring retreatment.[11]
- A recent systematic review of the available literature noted a weighted mean technical success rate of 97%. The authors estimated mean periprocedural stroke and death rate from combined angioplasty and stenting to be around 1.1%. Transient ischemic events occurred in 1.5% of patients. Recurrent symptoms occurred in 8% of patients within a reported range of follow-up of 6 to 54 months and greater than 50% restenosis developed in 23% of the subset of patients who underwent follow-up imaging.[8]

COMPLICATIONS

- Proximal vertebral to common carotid transposition has been reported to have a combined stroke and death rate of 0.9%.[9] Among patients undergoing this operation, in one report, there were no deaths or strokes in those who underwent only a vertebral reconstruction. Berguer and coauthors reported four instances of immediate postoperative thrombosis (1.4%). Three of the four patients had vein grafts interposed between the vertebral artery and the common carotid because of a short V1 segment. The grafts kinked and thrombosed. Other complications that are particular to proximal reconstruction include vagus and recurrent laryngeal nerve palsy (2%), Horner's syndrome (8.4% to 28%), lymphocele (4%), and chylothorax (0.5%).
- Periprocedural risks for angioplasty and stenting include access complications, distal embolization and stroke, arterial rupture, stent malposition, and vessel thrombosis or dissection. Later, restenosis and stent fracture are not uncommon (**FIG 4**).

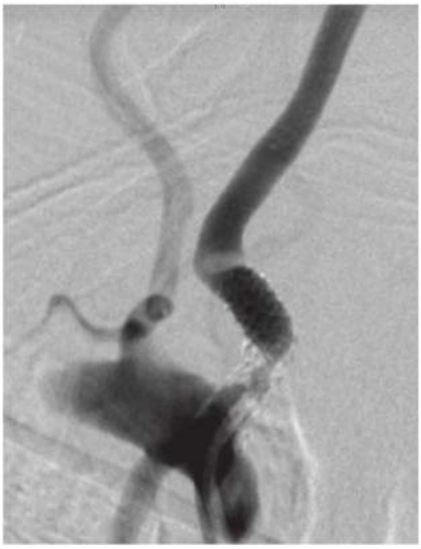

FIG 4 • Vertebral artery stent with fracture and in-stent restenosis (From: Cronenwett JL, Johnston KW, eds. *Rutherford's Vascular Surgery*. 7th ed. Philadelphia, PA: Saunders; 2010, with permission.)

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Chapter 7

Neurogenic Thoracic Outlet Syndrome Exposure and Decompression: Supraclavicular

Robert W. Thompson   Chandu Vemuri

DEFINITION

- Thoracic outlet syndrome (TOS) is a group of conditions caused by compression of one of the neurovascular structures that serve the upper extremity.[1–3] Neurogenic thoracic outlet syndrome (NTOS) is the most frequent of these, occurring in 85% to 90% of thoracic outlet patients. It is caused by compression and irritation of the brachial plexus nerves within the supraclavicular scalene triangle and/or underneath the pectoralis minor muscle tendon in the subcoracoid space (**FIG 1**). NTOS tends to occur in patients between the ages of 15 and 40 years, typically manifesting as neck and upper extremity pain, paresthesias, and functional limitations in the ipsilateral arm. Although relatively uncommon, clinical recognition and appropriate treatment are crucial to optimizing outcome in young active individuals with NTOS-related disability.[4]
- The causes of NTOS include anatomic variations (anomalous scalene musculature, aberrant fibrofascial bands, and/or cervical ribs) and previous neck or upper extremity injury, which promotes scalene/pectoralis muscle spasm, fibrosis, and other pathologic changes.[4] These muscular alterations, in turn, lead to compression and irritation of the adjacent brachial plexus nerves. The presence of a cervical rib is often cited as a risk factor for NTOS; however, few NTOS patients (approximately 10%) have a definable cervical rib, and development of NTOS symptoms are rare in cervical rib patients in the absence of predisposing injury.[5]
- NTOS often occurs in individuals involved in occupational or recreational activities requiring repetitive overhead activities with the arms and/or heavy lifting, occasionally aggravated by injury (e.g., motor vehicle collisions or falls upon the outstretched arm). Other predisposing conditions include low-grade repetitive strain injury (e.g., prolonged keyboard use), poor posture, and dysfunctional shoulder girdle mechanics.
- Surgical treatment for NTOS may be effectively accomplished by several different approaches, including transaxillary 1st rib resection and anterior (supraclavicular) decompression. The supraclavicular approach has long been a mainstay in the surgical

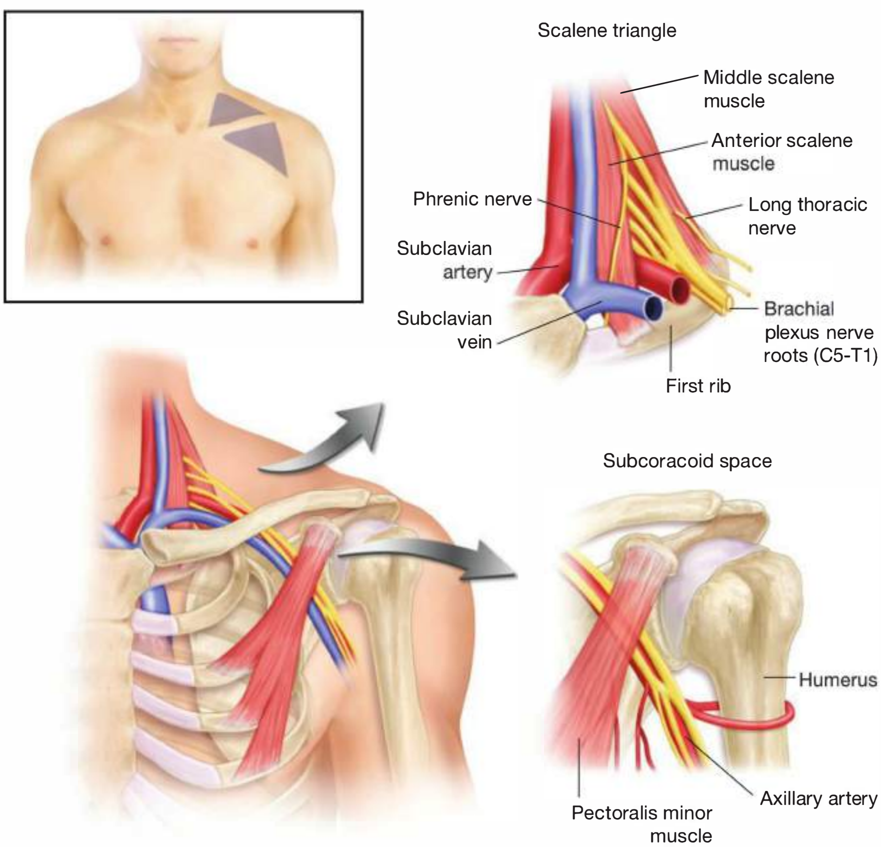

FIG 1 • Anatomy of the thoracic outlet, with emphasis on the supraclavicular scalene triangle and the infraclavicular subcoracoid space.

Table 1: Differential Diagnosis of Neurogenic Thoracic Outlet Syndrome

Acromioclavicular arthropathy	Fibromyalgia and fibromyositis
Arterial atheroembolism	Nerve sheath neoplasm
Brachial plexus (stretch) injury	Pancoast tumor (lung apex)
Carpal tunnel syndrome (median nerve)	Parsonage-Turner syndrome
Cervical dystonia	Psychogenic syndrome
Cervical spine degenerative arthritis	Radial nerve compression (extensor forearm)
Complex regional pain syndrome	Raynaud syndrome
Cervical spine degenerative disc disease	Rotator cuff tendinitis
Cervical spine (muscular) strain	Scleroderma
Cubital canal syndrome (ulnar nerve)	Vasculitis

treatment of NTOS, providing excellent exposure for safe and definitive decompression of the relevant neurovascular structures as well as the flexibility to manage the entire spectrum of circumstances that may be encountered intraoperatively.[6–10]

DIFFERENTIAL DIAGNOSIS

- NTOS-related symptoms may mimic or overlap those observed in other upper extremity neurologic and musculoskeletal disorders, expanding the differential diagnosis (Table 1).[11,12] Successful intervention requires differentiation of NTOS from other cervical–brachial syndromes as well as optimal patient and procedural selection.[13]
- NTOS should be readily differentiated from venous TOS, which produces marked arm swelling, cyanotic discoloration, and distention of subcutaneous veins around the shoulder and chest wall. Venous TOS often presents clinically as axillary-subclavian vein "effort-related thrombosis" (Paget-Schroetter syndrome). NTOS should also be distinguished from arterial TOS, which causes either fixed subclavian artery obstruction or poststenotic aneurysm formation. The former may precipitate arm or hand pain with exercise ("arm claudication"), the latter aneurysm thrombosis and distal embolization, hand ischemia, rest pain, and/or digital ulceration and necrosis.
- Some NTOS patients exhibit severe upper extremity pain and hypersensitivity, with digital swelling and discoloration, suggesting the presence of sympathetic nerve overactivity. In such cases, the coexistence of reflex sympathetic dystrophy (complex regional pain syndrome [CRPS]) should be determined by assessing the symptomatic response to a temporary cervical sympathetic (stellate ganglion) anesthetic block.

PATIENT HISTORY AND PHYSICAL FINDINGS

- Symptoms attributable to brachial plexus nerve compression include pain, numbness, and tingling (paresthesia) in the neck, shoulder, arm, and hand. The distribution of symptoms in the hand often extends beyond that expected for either the median or ulnar nerves, involving all fingers. Patients with NTOS attributable to compression at the pectoralis minor tendon often describe upper anterior chest and axillary pain. The intensity of symptoms of NTOS can vary with the extent of upper extremity activity and are usually reliably exacerbated with arm elevation and abduction.
- Many NTOS patients experience relatively mild symptoms, with gradual progression in severity punctuated by periodic exacerbations. Others experience steady, progressive worsening of symptoms and related disability. Hand muscle weakness and atrophy (Gilliatt-Sumner hand) are rare, typically following long-standing brachial plexus compression due to an associated cervical rib or similar bony anomaly.
- Physical examination typically identifies reproducible tenderness to palpation over the supraclavicular scalene triangle and/or the infraclavicular subcoracoid space (**FIG 2**).
- Most NTOS patients experience recurrent upper extremity symptoms in response to provocative positional maneuvers, such as the upper limb tension test (ULTT) or the 3-minute elevated arm stress test (EAST) (**FIG 2**). Positional dampening of the radial artery pulse at the wrist during arm abduction and external rotation (Adson's test) is nonspecific and inaccurate and is generally not useful in establishing or excluding a diagnosis of NTOS.
- Directed physical examination is performed to determine the presence of cervical spine degenerative disease or peripheral nerve compression (carpal tunnel and cubital canal syndromes) as potential alternative sources of NTOS-like symptoms as well as evidence of arterial or venous compromise to the affected extremity. Signs of increased upper extremity sympathetic tone are also sought, including digital swelling, discoloration, and skin hypersensitivity (allodynia).
- Documentation of patient-reported symptoms and quantification of disability prior to treatment are accomplished by completion of standardized outcomes measurement tools such as the Disabilities of the Arm, Shoulder, and Hand (DASH) questionnaire and quality-of-life instruments.[14] Repeated use of these instruments at various intervals before and after treatment has provided increasing insight into the relative value of alternative management strategies.[15]

IMAGING AND OTHER DIAGNOSTIC STUDIES

- Although imaging and other diagnostic studies may provide helpful ancillary information, there is no definitive test to confirm or exclude the diagnosis of NTOS. Diagnosis remains quintessentially clinical and dependent on experienced pattern recognition.
- Plain anteroposterior chest radiographs will identify a cervical rib when present. No other currently available imaging study adds significant value to the clinical diagnosis of NTOS (**FIG 3**).
- Conventional electrophysiologic tests (electromyography and nerve conduction studies) are often performed to exclude peripheral nerve compression disorders or cervical radiculopathy. These tests are usually negative or nonspecific in NTOS and cannot be used to establish or exclude the diagnosis.
- Vascular laboratory studies (Duplex ultrasound) may detect alterations in upper extremity blood flow attributable to subclavian artery compression during arm elevation. However, positional subclavian artery compression may represent an incidental and unrelated vascular finding and does not establish a diagnosis of neurogenic or arterial TOS. As they do not assess the presence or severity of brachial plexopathy, vascular laboratory studies add little specificity beyond the clinical diagnostic criteria.
- Performance of image-guided anterior scalene and/or pectoralis minor muscle anesthetic blocks may assist the clinical diagnosis of NTOS.[16] A positive block, characterized as temporary relief or improvement in the presenting

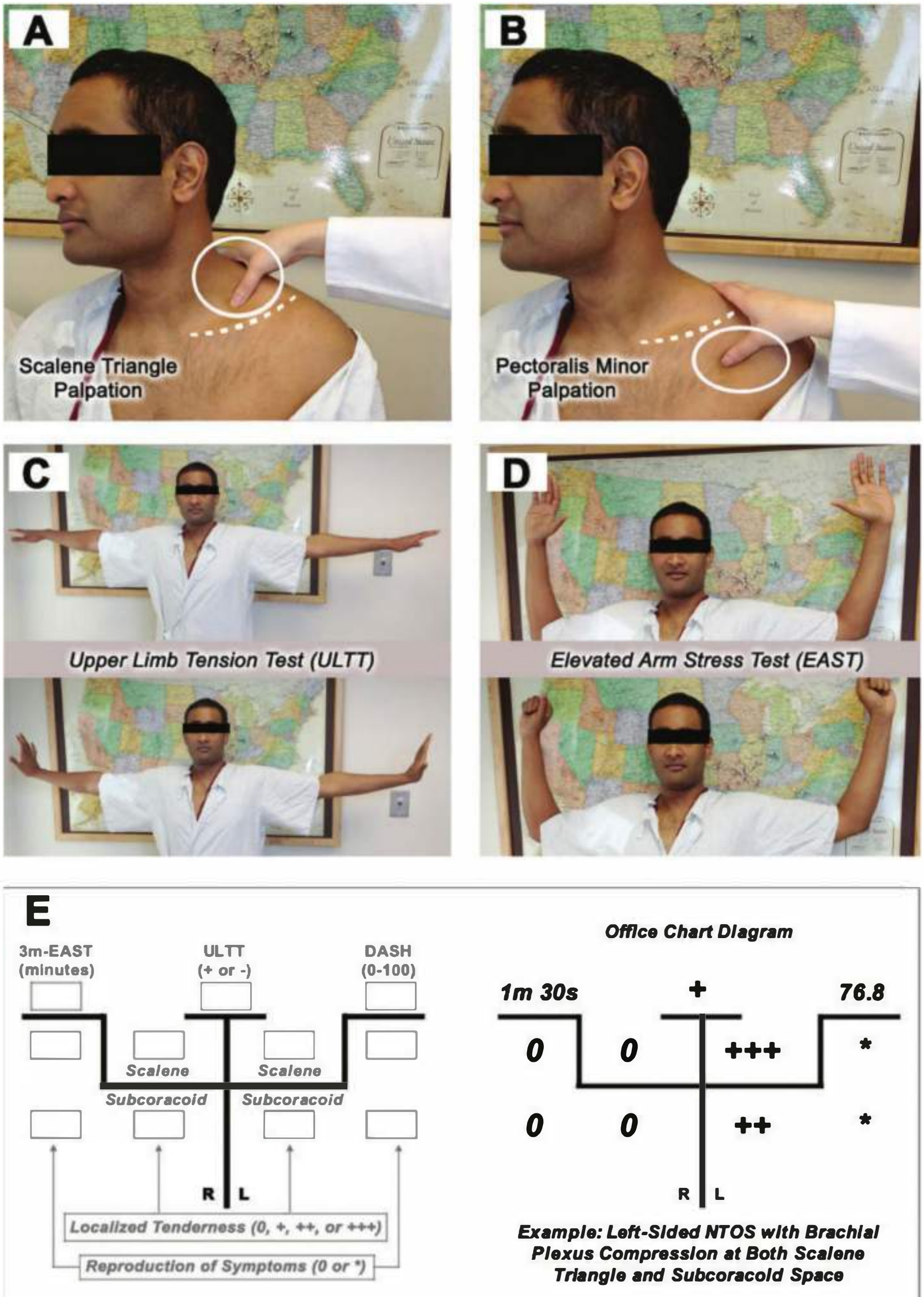

FIG 2 ● Physical examination reveals localized tenderness to palpation over the supraclavicular scalene triangle **(A)** and/or the infraclavicular subcoracoid space **(B)**. The ULTT **(C)** and the 3-minute EAST **(D)** use provocative positional maneuvers that rapidly elicit reproduction of upper extremity symptoms in patients with NTOS. **E.** An office chart diagram is used to easily summarize physical examination findings for patients being evaluated for NTOS.

symptoms, strongly supports the clinical diagnosis of NTOS. A positive block may predict symptomatic relief from surgical decompression and is therefore highly useful in selecting candidates for 1st rib resection. Unfortunately, however, failure of temporary symptom resolution following muscle blockade does exclude the diagnosis of NTOS and should not preclude consideration of surgical management in otherwise compelling clinical candidates.

- Initial treatment for NTOS is based on physical therapy to relieve scalene/pectoralis minor muscle spasm, improve

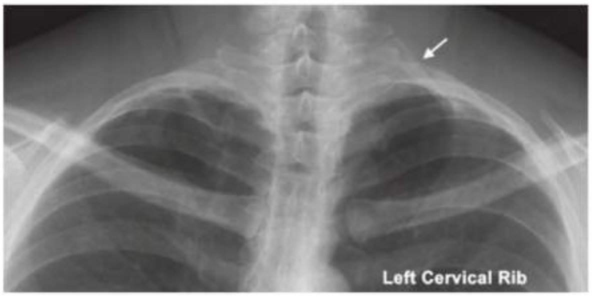

FIG 3 ● A left-sided cervical rib identified by plain chest radiography *(arrow)*.

posture, enhance functional limb mobility, strengthen associated shoulder girdle musculature, and diminish repetitive strain exposure in the workplace. Incorrect approaches to physical therapy can result in worsening of symptoms and failure of conservative management. In many NTOS patients, significant symptomatic improvement may be experienced in response to physical therapy, particularly in the first 4 to 6 weeks. Because NTOS is commonly chronic, however, and subject to acute symptomatic "flare ups" (often related to overuse activities or new injury), such patients should continue prescribed physical therapy exercises during long-term follow-up. Patients that fail a conscientious and effective physical therapy, as well as alternative conservative measures, are referred for consideration of surgical intervention.

SURGICAL MANAGEMENT

- Supraclavicular decompression (scalenectomy, 1st rib resection, and brachial plexus neurolysis) is recommended on the basis of (1) sound clinical diagnosis of NTOS, (2) substantial resulting disability (interference with daily activities and/or work), and (3) an inadequate response to standard physical therapy. Supraclavicular decompression may also provide relief from persistent or recurrent NTOS symptoms following prior surgery, particularly when continued conservative measures prove ineffective.
- For patients with symptoms referable to the subcoracoid space, release of the pectoralis minor tendon should be included in the supraclavicular thoracic outlet decompression procedure. Pectoralis minor tenotomy may also be performed as a stand-alone procedure when nerve compression symptoms are limited to this area.[17,18]
- Decompression should be performed as a staged, sequential procedure in patients with bilateral NTOS symptoms. The initial supraclavicular decompression, with or without pectoralis minor tenotomy, is performed on most symptomatic or dominant extremity. If symptoms remain present or progress, contralateral supraclavicular decompression may be performed within 6 to 12 weeks of the initial procedure. Normal phrenic nerve function should be verified on the side of the previous procedure, by chest fluoroscopic examination, before contralateral intervention.

Preoperative Planning

- The supraclavicular surgical site is marked in the preoperative holding area, including the subcoracoid space when concomitant pectoralis minor tenotomy is planned. Prophylactic antibiotics are administered within an hour of the planned procedure.

Positioning

- After the induction of general endotracheal anesthesia, the patient is positioned supine with the head of the operating table elevated 30 degrees. The neck is extended and turned to the opposite side; a small inflatable pillow is placed behind the shoulders; and the neck, chest, and affected upper extremity are prepped into the field. The arm is wrapped in stockinette to permit free range of movement during the operation and then held comfortably across the abdomen (**FIG 4**). Lower extremity sequential compression devices are used for thromboprophylaxis. Neuromuscular blocking agents are not used following the initial induction of anesthesia.

FIG 4 ● Patient position and planned incisions for left-sided supraclavicular thoracic outlet decompression with pectoralis minor tenotomy.

SUPRACLAVICULAR DECOMPRESSION

Incision and Mobilization of the Scalene Fat Pad

- A transverse neck incision is made parallel to and just above the clavicle, beginning at the lateral edge of the sternocleidomastoid muscle and extending to the anterior edge of the trapezius muscle. The incision is carried through the subcutaneous layer, the platysma muscle is divided, and subplatysmal flaps are developed to expose the scalene fat pad. The sternocleidomastoid muscle is retracted medially but is not divided (**FIG 5**).
- One of the keys to simplifying the supraclavicular exposure is proper mobilization and lateral reflection of the scalene fat pad. This begins with detachment of the fat pad along the lateral edge of the internal jugular vein and the superior edge of the clavicle, with ligation of small blood vessels and lymphatic tissues. The thoracic duct, usually observed near the junction of the internal

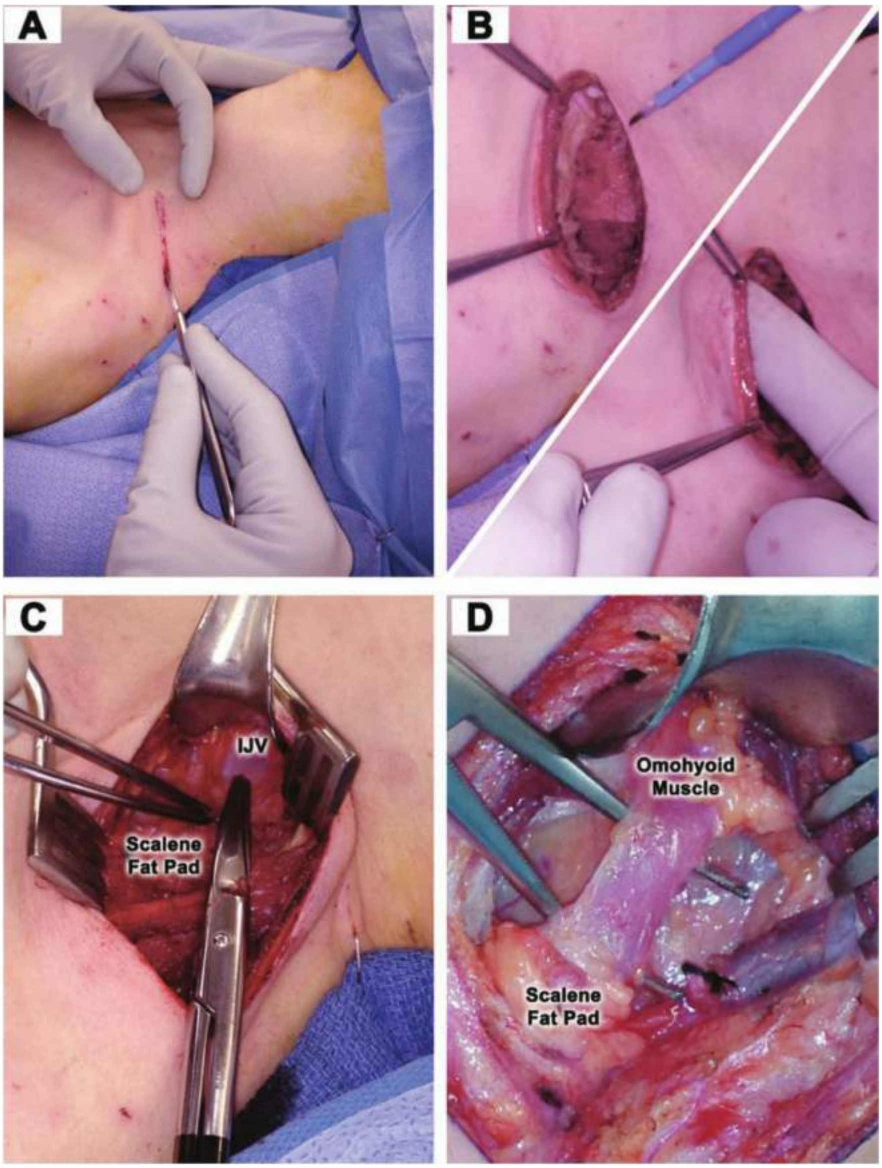

FIG 5 ● **A.** The skin incision is made just above and parallel to the clavicle, extending from the lateral border of the sternocleidomastoid muscle to the anterior border of the trapezius muscle. **B.** Subplatysmal flaps are created to expose the underlying scalene fat pad. The scalene fat pad is mobilized, beginning with its medial attachments to the internal jugular vein *(IJV)* **(C)**, and the omohyoid muscle is divided **(D)**.

Table 2: Critical Views Obtained during Supraclavicular Thoracic Outlet Decompression

1. View of the operative field after lateral reflection of the scalene fat pad, with visualization of the internal jugular vein, anterior scalene muscle, phrenic nerve, brachial plexus, subclavian artery, middle scalene muscle, and long thoracic nerve
2. View of the lower part of the anterior scalene muscle where it attaches to the 1st rib, with space sufficient to allow a finger to pass behind the anterior scalene muscle and in front of the brachial plexus and subclavian artery, prior to division of the anterior scalene muscle insertion from the top of the 1st rib
3. View of the upper part of the anterior scalene muscle at the level of the C6 transverse process, in relation to the C5 and C6 nerve roots, prior to division of the anterior scalene muscle origin
4. View of the insertion of the middle scalene muscle on the 1st rib, with each of the five nerve roots of the brachial plexus and the subclavian artery retracted medially and the long thoracic nerve retracted laterally, prior to division of the middle scalene muscle insertion from the top of the lateral 1st rib
5. View of the posterior neck of the 1st rib, with the T1 nerve root passing from underneath the rib to join the C8 nerve root to form the inferior trunk of the brachial plexus, prior to division of the posterior 1st rib
6. View of the anterior portion of the 1st rib, with placement of the rib shears medial to the scalene tubercle, prior to division of the anterior 1st rib

jugular and subclavian veins on the left side (a prominent accessory thoracic duct may also exist on the right side), may be ligated and divided. The omohyoid muscle is routinely divided (**FIG 5**).

- The scalene fat pad is progressively elevated in a medial to lateral direction, by gentle fingertip dissection over the surface of the anterior scalene muscle. The phrenic nerve is observed passing in a lateral to medial direction as it descends along the muscle surface. Gentle manipulation of the phrenic nerve produces a "dartle" (diaphragmatic startle) response.
- Upon further lateral rotation of the scalene fat pad, the brachial plexus nerve roots (posterior and lateral to the anterior scalene muscle) and the middle scalene muscle (behind the brachial plexus) are brought into view. The lateral aspect of the 1st rib is palpated and visualized, and the long thoracic nerve is identified as it emerges from the body of the middle scalene muscle to course past the lateral part of the 1st rib. The scalene fat pad is then held in position with several silk retraction sutures and the exposure is maintained with a Henley self-retaining retractor (using the third arm to hold the edge of the sternocleidomastoid muscle). The resulting exposure represents the first and most important of six "critical views" to be obtained during supraclavicular decompression (Table 2) (**FIG 6**).

Anterior Scalenectomy

- Attention is turned to the insertion of the anterior scalene muscle on the 1st rib. At the lower lateral edge of the anterior scalene muscle, the subclavian artery and brachial plexus are carefully mobilized until a fingertip can be easily passed behind the muscle just above the 1st rib, thereby displacing the neurovascular structures posterolaterally. Blunt fingertip dissection is continued behind the muscle to its medial edge, taking care to avoid the phrenic nerve. Once the insertion of the anterior scalene muscle onto the 1st rib has been isolated under direct vision to protect the phrenic nerve, the subclavian artery, and the brachial plexus, it is sharply divided from the top of the bone with scissors (**FIG 7**).
- The end of the divided anterior scalene muscle is elevated and its attachments to the underlying extrapleural fascia are sharply divided (electrocautery is not used to avoid inadvertent nerve injury). Muscle fibers extending from the posterior aspect of the muscle often pass around the subclavian artery to form a tethering "sling" and should also be resected to fully release the artery. Any scalene minimus muscle fibers found to be present (passing between the roots of the brachial plexus) are divided as the anterior scalene muscle is mobilized. As the anterior scalene muscle is lifted further, it is passed underneath and medial to the phrenic nerve and its posterior attachments are divided with direct visualization and protection of the upper brachial plexus nerve roots. Dissection of the muscle is carried superiorly to its origin on the C6 transverse process, which is easily palpated in the upper aspect of the operative field (the apex of the "scalene triangle"). The anterior scalene muscle is then divided with scissors from its origin on the transverse process under direct vision and the entire muscle is removed, with a

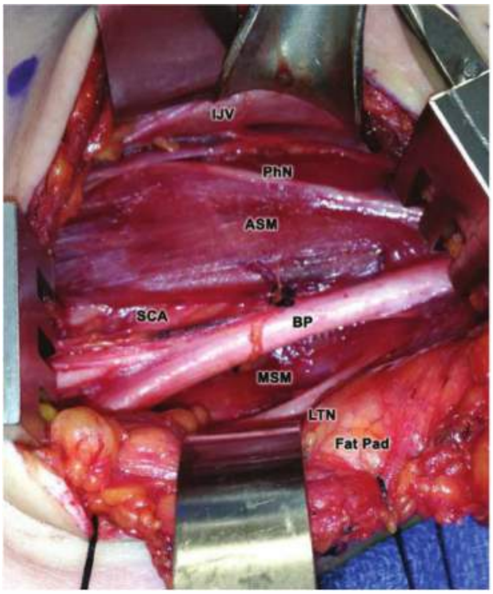

FIG 6 ● Following lateral reflection of the scalene fat pad, direct visualization is obtained of the internal jugular vein *(IJV)*, anterior scalene muscle *(ASM)*, phrenic nerve *(PhN)*, brachial plexus *(BP)*, subclavian artery *(SCA)*, middle scalene muscle *(MSM)*, and long thoracic nerve *(LTN)*.

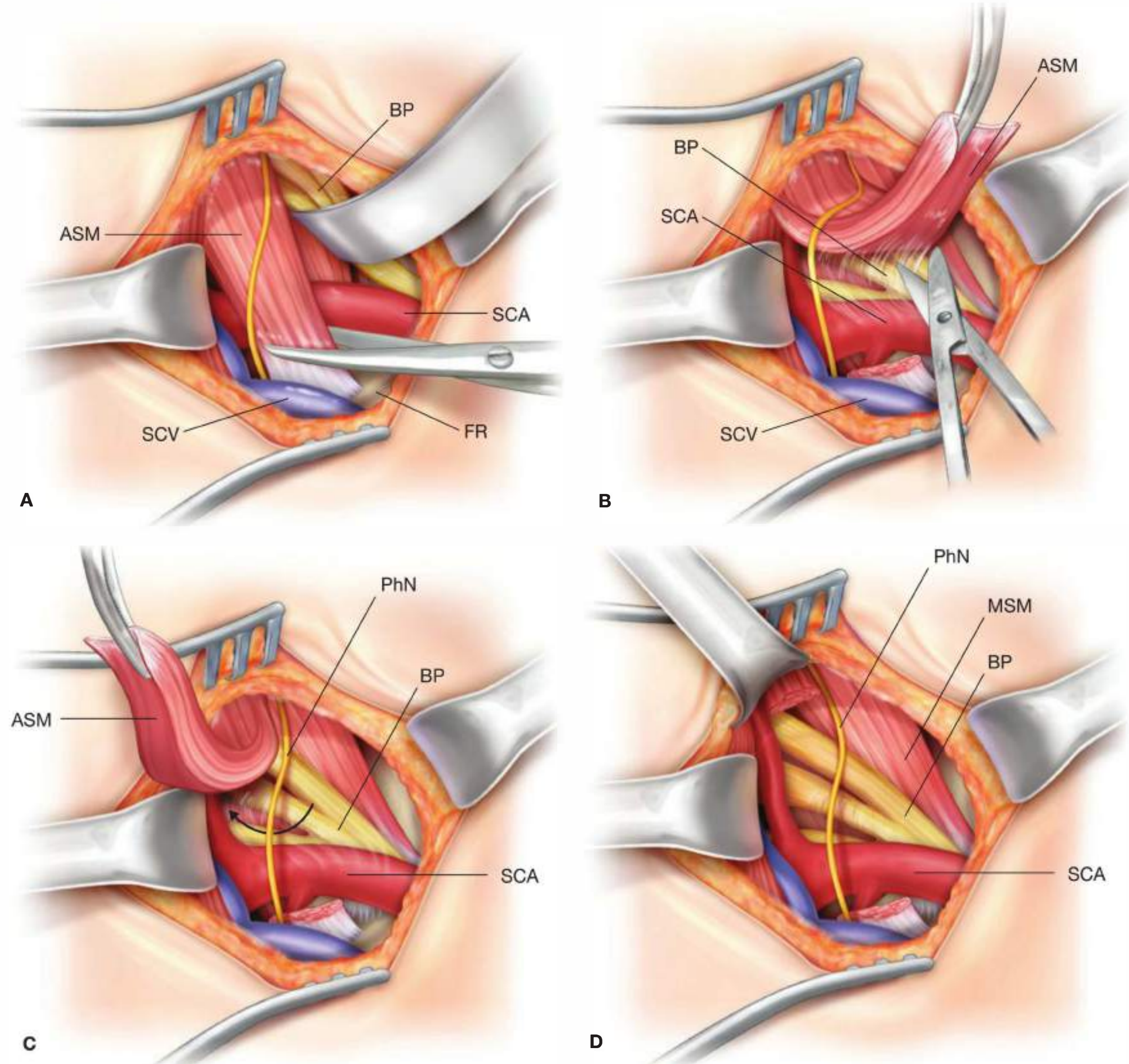

FIG 7 ● **A.** The anterior scalene muscle (ASM) insertion is isolated by displacing the underlying subclavian artery (SCA) and brachial plexus (BP), using blunt fingertip dissection behind the muscle, and the muscle is sharply divided from the top of the 1st rib. **B.** The end of the divided anterior scalene muscle is lifted and sharply dissected free of structures lying behind the muscle, including the subclavian artery. **C.** As it is mobilized, the anterior scalene muscle is passed underneath and to the medial side of the phrenic nerve (PhN). **D.** The dissection is carried up to the level of the C6 transverse process where the anterior scalene muscle can be safely divided from its origin and removed.

typical specimen weighing 5 to 10 g. Any minor bleeding from the edge of the divided muscle origin is controlled with small polypropylene sutures rather than electrocautery, given the proximity of the nerve roots (FIG 7).

- Anomalous fibrofascial bands may be observed after anterior scalene muscle resection, typically passing in front of the lower brachial plexus nerve roots. These structures are also resected as they are encountered to ensure thorough decompression and full nerve root mobility.

Mobilization of the Brachial Plexus and Middle Scalenectomy

- The brachial plexus nerve roots are next separated from the front edge of the middle scalene muscle. Blunt fingertip dissection along the lateral aspect of the nerves is used to extend the exposure deeper to the inner curve of the 1st rib and the extrapleural space, and a small malleable retractor is placed between the brachial plexus

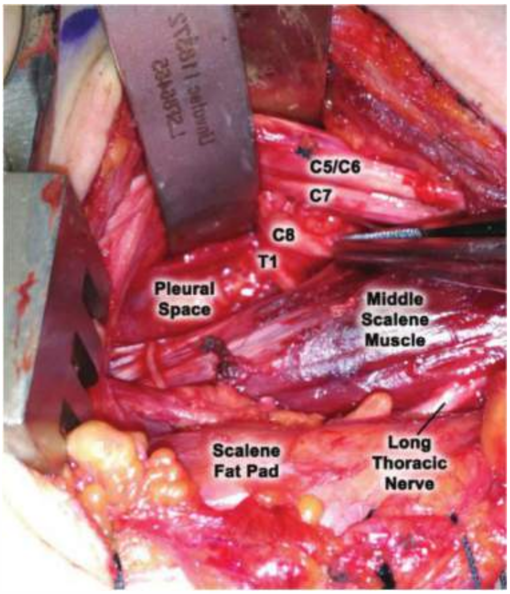

FIG 8 ● The brachial plexus is separated from the anteromedial border of the middle scalene muscle down to the level of the 1st rib and extrapleural fascia and gently retracted medially to visualize all five nerve roots (C5 to T1).

nerves and the middle scalene muscle. With gentle medial retraction of the brachial plexus, each nerve root from C5 to T1 is sequentially identified (**FIG 8**).

- The transverse cervical artery and vein should be ligated and divided where they pass through the brachial plexus and middle scalene muscle to avoid bleeding should these vessels be avulsed during retraction.
- A second malleable retractor is placed lateral to the middle scalene muscle and 1st rib, to displace the long thoracic nerve posteriorly. The oblique attachment of the middle scalene muscle along the top of the posterolateral 1st rib is exposed. This muscle insertion is carefully divided from the surface of the bone with the electrocautery, using a periosteal elevator as the dissection proceeds posteriorly, extending to a point on the 1st rib that is parallel with the underlying T1 nerve root. The bulk of the middle scalene muscle anterior to the long thoracic nerve is then sharply excised, with a typical specimen weight of 3 to 8 g (**FIG 9**). Minor bleeding from the cut edge of the middle scalene muscle should be controlled with sutures rather than the electrocautery to avoid thermal injury to the C8 nerve root or long thoracic nerve.

First Rib Resection

- Once the scalenectomy has been completed, the intercostal muscle attaching to the lateral edge of the 1st rib is separated from the bone with the electrocautery. The 1st rib is fully exposed posteriorly, where the T1 nerve root emerges from underneath the bone to join the C8 nerve root in forming the lower trunk of the brachial plexus. A right-angle clamp is passed underneath the posterior neck of the 1st rib and gently spread to detach additional intercostal tissues. A modified Stille-Giertz rib cutter is inserted around the neck of the 1st rib. After verifying protection of the C8 and T1 nerve roots, the bone is sharply divided. A Kerrison bone rongeur is used to smooth the posterior end of the bone, to a level medial to the underlying T1 nerve root, and the end of the bone is sealed with bone wax (**FIG 9**).
- The free end of the divided posterior 1st rib is elevated, and blunt fingertip dissection is used to separate the remaining extrapleural fascia and intercostal muscle attaching to the undersurface of the rib, progressing anteriorly to the level of the scalene tubercle (the previous site of attachment of the anterior scalene muscle). No effort is made to avoid opening the pleura during 1st rib resection, as the opened pleural space will allow better drainage of postoperative fluids away from the brachial plexus (which might otherwise promote perineural adhesions).
- The soft tissues underneath the clavicle, including the subclavian vein, are elevated with a small Richardson retractor. The posterior 1st rib is displaced inferiorly with fingertip pressure to open the anterior costoclavicular space, and the subclavian artery and brachial plexus are displaced laterally with a small malleable retractor. The Stille-Giertz rib cutter is placed around the anterior 1st rib, immediately medial to the scalene tubercle (**FIG 10**). The 1st rib is then divided under direct vision, and the intact specimen is extracted from the operative field (**FIG 11**). The remaining anterior end of the 1st rib is remodeled to a smooth surface with a bone rongeur, to a level well underneath the clavicle. Oxidized cellulose fabric (Ethicon, Inc., Somerville, NJ) is placed within the bed of the resected 1st rib as a topical hemostatic agent.
- Cervical ribs arise within the plane of the middle scalene muscle, posterior to the brachial plexus and subclavian artery and anterior to the long thoracic nerve. Incomplete cervical ribs typically have a ligamentous extension to the 1st rib, whereas complete cervical ribs attach to the lateral 1st rib in the form of a true joint. The posterior portion of a cervical rib is thereby readily encountered during dissection of the middle scalene muscle and is divided in a manner similar to the posterior 1st rib. The anterior attachment of the cervical rib is then divided and the bone is removed prior to 1st rib resection. When there is a true joint between a complete cervical rib and the 1st rib, the anterior portion of the cervical rib is left attached while the 1st rib resection is completed, and the two are removed together as a single specimen (**FIG 11**).

Brachial Plexus Neurolysis

- The last step of supraclavicular decompression is to fully mobilize each of the individual nerve roots contributing to the brachial plexus. Each nerve root from C5 to T1 is meticulously dissected free of any adherent perineural fibrous scar tissue that might impair

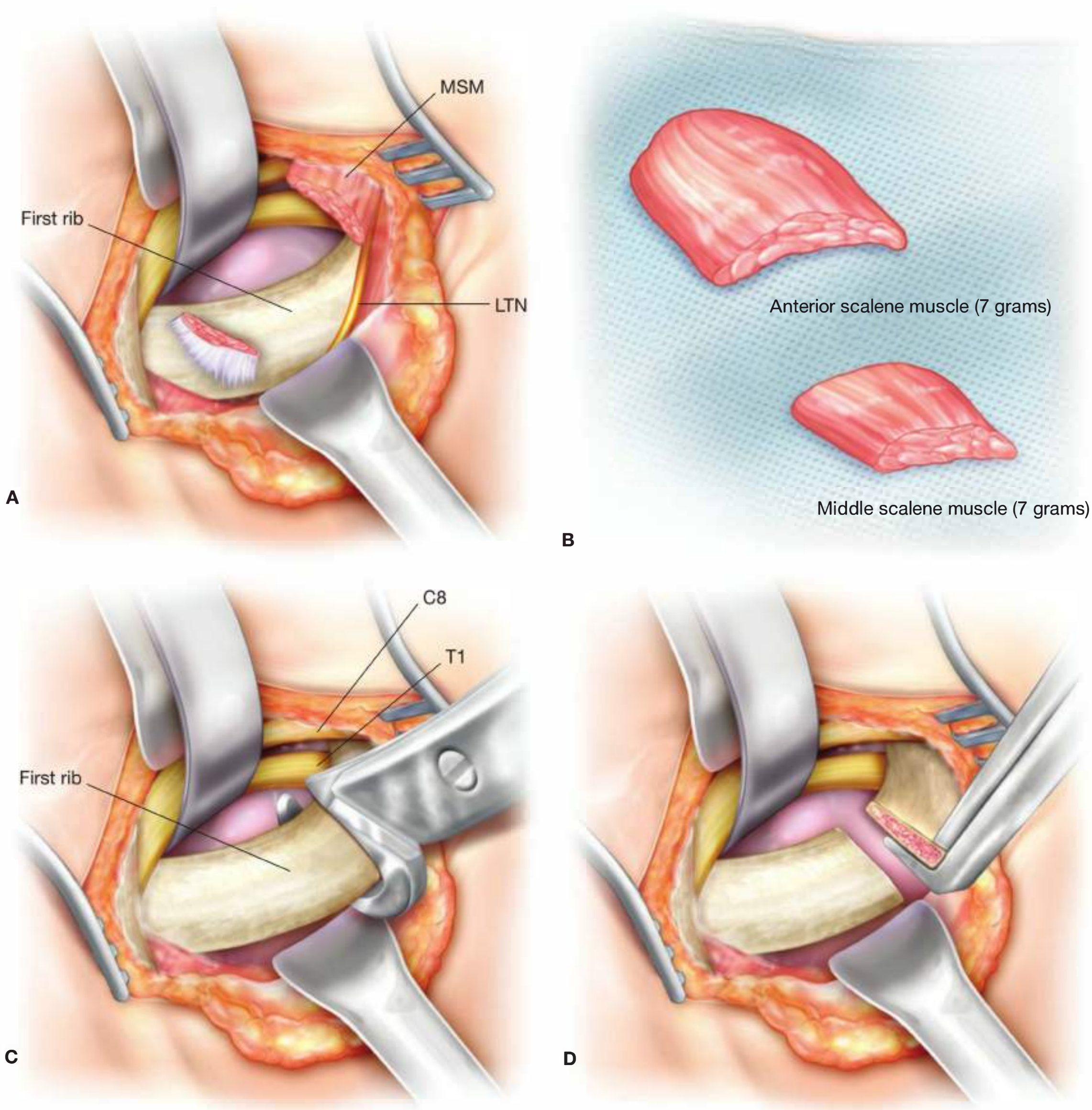

FIG 9 ● **A.** After detaching the middle scalene muscle (MSM) from the top of the posterolateral 1st rib using the electrocautery, the muscle tissue lying anterior to the long thoracic nerve (LTN) is excised. **B.** Typical operative specimens of the anterior and middle scalene muscles. **C.** The posterior 1st rib is exposed with visualization of the C8 and T1 nerve roots, and the rib is divided with a modified Giertz-Stille rib cutter. **D.** The posterior edge of the 1st rib is further remodeled with a Kerrison rongeur to obtain a smooth edge immediately medial to the T1 nerve root.

mobility (external neurolysis). Inspection of the most proximal aspect of the C8 and T1 nerve roots will often reveal a small fibrofascial band overlying these nerves, which should be specifically sought out and resected. This aspect of the operation is not considered complete until each nerve root has been completely cleared throughout its course in the operative field (**FIG 12**).

Drain Placement and Closure

- Upon the completion of supraclavicular decompression, the apex of the pleural membrane is opened to promote postoperative drainage of fluid into the chest cavity, away from the brachial plexus. 19-Fr closed suction drain is placed through a separate stab wound into the operative field, placed posterior to the brachial plexus with its

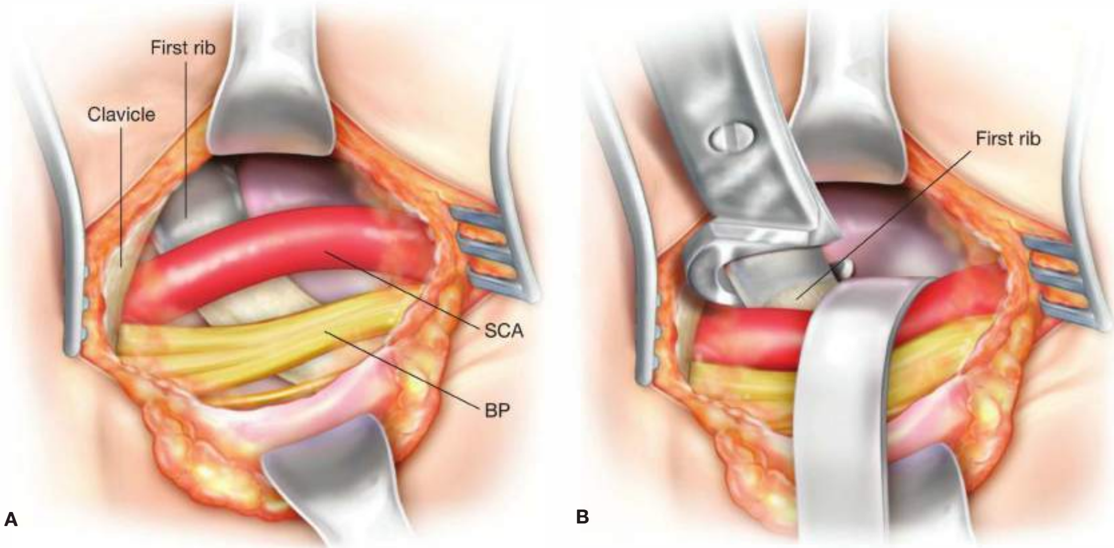

FIG 10 ● **A.** With the posterior end of the 1st rib pushed downward to open the anterior costoclavicular space, the anterior portion of the 1st rib is exposed underneath the clavicle and the subclavian vein. **B.** The subclavian artery (SCA) and brachial plexus (BP) are protected, and the anterior 1st rib is divided with a rib cutter immediately medial to the scalene tubercle.

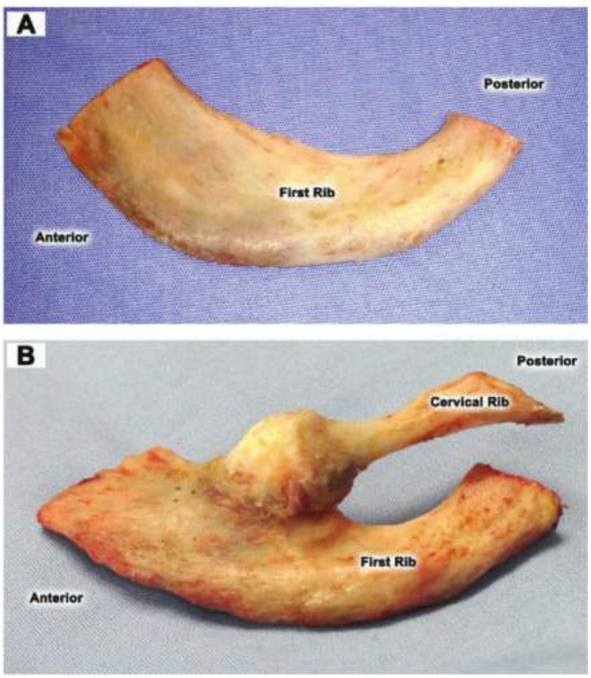

FIG 11 ● Operative specimens following 1st rib resection **(A)** and following combined resection of a cervical rib and 1st rib **(B)**.

tip extending into the posterior pleural space. Two multihole perfusion catheters are placed within the wound, positioned adjacent to the brachial plexus and within the bed of the resected 1st rib, and connected to an osmotic pump for continuous postoperative infusion of local anesthetic (0.5% bupivacaine for 3 days). A bioresorbable polylactide film (Ethicon, Inc., Somerville, NJ) is placed around the brachial plexus to suppress development of postoperative perineural fibrosis and held in place with several 5-0 polydioxanone sutures. The scalene fat pad is restored to its anatomic position overlying the brachial plexus and held in place with several tacking sutures to the back of the sternocleidomastoid muscle and to the periclavicular subcutaneous fascia. The platysma muscle layer is reapproximated with interrupted sutures and the skin is closed with an absorbable subcuticular stitch.

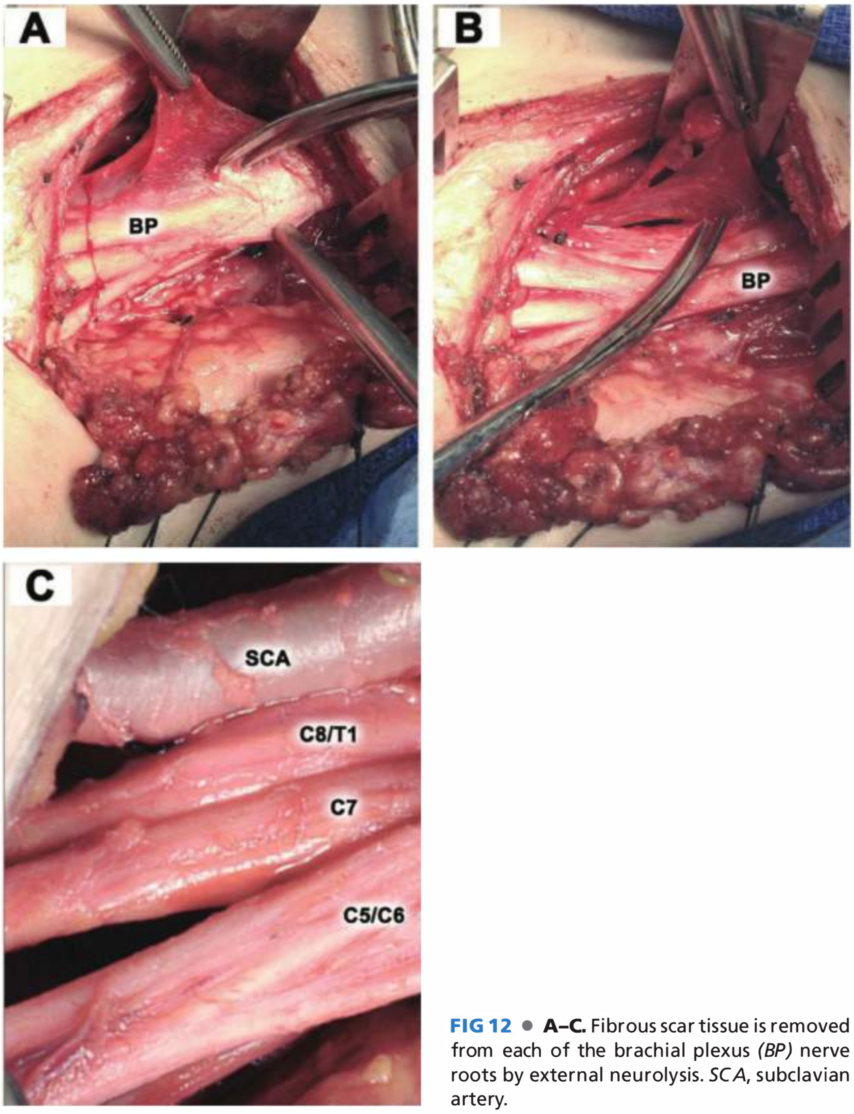

FIG 12 ● **A–C.** Fibrous scar tissue is removed from each of the brachial plexus *(BP)* nerve roots by external neurolysis. *SCA*, subclavian artery.

PECTORALIS MINOR TENOTOMY

Incision and Exposure

- A short vertical incision is made in the deltopectoral groove, beginning at the level of the coracoid process. The deltoid and pectoralis major muscles are gently separated and the plane of deeper dissection is carried medial to the cephalic vein. The lateral edge of the pectoralis major muscle is gently lifted with a small Deaver retractor, and the plane underneath the muscle is separated from the underlying fascia by blunt fingertip dissection. The fascia over the pectoralis minor muscle is exposed, where the muscle can be easily identified by palpation (**FIG 13**).

Division of the Pectoralis Minor Muscle Tendon

- The pectoralis minor muscle tendon is identified where it extends from the anterior chest wall to the coracoid process. The fascia along its medial border is opened and the muscle is encircled using blunt fingertip dissection. The fascia along the lateral border of the pectoralis minor muscle is opened to ensure its separation from the short head of the biceps muscle, which also inserts on the coracoid process. Taking care to protect the underlying neurovascular bundle, the pectoralis minor tendon is then elevated with umbilical tape or rubber tubing and its insertion on the coracoid process is exposed with a small Richardson retractor. A finger is placed behind the muscle to prevent thermal

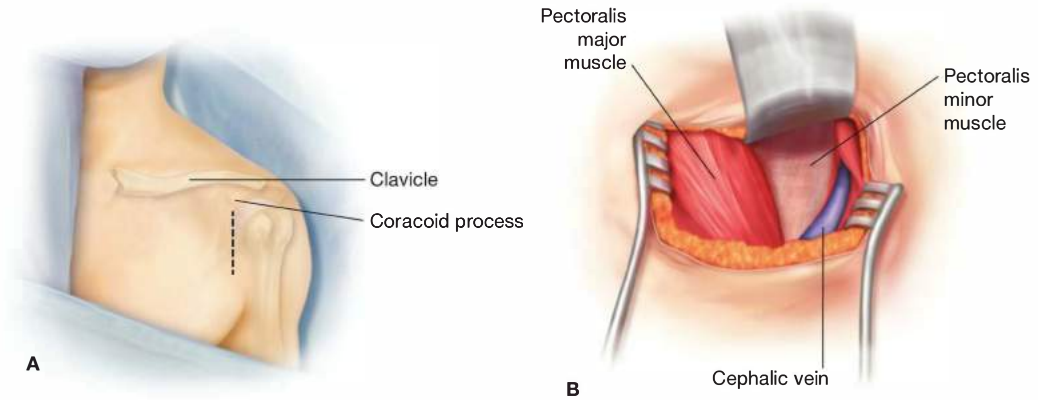

FIG 13 ● **A.** Pectoralis minor tenotomy is performed through a short vertical incision in the deltopectoral groove just below the coracoid process. **B.** The plane of dissection is carried medial to the cephalic vein, and the pectoralis major muscle is lifted to expose the fascia over the pectoralis minor muscle.

injury to the neurovascular structures and the insertion of the pectoralis minor tendon is divided with the electrocautery. After the pectoralis minor muscle has been divided, the lower edge will retract inferiorly to release any compression of the neurovascular bundle (**FIG 14**).

- The inferior edge of the divided pectoralis minor muscle is oversewn with a running suture to ensure hemostasis and to facilitate contraction of the muscle underneath the pectoralis major muscle. The remaining clavipectoral fascia is also incised to the level of the clavicle, along with any other anomalous fascial bands that might be present over the brachial plexus, such as Langer's axillary arch, but no further dissection of the brachial plexus nerves or the axillary vessels is performed. The edge of the pectoralis major muscle is infiltrated with a long-acting local anesthetic and the wound is irrigated, then closed in layers without a drain.

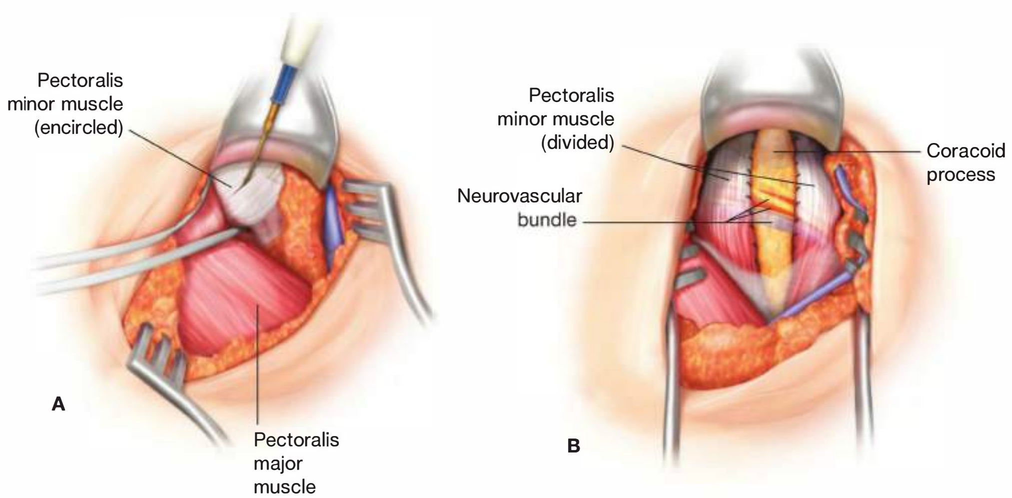

FIG 14 ● **A.** The pectoralis minor muscle is encircled near its insertion on the coracoid process and then divided with the electrocautery. **B.** The retracted edge of the divided pectoralis minor muscle is oversewn with a continuous suture.

PEARLS AND PITFALLS

Indications	■ Operative treatment of NTOS should be based on a sound clinical diagnosis, a substantial level of disability, and failure of symptoms to improve with an adequate trial of conservative management. ■ Imaging studies, electrophysiologic tests, and vascular laboratory examinations add little in the evaluation of NTOS but may be useful in excluding other conditions. ■ A positive anterior scalene muscle block supports the diagnosis of NTOS and indicates a strong likelihood of responsiveness to surgical treatment. ■ Assess the potential contribution of brachial plexus compression at the level of the subcoracoid space and include pectoralis minor tenotomy if present.
Mobilization of the scalene fat pad	■ Avoid division of the sternocleidomastoid muscle. ■ Proper mobilization and lateral reflection of the scalene fat pad is a key step in simplifying supraclavicular exposure for thoracic outlet decompression. This permits the critical view to be obtained in which all of the relevant structures can be visualized in the same operative field (internal jugular vein, phrenic nerve, anterior scalene muscle, brachial plexus, middle scalene muscle, 1st rib, and long thoracic nerve). ■ Ligate and divide the thoracic duct, if necessary, to prevent postoperative lymph leak. ■ Visualize and protect the phrenic nerve.
Anterior scalenectomy	■ Divide all fibers passing from the posterior aspect of the anterior scalene muscle to the subclavian artery and extrapleural fascia. ■ Divide any scalene minimus muscle encountered. ■ Pass the anterior scalene muscle underneath the phrenic nerve to facilitate dissection of the muscle up to its superior origin on the C6 transverse process.
Mobilization of the brachial plexus	■ Visualize all five nerve roots of the brachial plexus. ■ Ligate and divide the transverse cervical vessels where they pass through the brachial plexus and middle scalene muscle.
Middle scalenectomy	■ Visualize and protect the long thoracic nerve. ■ Control minor bleeding from the cut edge of the muscle with silk sutures rather than electrocautery.
1st rib resection	■ Visualize the T1 and C8 nerve roots at the level of the posterior 1st rib, prior to division of the bone, to avoid nerve injury. ■ Remove a small segment of the divided posterior 1st rib to facilitate fingertip dissection underneath the remaining lateral and anterior portions of the bone. ■ Do not try to avoid opening the pleura. ■ Divide the anterior 1st rib at a level medial to the scalene tubercle, underneath the clavicle and subclavian vein, while protecting the subclavian artery and brachial plexus. ■ Resect any cervical rib present along with the 1st rib.
Brachial plexus neurolysis	■ Thoroughly remove fibrous scar tissues from around each nerve root (C5 to T1) of the brachial plexus to avoid one of the causes of persistent symptoms. ■ Resect any small fibrofascial bands overlying the proximal aspect of the C8 and T1 nerve roots.
Drain placement and closure	■ Wrap the brachial plexus with a bioresorbable film to minimize perineural fibrosis. ■ Place a closed suction drain behind the brachial plexus with its tip extending into the pleural space. ■ Use continuous postoperative infusion of a local anesthetic to diminish the need for opiate pain medications.
Pectoralis minor tenotomy	■ Include pectoralis minor tenotomy as part of the supraclavicular decompression if there are concomitant symptoms of NTOS referable to the subcoracoid space. ■ Divide the pectoralis minor tendon close to its insertion on the coracoid process. ■ Oversew the divided edge of the pectoralis minor muscle for hemostasis. ■ It is not necessary to place a separate drain in the subcoracoid space.

POSTOPERATIVE CARE

- An upright chest radiograph is performed in the recovery room and each morning for 3 days, and any small air or pleural fluid collections are observed with the expectation of spontaneous resolution. Postoperative analgesia is provided by continuous-infusion perineural local anesthesia (discontinued on postoperative day 3) and patient-controlled intravenous opiates until adequate pain control is achieved by oral medications alone. Oral narcotics, a muscle relaxant, and a nonsteroidal antiinflammatory agent are routinely prescribed at hospital discharge and for at least several weeks following surgery. Postoperative hospital stay is typically 3 to 4 days. The closed suction drain is removed in the outpatient office when its output is less than 50 mL per day, usually 5 to 7 days after surgery.
- Physical therapy is resumed the day after surgery to maintain range of motion and limit muscle spasm. The patient is allowed to use the extremity as tolerated, with no use of a sling or other restraint. Physical therapy is continued after hospital discharge, with advice to avoid excessive reaching overhead or heavy lifting with the affected upper extremity and other

activities that might result in muscle strain, spasm, and significant pain in the sternocleidomastoid, trapezius, and other neck muscles. Further rehabilitation is overseen by a physical therapist with expertise in the management of NTOS, usually in conjunction with a physical therapist located near the patient, emphasizing a gradual steady return to normal use of the upper extremity.

- The majority of patients are permitted cautious light duty work activities by 4 to 6 weeks. Restrictions on upper extremity activity are progressively lifted between 6 and 12 weeks, when recovery from surgery is typically considered complete. Patients are seen in follow-up every 3 months in the first year to assess long-term results. Physical therapy and other aspects of care are continued as long as necessary to achieve an optimal level of function.

OUTCOMES

- In properly selected patients with disabling NTOS, approximately 80% to 85% can expect a substantial improvement in symptoms and increased functional use of the upper extremity within several months of supraclavicular decompression.[1–3,19] This estimate is elevated to approximately 90% to 95% in those who exhibited a positive anterior scalene/pectoralis minor muscle block prior to treatment. Factors that tend to diminish responsiveness to treatment include extremely long-standing (>5 years) and debilitating symptoms, widespread pain syndromes, multiple previous operations (cervical spine, shoulder, or peripheral nerves), depression, older age (>50 years), and preexisting use of opiate pain medications.
- Patients with long-standing NTOS can often display residual symptoms that may not be completely eliminated by thoracic outlet decompression. Although these symptoms may be tolerable and are expected to gradually improve, the surgeon must provide continuing support and reassurance during the prolonged period of recovery and rehabilitation.
- Patients in the adolescent age-group (<21 years) tend to have even better outcomes than adults, based on assessment of patient-reported survey instruments and postoperative use of opiate pain medications.[14] Patients that have been selected for isolated pectoralis minor tenotomy can exhibit early outcomes similar to those of patients that have undergone combined supraclavicular decompression and pectoralis minor tenotomy but require ongoing follow-up for recurrent symptoms to determine if supraclavicular decompression may be warranted at a later time.[17,18]
- Recurrent symptoms of NTOS that might warrant reoperation occur in 1% to 2% of patients, usually within the first 2 years of treatment. Reoperations for NTOS are generally performed using the supraclavicular approach, because this provides the most complete exposure of the anatomy with the greatest margin of safety.[20] Following lateral reflection of the scalene fat pad, the brachial plexus nerve roots are carefully exposed and mobilized. Great care must be taken during this dissection to avoid nerve and blood vessel injury, given the dense fibrous scar tissue that is usually present within the operative field. Any structures that were retained at the initial operation are then resected, including the scalene muscles, anomalous fibrofascial bands, and/or the 1st rib. A complete brachial plexus neurolysis is performed and the nerves are protected with a bioabsorbable film and soft tissue coverage with the scalene fat pad.

COMPLICATIONS

- Persistent pain, numbness, and/or paresthesias
- Postoperative bleeding, localized hematoma, or hemothorax
- Wound infection (cellulitis or abscess)
- Pleural effusion (serosanguineous)
- Persistent lymph leak, chylothorax
- Brachial plexus nerve dysfunction (temporary or sustained)
- Phrenic nerve dysfunction (temporary or sustained)
- Long thoracic nerve dysfunction (temporary or sustained)
- Recurrent NTOS

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Chapter 8

Neurogenic Thoracic Outlet Syndrome Exposure and Decompression: Transaxillary

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DEFINITION

- In 1821, Sir Astley Cooper recognized the constellation of neurovascular symptoms involving the thoracic outlet. Ochsner called this the *scalenus anticus syndrome* in 1936 and described the presence of muscle abnormalities secondary to repetitive trauma. Peet assigned this condition its contemporaneous moniker *thoracic outlet syndrome (TOS)* in 1966.[1]
- TOS is a condition defined as compression of one or more of the neurovascular structures contained within the thoracic outlet.
- The thoracic outlet is a narrowly defined anatomic region encompassing the space between the neck and the shoulder, cephalad to the thoracic cavity, and beneath the clavicle. From the surgeon's point of view the thoracic outlet can be visualized as an anatomic triangle: the two sides being the anterior and middle scalene muscles with the 1st rib serving as the base of the triangle. The scalene muscles, which originate from the lower cervical spine, may hypertrophy with repetitive neck motion or minor trauma. This hypertrophy is believed to contribute to compression of thoracic outlet structures.
- TOS is subdivided into three discrete entities.
  - Neurogenic
  - Venous
  - Arterial
- Appropriate classification of the type of TOS is important in guiding perioperative management, as well as surgical approach. This chapter focuses on transaxillary decompression and 1st rib resection for neurogenic TOS.

DIFFERENTIAL DIAGNOSIS

- Carpal tunnel syndrome
- Ulnar nerve compression
- Rotator cuff tendinitis
- Pectoralis minor syndrome
- Cervical spine strain
- Cervical disc disease
- Cervical arthritis
- Brachial plexus injury
- Fibromyositis

PATIENT HISTORY AND PHYSICAL FINDINGS

- A careful history and physical examination enables proper classification of TOS.
- The neurogenic form accounts for the majority of cases in modern series (>95%).[2] Symptoms of neurogenic TOS, which is more prevalent in women, include paresthesia; pain; and impaired strength in the affected shoulder, arm, or hand along with occipital headaches and neck discomfort. There is commonly an antecedent history of hyperextension neck injury or repetitive neck trauma. Patients frequently manifest tenderness on palpation in the supraclavicular fossa over the anterior scalene muscle. A careful vascular physical examination should confirm the presence of normal circulation.
  - Three physical examination maneuvers support the diagnosis of neurogenic TOS.
    - Rotation of the neck and tilting of the head to the opposite side elicit pain in the affected arm.
    - The upper limb tension test in which the patient first abducts both arms to 90 degrees with the elbows in a locked position, then dorsiflexes the wrists, and finally, tilts the head to the side. Each subsequent step imparts greater traction on the brachial plexus, with the first two positions causing discomfort on the ipsilateral side and the head-tilt position causing pain on the contralateral side.
    - During the elevated arm stress test (EAST), the patient raises both arms directly above the head and repeatedly opens and closes the fists. Characteristic upper extremity symptoms arise within 60 seconds in patients with neurogenic TOS.
- Approximately 4% of patients with TOS present with venous involvement. **Venous TOS** patients typically present with acute onset of dull aching pain of the upper extremity associated with arm edema and cyanosis. Paresthesias may be present but are due to hand swelling instead of thoracic outlet nerve involvement. A history of strenuous and repetitive work or athletics involving the affected extremity is common, and most patients are young. This specific condition is also known as Paget-Schroetter syndrome or effort vein thrombosis, as the entrapped subclavian vein has progressed to thrombosis. Some patients will present less acutely with nonthrombotic subclavian vein occlusion or stenosis manifested by intermittent swelling with activity. Regardless, the etiology of venous TOS is mechanical, and treatment is ultimately aimed at eliminating not only the venous obstruction but also the muscular bands and ligaments that have entrapped and damaged the vein.
- **Arterial TOS** typically presents in one of three ways: (1) asymptomatic, (2) arm claudication, and (3) critical ischemia of the hand. The majority of these patients have a cervical rib, which may or may not be fused to the 1st rib and is most commonly posterior to the subclavian artery. The etiology is chronic repetitive injury to the subclavian artery as it exits the thoracic outlet. This injury may cause subclavian artery stenosis but more commonly leads to ectasia or a true aneurysm.
  - In asymptomatic patients, a pulsatile mass or supraclavicular bruit can be detected on physical examination.
  - Arm claudication is caused by areas of stenosis which may be static due to long-standing repetitive injury or dynamic, occurring only with arm abduction or extension.

- Critical ischemia is due to emboli of fibrinoplatelet aggregates that originate from an ulcerated mural thrombus in the aneurysmal segment.

PREOPERATIVE EVALUATION AND OTHER DIAGNOSTIC STUDIES

- In young patients (<40 years of age) with a classic presentation of neurogenic TOS, there is no need for extensive preoperative testing.
- Older patients and those with a history of neck trauma should undergo magnetic resonance imaging (MRI) to rule out cervical disc pathology.
- Preoperative physical therapy should be attempted for at least 8 weeks in patients with a diagnosis of neurogenic TOS. The aims of therapy are to improve posture and achieve greater range of motion. Patients with persistent symptoms of neurogenic TOS despite 8 weeks of physical therapy merit surgical intervention. At least 60% of patients will improve with physical therapy and lifestyle alterations.
- A radiographically guided anterior scalene block with local anesthetic (lidocaine) injection may provide a few hours of symptomatic relief. Patients with suspected neurogenic TOS often present with a wide constellation of physical complaints, not all of which are directly attributable to the disorder. A scalene block not only helps confirm the diagnosis but also simulates the expected postoperative result, especially in older patients.[3] This provides the patient and the surgeon reassurance that surgical intervention will be of benefit and demonstrates which symptoms can be reliably expected to improve.
- As an alternative to surgical therapy, patients can then opt for a Botox (Allergan, Irvine, CA) injection. The Botox takes an average of 2 weeks to work and may be repeated. This may provide symptomatic relief for 2 to 3 months, allowing participation in physical therapy. However, not all TOS patients respond to Botox. This practice is especially helpful in patients who have had cervical spine fusions or shoulder operations as they can strengthen the muscles of their neck and back, which may alleviate the TOS symptoms.
- Plain film chest x-ray is recommended for all patients undergoing surgical intervention for TOS to rule out a cervical rib.
- Nerve conduction studies are typically normal in neurogenic TOS but may be useful in ruling out nerve compression such as carpal tunnel or cubital compression syndrome.
- Duplex ultrasonography is the initial diagnostic modality to confirm pathology in patients with arterial TOS. Although useful to confirm axillosubclavian vein thrombosis in patients with suspected venous TOS, venography often supplants it for both diagnostic and therapeutic reasons. Lastly, venous TOS is frequently bilateral.

SURGICAL MANAGEMENT

Surgical Approach

- Patients with a diagnosis of TOS who are appropriate surgical candidates should undergo surgical decompression of the thoracic outlet.
- The optimal approach should be individualized depending on the patient's symptoms, anatomy, and surgeon's experience.
- The transaxillary approach is preferred by many surgeons because of its relative ease, low-risk profile, and documented improvement in patients' quality of life.[4,5] This approach effectively decompresses the thoracic outlet and is generally reserved for patients with neurogenic or venous TOS.
- If vessel reconstruction is anticipated, a different approach should be considered as the transaxillary approach limits vessel exposure.

Surgical Anatomy

- The subclavian artery and the five nerve roots (C5–T1) to the brachial plexus are located within the thoracic outlet. The artery courses anterior to the brachial plexus nerve roots and exits the mediastinum in its course over the 1st rib behind the posterior border of the anterior scalene muscle. The cervical spine nerve roots join to form the initial trunks of the brachial plexus within the thoracic outlet and are located posterior to the subclavian artery. Subsequent merging and branching of these trunks into divisions, cords, and terminal nerves occurs outside the thoracic outlet.
- Other significant nerves within the thoracic outlet are the phrenic and long thoracic nerves.
  - The phrenic nerve receives fibers from C3–C5 and courses in a descending oblique direction from the lateral to the medial edge of the middle portion of the anterior scalene muscle. The phrenic nerve approaches the mediastinum posterior to the subclavian vein.
  - The long thoracic nerve, composed of nerve fibers from C5–C7, passes through the center of the middle scalene muscle and heads toward the chest wall to innervate the serratus anterior muscle.
- The subclavian vein technically does not course through the thoracic outlet. It passes over the 1st rib anterior to the anterior scalene muscle. However, the middle segment of the vein remains susceptible to compression between the anteromedial 1st rib, clavicle, and the subclavius muscle (**FIG 1**). Hypertrophy of the subclavius muscle and tendon may occur in athletes and is often implicated in venous TOS.
- Several anatomic anomalies are relevant to the surgeon, as they predispose patients to the development of TOS.
  - The most common is a cervical rib, and a preoperative chest radiograph is adequate for its detection. When present, cervical ribs appear as extensions of the transverse process of C7. Cervical ribs may be complete or partial, with the anterior end attaching to the 1st rib or floating freely. Additionally, the anterior end may be fibrous and not calcified and thus not completely visualized on chest radiograph. By rigidly confining the thoracic outlet, cervical ribs render the neurovascular structures more prone to compression. Although present in the general population with an incidence of 0.5% to 1%, they are found in 5% to 10% of all TOS patients.
  - A prominent C7 transverse process or bifid 1st rib is also associated with TOS.

Positioning

- General endotracheal anesthesia is induced and sequential compression devices are applied.

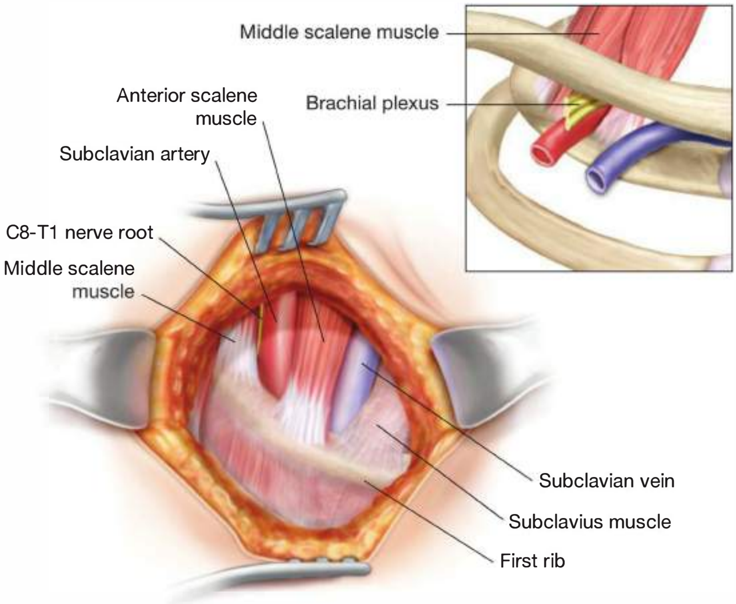

FIG 1 ● Right-sided thoracic outlet anatomy from the surgeon's perspective as viewed through the operative field in a transaxillary approach. *Inset*, normal anatomic relationships of important thoracic outlet structures.

- The patient is then moved to the lateral decubitus position using a beanbag to facilitate positioning.
  - Care should be taken to pad the dependent axilla and support the head. The sterile field incorporates the arm, axilla, and shoulder.
- An adjustable Machleder arm support is affixed to the operating table with the vertical support bar attached to the operating table at the level of the patient's chin.
  - Generous padding around the patient's arm prior to placement in the arm holder protects the median and ulnar nerves from compression as they cross the elbow joint (**FIG 2**).

FIG 2 ● A photograph depicting proper patient positioning for right transaxillary 1st rib resection and use of the Machleder arm support with generous padding to prevent compression nerve injury. A padded axillary roll is placed under the dependent (left) axilla, and the patient is stabilized in the left lateral decubitus with the aid of a beanbag. The *dashed line* indicates the preferred location of the skin incision. (Reprinted from Arnaoutakis G, Freischlag JA, Reifsnyder T. Transaxillary rib resection for thoracic outlet syndrome. In: Cambria R, Chaikof E, eds. *Atlas of Vascular and Endovascular Surgery: Anatomy and Technique*. Philadelphia, PA: Elsevier; 2014:193–203, with permission from Elsevier.)

INCISION

- Prophylactic antibiotics are administered. A first-generation cephalosporin is preferred. In patients with penicillin allergy, clindamycin or vancomycin is used.
- After securing the arm in the retractor, the surgeon identifies the anterior border of the latissimus dorsi muscle and the posterior surface of the pectoralis major muscle.
- A transverse skin line incision should be made in the inferior axillary hairline extending between these two muscle borders.

EXPOSURE

- Electrocautery is used to divide the subcutaneous tissue until thin areolar tissue superficial to the chest wall is encountered. A self-retaining Cerebellar or Weitlaner retractor is then inserted into the wound. Upon encountering the chest wall—and if in the correct anatomic plane—gentle blunt dissection with the surgeon's fingers or a pair of Kittner or peanut dissectors easily separates the soft tissues from the chest wall. This dissection is in a cephalad direction and the 2nd rib will rapidly come into view.

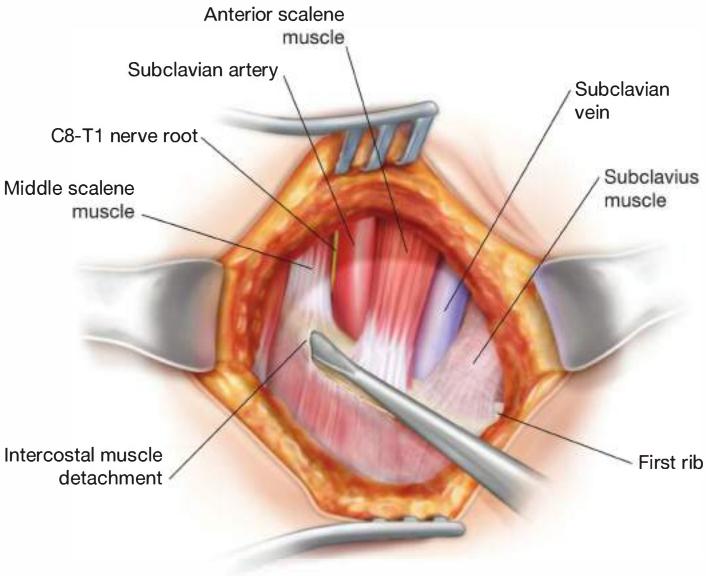

FIG 3 ● A periosteal elevator is used to dissect along the superior surface of the 1st rib in order to divide intercostal muscle attachments.

- The intercostobrachial nerve is located in the 2nd intercostal space. Although frequently difficult to avoid, care should be taken not to impart excess traction as injury results in numbness or dysesthesia of the medial aspect of the proximal arm.
- Raising the Machleder arm support at this point allows for optimal access to the 1st rib and thoracic outlet. The aid of fiberoptic-lighted Deaver retractors facilitates visualization during this portion of the dissection. Alternatively, the surgeon should wear a headlight.
- The 1st rib is identified near its insertion at the sternoclavicular joint and generally encountered higher than anticipated. A Kittner or peanut dissector is then used to gently sweep away the loose fibrous tissue overlying the 1st rib partially exposing the brachial plexus, subclavian artery and vein, and scalene muscles. There is occasionally a small branch of the subclavian artery that must be ligated and divided in order to fully expose the operative field.
- The next step is to fully expose the rib. Depending on the patient's anatomy, it generally is easiest to first clear off the intercostal muscles laterally. A Cobb periosteal elevator works best, but any type of long elevator may be used (**FIG 3**). The dissection proceeds in the anterior and posterior directions until all the intercostal muscle attachments are divided from the rib. The elevator can then be used to elevate the 1st rib, thus separating the rib from the underlying parietal pleura. This mobilization should continue from behind the brachial plexus in the posterior direction to beyond the subclavian vein in the anterior direction.
- Attention is then directed to the superior border of the 1st rib, where the periosteal elevator is used to bluntly detach the scalene medius fibers from the rib. The long thoracic nerve courses along the lateral edge of the scalene medius muscle but is generally not visualized. Avoiding sharp dissection and closely adhering to the surface of the rib during blunt dissection prevents injury to the long thoracic nerve.
- The anterior scalene muscle should now be clearly identified as it arises from the medial superior aspect of the 1st rib (**FIG 4**). A right-angled clamp is passed behind the anterior scalene muscle near its insertion on the scalene tubercle. Gently lifting the anterior scalene with the

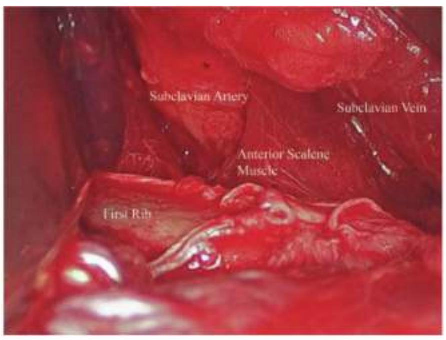

FIG 4 ● An image of the gross anatomy from a close-up perspective of the right-sided thoracic outlet. The important relationships between the 1st rib, anterior scalene muscle, and subclavian vessels can be seen. (Reprinted from Arnaoutakis G, Freischlag JA, Reifsnyder T. Transaxillary rib resection for thoracic outlet syndrome. In: Cambria R, Chaikof E, eds. *Atlas of Vascular and Endovascular Surgery: Anatomy and Technique*. Philadelphia, PA: Elsevier; 2014:193–203, with permission from Elsevier.)

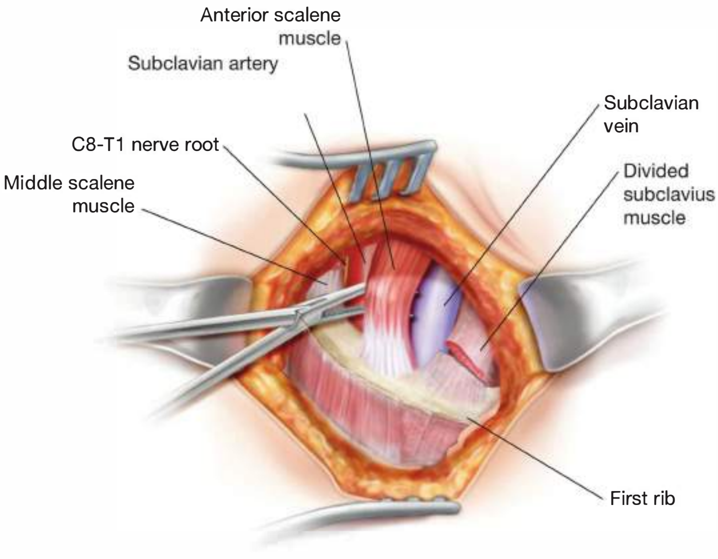

FIG 5 ● A right-angled clamp is insinuated behind the anterior scalene muscle. Gentle elevation pulls the muscle away from the underlying subclavian artery thereby protecting the artery prior to dividing the muscle with scissors. The subclavius muscle is a crescent-shaped ligamentous attachment to the 1st rib adjacent to the subclavian vein. The subclavius muscle is sharply divided with scissors with care not to injure the subclavian vein.

right-angled clamp protects the subclavian artery as it courses posterior to the muscle (**FIG 5**). It is important to free several centimeters of the muscle prior to dividing it with Metzenbaum scissors (**FIG 6**). This maneuver facilitates resection of a portion of the anterior scalene muscle, which has been shown to reduce recurrence rates when compared with division at its insertion point on the rib.

- Lastly, the subclavius muscle will appear as a crescent-shaped ligamentous attachment to the 1st rib adjacent to the subclavian vein. With care not to injure the subclavian vein, the subclavius muscle is sharply divided with scissors.

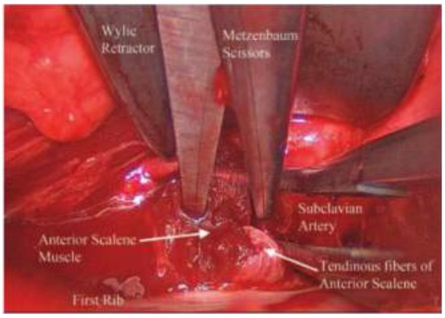

FIG 6 ● The 1st rib is seen in the foreground of the operative photo taken during a left 1st rib resection. Metzenbaum scissors are used to sharply divide the anterior scalene muscle, with the right-angled clamp elevating the muscle to protect the subclavian artery as it courses behind the muscle. The divided ends of the tendinous anterior scalene fibers can be seen. (Reprinted from Arnaoutakis G, Freischlag JA, Reifsnyder T. Transaxillary rib resection for thoracic outlet syndrome. In: Cambria R, Chaikof E, eds. *Atlas of Vascular and Endovascular Surgery: Anatomy and Technique*. Philadelphia, PA: Elsevier; 2014:193–203, with permission from Elsevier.)

RIB RESECTION

- With the rib completely mobilized, a bone cutter is used to divide the 1st rib. Generally, it is divided anteriorly and then posteriorly; however, the patient's body habitus may make the reverse order easier (**FIG 7**).
- In its anterior extent, the rib is divided adjacent to the subclavian vein, and in the posterior direction, it is divided just anterior to the brachial plexus; this ensures that the nerve roots are not inadvertently injured. The rib is then removed.
- A bone rongeur is used to remove residual rib and to smooth the cut ends until there is no residual nerve impingement. A Roos retractor or similar instrument may be used to protect the nerves during use of the rongeur (**FIG 8**).
- It is important to ensure that no residual fibers from the anterior scalene muscle crosses beneath the subclavian artery and inserts onto the thickened surface at the apex of the pleura, known as Sibson's fascia. Any such fibers should be identified and divided.

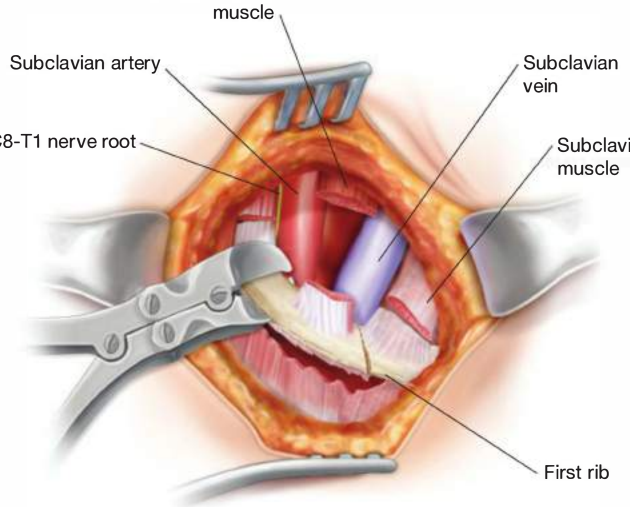

FIG 7 ● A bone cutter is used to divide the 1st rib in its anterior and posterior direction. Once removed, the rongeur is used to achieve smooth rib edges.

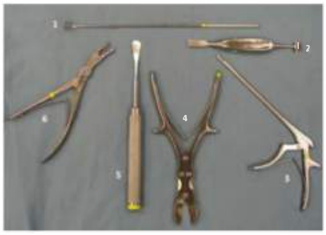

FIG 8 ● From the top of the image in the clockwise direction, the instruments depicted are *(1)* Roos retractor, *(2)* Alexander periosteotome, *(3)* Kerrison punch upbiting instrument, *(4)* double-action bone cutter, *(5)* Cobb periosteal elevator, and *(6)* Rongeur. (Reprinted from Arnaoutakis G, Freischlag JA, Reifsnyder T. Transaxillary rib resection for thoracic outlet syndrome. In: Cambria R, Chaikof E, eds. *Atlas of Vascular and Endovascular Surgery: Anatomy and Technique*. Philadelphia, PA: Elsevier; 2014:193–203, with permission from Elsevier.)

CLOSURE

- The surgical field is next inspected for bleeding. Temporarily packing the wound reliably controls minor bleeding. The wound is then reinspected, and hemostasis is completed with judicious use of electrocautery.
- The wound is then filled with saline. Several positive pressure ventilations are administered with saline left in the wound to assess for an air leak indicative of a postoperative pneumothorax. If an air leak is present, a small caliber (12 French [Fr]) chest tube is warranted prior to closure.
- If the irrigation drains into the pleural space but there is no air leak, the pleura has been breached, but a chest tube may not be necessary. In this situation, a 12- or 14-Fr red rubber catheter is placed into the bed of the 1st rib and attached to gentle suction. The Machleder arm holder is lowered to facilitate a tension-free closure. The subcutaneous fascia is then closed around the tube. While suction is applied to the red rubber catheter, the anesthesia team provides a sustained Valsalva and the fascial suture is tied as the suction tube is rapidly removed. This maneuver generally avoids a clinically significant postoperative pneumothorax.
- Closure is performed with absorbable 2-0 suture in the fascia and a 4-0 subcuticular skin closure.

PEARLS AND PITFALLS

Operative mantra	■ Look twice and cut once. Always double-check placement of the bone cutters before dividing the 1st rib.
Incorrect diagnosis	■ A successful operation hinges on an accurate preoperative diagnosis. A thorough history and physical and the anterior scalene block help to identify patients likely to benefit from 1st rib resection.
Brachial plexus injury	■ Proper positioning and careful retraction help prevent excessive traction and injury to the brachial plexus.
Misidentification of the 1st rib	■ During initial exposure, the 2nd rib is often mistaken for the 1st rib. The cephalad surface of the 1st rib is flat unlike the 2nd, which is more concave.

Incomplete 1st rib resection	■ Incomplete 1st rib resection has been associated with recurrent TOS. After cutting and removing the rib, take your time to trim back the ends with the rongeur.
Hemostasis	■ To keep a clean operative field, pack a 4 × 4 gauze into the wound, lower the arm retractor, and wait a couple of minutes. This often aids in hemostasis.

POSTOPERATIVE CARE

- A chest x-ray is performed in the recovery room.
  - Small, clinically asymptomatic pneumothoraces may be observed with a follow-up chest x-ray the next morning.
- Patients are typically discharged from the hospital when adequate oral analgesia has been achieved.
  - Activity is restricted by the amount of postoperative pain. Occasionally, a sling is required for patient comfort, but it is preferable to have the arm as mobile as tolerated.
- Physical therapy should be prescribed after 2 weeks in all patients undergoing transaxillary 1st rib resection, regardless of the cause, to restore range of motion and strength.

OUTCOMES

- Improvement after surgery for neurogenic TOS is somewhat subjective and based on the patient's perception of disability before and after decompression. Improvement in symptoms exceeds 90%.[6]
- Over time, the durability of these results may decrease, reinforcing the need for close follow-up of these patients beyond 2 years.[7,8]
- Factors that predict surgical failure include major depression, chronic symptoms, work-related injury, lack of response to anterior scalene muscle blocks, and a short segment of divided anterior scalene muscle.[9]

COMPLICATIONS

- **Vascular injury**
  - A national query identified injury to the subclavian vessels as the most common complication following transaxillary rib resection for neurogenic TOS, occurring in 1% to 2% of cases.[4]
  - Patients experiencing a vascular injury have greater lengths of stay as well as increased hospital charges.
  - It is difficult to obtain proximal control of these vessels from the transaxillary approach, and therefore, the surgeon should exercise extreme caution when dissecting near these vessels.
- **Nerve injury**
  - Major nerve injury has been traditionally regarded as the most common complication following surgery for TOS. However, large contemporary series disprove this belief, with rates of brachial plexus injury for patients undergoing transaxillary 1st rib resection approaching 0%.[4,8]
  - Temporary or permanent numbness of the upper medial arm due to excessive traction or division of the intercostobrachial nerve occurs in up to 10%. Frequently, these symptoms will improve over time.
- **Pneumothorax**
  - This complication occurs in 2% to 10% of patients.[8] Accordingly, an upright chest x-ray is routinely performed in the recovery room.
  - Radiographically detected pneumothoraces only require a chest tube if symptomatic or enlarging.
  - Adhering closely to the inferior surface of the 1st rib during blunt dissection will help protect against postoperative pneumothorax.
- **Recurrence**
  - Symptoms of TOS recur in 10% to 20% of patients.[10–12]
  - Two intraoperative factors are known to reduce recurrence rates.
    - Resecting a significant portion (2 to 3 cm) of the anterior scalene muscle as opposed to simply dividing it at its insertion point
    - Ensuring that the posterior edge of the 1st rib is resected sufficiently so as to leave as short a rib stump as technically feasible
  - Patients with spontaneous recurrence compared to those that are reinjured have worse outcomes when reoperation is performed.

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Chapter 9 Venous and Arterial Thoracic Outlet Syndrome

Jason T. Lee

DEFINITION

- Venous thoracic outlet syndrome (vTOS), also known as effort thrombosis or Paget-von Schrotter syndrome, involves repetitive subclavian venous compression that leads to endothelial injury and intermittent stasis that ultimately contributes to acute thrombosis of the axillosubclavian venous system. The external compression of the vein occurs between the clavicle and subclavius muscle from above and by the 1st rib and the anterior scalene muscle insertion from below (**FIG 1**).
- Arterial thoracic outlet syndrome (aTOS) is the least common presentation of thoracic outlet syndrome and most often involves subclavian artery compression leading to extrinsic compression, poststenotic dilatation, aneurysmal degeneration, and subsequent distal embolization.[1] Bony and muscular abnormalities are typically present in patients with aTOS and can include a cervical rib, anomalous 1st rib, anterior or middle scalene muscle bands, or hypertrophic callus from a healed clavicular injury or fracture (**FIG 2**).

DIFFERENTIAL DIAGNOSIS

- Compared to neurogenic thoracic outlet syndrome (TOS), vTOS and aTOS are much more straightforward in their diagnostic workup. vTOS patients with swelling must be distinguished from secondary causes of axillosubclavian thrombosis, namely iatrogenic catheterization or instrumentation of the venous system leading to thrombosis, which is obvious upon eliciting a careful history. Also, a hypercoagulable state or malignancy can present as isolated upper extremity venous thrombosis and there is some debate about the need for additional medical workup in patients suspected of having vTOS.[2]

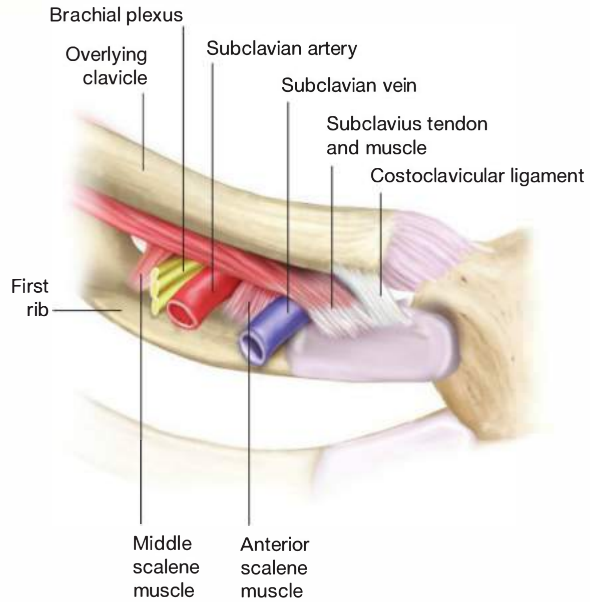

FIG 1 • Normal structures in the thoracic outlet that can contribute to venous compression.

- Because aTOS usually involves distal embolization to the hand from thrombus in a subclavian aneurysm, a thorough workup for a cardiogenic source should be sought before assigning the etiology to aTOS. Transesophageal echocardiography, with bubble enhancement to identify paradoxical

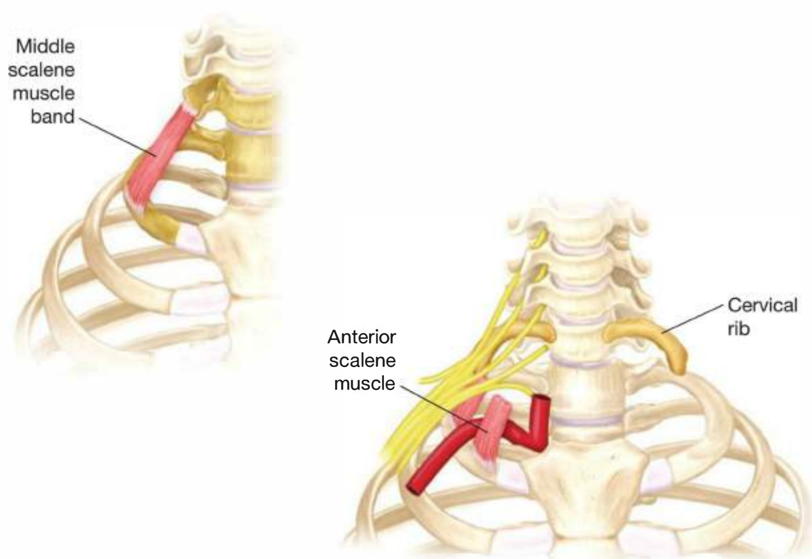

FIG 2 • Abnormal anterior and middle scalene bands and abnormal cervical ribs lead to compression and subsequent poststenotic dilatation of the subclavian artery, causing arterial TOS.

FIG 3 • 18-year-old baseball catcher presenting with arm swelling, pain, cyanosis, and prominent superficial vasculature after a strenuous workout after a game.

emboli, may be necessary to exclude cardiogenic emboli. Computed tomography angiography (CT-A) of the arch and upper extremity vessels would also be reasonable to exclude other arterial causes including axillary branch artery aneurysms, congenital abnormalities, or traumatic injuries and dissections of the axillosubclavian arterial system, which can be seen in high-performance athletes and individuals performing repetitive upper extremity motions.

PATIENT HISTORY AND PHYSICAL FINDINGS

- Most patients with vTOS are young, healthy, and often athletically inclined who present with the abrupt onset of unilateral arm swelling in their dominant arm after repetitive, strenuous use for sport, work, or recreation. Athletes affected can include baseball pitchers, rowers, swimmers, water polo players, weightlifters, volleyball players, surfers, football quarterbacks, or any others relying on repetitive upper extremity effort. The swelling is noted in the shoulder, arm, and hand and can be accompanied by aching, throbbing, or tightness that worsens with more activity. Because most patients are otherwise young and healthy, an orthopedic cause such as strain, muscle pull, or joint injury is often considered initially. Cyanosis of the affected extremity, visible chest wall venous collaterals, or progressively worsening symptoms suggest a vascular etiology, prompting referral to an interventionalist. On exam, the arm is swollen, tender to palpation, warm, and often has visible superficial collaterals that track onto the anterior chest wall (**FIG 3**). Range of motion of the affected extremity can be impeded due to patient discomfort.
- aTOS patients will present with mild hand ischemia due to distal embolization, which manifests as digital ischemia or splinter hemorrhage. The diagnosis is often delayed due to the fact that these patients have no typical atherosclerotic risk factors and are mostly young and athletic. A pulsatile mass or bruit may be present in the supraclavicular fossa or a bony prominence in that region may hint toward a cervical rib or muscular abnormality. Symptoms often are gradual and unnoticed by patients until occurring more frequently or when complete thrombosis occurs and the patient presents with critical upper extremity ischemia.

IMAGING AND OTHER DIAGNOSTIC STUDIES

- Patients suspected of having vTOS should undergo duplex ultrasound of the affected area. Axillosubclavian venous imaging can be challenging due to the clavicle's location as well as many of these patients being quite muscular. Color flow duplex, phasicity of flow with respiration, and augmentation with compressive maneuvers can all aid in confirming the diagnosis of deep venous thrombosis (DVT). An experienced vascular sonographer and interpreter can make the diagnosis with high accuracy based on duplex alone. Cross-sectional imaging with magnetic resonance imaging (MRI) or computed tomography (CT) venography is rarely needed or indicated in the workup of vTOS. Catheter-based venography is the key confirmatory imaging study to document the extent of vTOS and leads to the initial recommended therapeutic strategy of thrombolysis and reduction of clot burden.
- Patients presenting with digital ischemia suspicious for aTOS should undergo plain radiographic imaging to assess for a cervical rib (**FIG 4**). Digital plethysmography of bilateral upper extremities can be performed to visualize blood flow to each finger and can rule out Raynaud's type etiologies in the differential diagnosis. Wrist–brachial indices should be documented prior to any further intervention to establish baseline flow characteristics. CT-A of the neck and upper extremity in provocative positioning (arms at 180 degrees overhead) provides the most definitive visualization of the affected region, confirming the presence of the cervical rib, delineating the amount of thrombus in the subclavian aneurysm, and documenting the proximal and distal vasculature for operative planning (**FIG 5**).

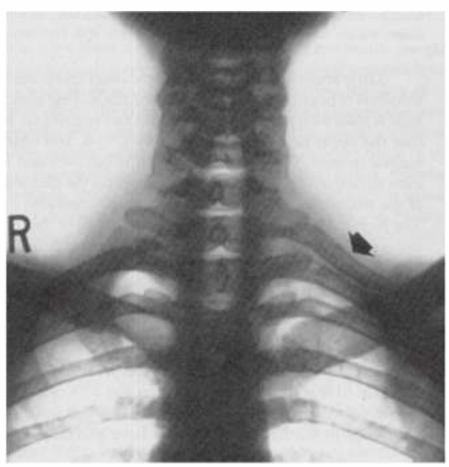

FIG 4 • Chest x-ray demonstrating left cervical rib *(arrow)*.

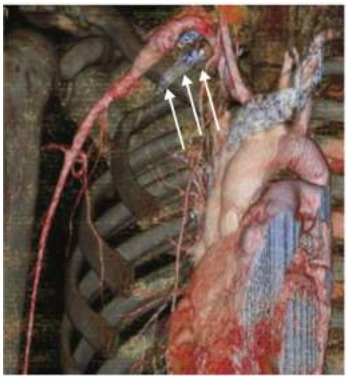

FIG 5 ● CT-A reconstruction of 19-year-old collegiate tennis player with cervical rib *(arrows)* that led to subclavian aneurysm formation. Patient presented with fingertip emboli after playing long matches.

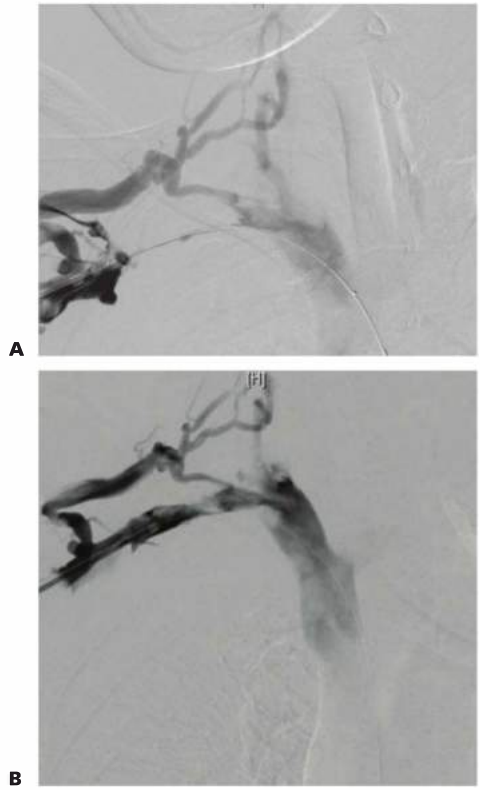

FIG 6 ● **A.** Initial venogram demonstrating right axillosubclavian occlusion with large collateral development. Wire was passed through this region and pharmacomechanical thrombolysis initiated. **B.** Follow-up venogram 24 hours later with resolution of majority of thrombus load. Vein still shows signs of disease and scarring particularly in the region of compression.

SURGICAL MANAGEMENT

Preoperative Planning

- vTOS patients diagnosed with acute axillosubclavian DVT should be anticoagulated with weight-based dosing of unfractionated heparin or low-molecular-weight heparin. Depending on the resource availability, admission for thrombolysis or urgent referral to a center capable of catheter-directed interventions has been generally accepted as standard of care.[3] There are patients that are simply put on anticoagulation that get referred much later (more than 2 weeks) due to lack of recognition of the TOS etiology of the DVT and this leads to a diminished success rate of thrombolysis.[4]
- Successful thrombolysis involves a combination of chemical and mechanical thrombectomy and is often quite effective in decreasing clot burden and reducing long-term sequelae of upper extremity DVT (**FIG 6A,B**). Technical details of thrombolysis are well described and can be performed with minimal morbidity.[5]
- Definitive therapy for vTOS after thrombolysis involves thoracic outlet decompression, consisting of anterior and middle scalenectomy, resection of the subclavius tendon, 1st rib resection, and venolysis or venous reconstruction. Timing of definitive surgery after thrombolysis is somewhat controversial and is limited by anecdotal reports and various surgeon biases.[6] Successful outcomes can be achieved with definitive thoracic outlet decompression performed during the same hospitalization as the thrombolysis[7] and up to 3 months later with nonresolution of mild venous obstructive symptoms,[5] leading some to adopt a more selective approach for offering rib resection. This lack of consensus provides some flexibility in offering definitive surgery as many of these young patients are often student-athletes and cannot miss certain periods of the school year. Management of anticoagulation during this time also impacts decisions about planning surgery, as intolerance to blood thinners or difficulty with maintaining adequate anticoagulation can affect the urgency of the required definitive decompression. If there is a delay in scheduling definitive rib resection, a duplex immediately prior to surgery after successful thrombolysis is important to document the status of the vein during the immediate pre-operative period.
- In contradistinction to the numerous pathways for vTOS surgery planning aTOS in the presence of an ipsilateral cervical rib and subclavian aneurysm presents a strong indication for definitive surgical intervention. Preoperative planning consists mainly of ensuring adequate and healthy vasculature proximal and distal to the diseased segment and determining a bypass route that is reasonable. Extraanatomic bypass via a carotid–subclavian or carotid–axillary with interval ligation may be necessary, depending on the size and length of the subclavian aneurysm and thrombus. Direct repair of the subclavian aneurysm with interposition grafting can be accomplished only when there is a short segment of disease that limits itself to the visualized region in the supraclavicular fossa. The preoperative CT-A provides the best road map to help decide amongst these reconstructive strategies. Endovascular techniques of the subclavian artery such as stent grafting in the setting of aTOS are generally not recommended, given the age of the typical patient, the compression that can occur from scarring even after cervical

or 1st rib decompression, and the likely desire to resume prior activities that often brought about these symptoms in the postoperative period.

Positioning

- vTOS decompression will often involve an infraclavicular incision (some prefer only this incision; some prefer a paraclavicular approach; still others prefer transaxillary), which is facilitated by positioning the patient with a small bump between the shoulder blades and in a "head up" position of 30 degrees. The affected arm is prepped out and placed in a stocking on the side of the patient to allow full movement during the case. This affords the anterior visualization of the 1st rib and particularly the subclavius tendon and costoclavicular ligament for safe and effective decompression. The entire ipsilateral neck, shoulder, arm, and anterior chest wall are prepped into the field as well as a region on the lateral chest wall should there be a small pneumothorax postprocedure.
- aTOS decompression with cervical rib is most often performed with a supraclavicular approach. When arterial reconstruction is planned, preparations should be made for saphenous or femoral vein harvesting.

VENOUS THORACIC OUTLET SYNDROME

Infraclavicular Approach

- A 5-cm transverse incision is made one fingerbreadth below the clavicle, starting along the edge of the sternum travelling laterally, and is carried through the subcutaneous tissue and pectoralis fascia to expose the upper fibers of the pectoralis muscles (FIG 7). Gentle spreading between muscle fibers in this region exposes the anteromedial quadrant of the axillary fat pad and allows easy palpation of the 1st rib. Appropriate retractors can be placed to fully expose the most anterior portion of the 1st rib beneath a layer of axillary fat (FIG 8).
- When the rib is visualized, cautery is used to separate the inferior-lying intercostal musculature from the rib, with curved dissection heading superolaterally along the C curve of the rib (FIG 9). Lung pleura are often visualized immediately beneath the rib and care should be taken to not injure lung parenchyma. Superiorly, the subclavius tendon and costoclavicular ligament are taken down sharply with cautery to free up the anterior portion of the 1st rib from the overhanging

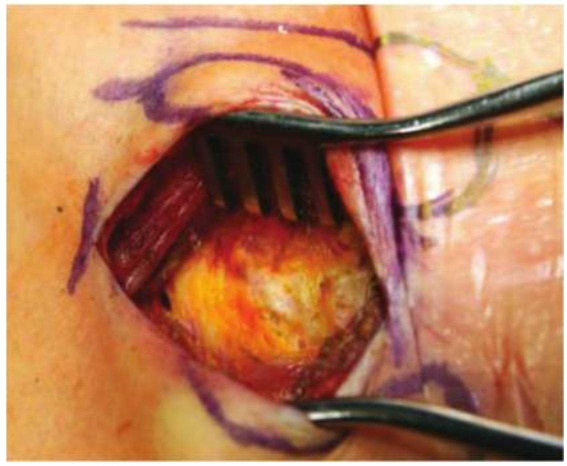

FIG 8 ● Incision is carried down through pectoralis fascia, then the muscle fibers are split until axillary fat that covers the 1st rib is reached.

FIG 7 ● Infraclavicular incision is made one fingerbreadth below clavicle.

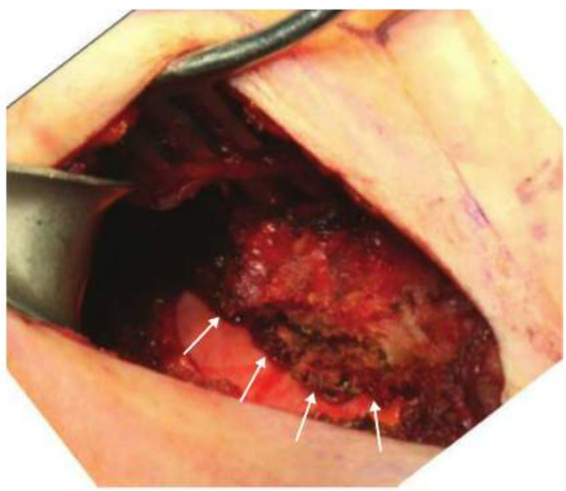

FIG 9 ● Further dissection around the 1st rib involves sharp dissection of intercostal musculature along inferior aspect of 1st rib *(arrows)*.

clavicle. Following along the superior aspect of the 1st rib, the anterior scalene fibers are also sharply taken down and further superior dissection takes place along the lateral edge of the 1st rib until palpation of the subclavian artery is noted. This level is as far necessary to decompress the subclavian vein. Often, moving the arm in a superior position facilitates more superior exposure of the 1st rib near the artery.

- When the rib is clear on its superior, lateral, and inferior edge, a rib cutter can be inserted superiorly, taking care to visualize the jaws, and then the superior cut is made in the rib. The inferior cut is done near the manubrial junction, commonly with a power saw. As the rib is pulled away from the body, sharp cautery can be used to facilitate hemostasis of individual muscle fibers (intercostals, anterior and middle scalene) holding the 1st rib in place.

Venous Reconstruction

- With the anterior half to two-thirds of the rib removed from this infraclavicular approach, the vein is often palpable in a bed of tissue and muscle fibers immediately below the clavicle. Venolysis consists of freeing up these muscle fibers to expose the vein (**FIG 10**). More proximal exposure of the vein can be accomplished via a transmanubrial extension of the infraclavicular incision to the center of the sternum and vertically up to the sternal notch (**FIG 11**). This can be necessary to obtain adequate vascular control for patching of chronically diseased venous segments. When a strictured segment of vein is localized, saphenous vein or bovine pericardial or bovine pericardial patching provides an excellent strategy for restoration of luminal diameter and can be performed with adequate proximal and distal control of the vein under direct visualization (**FIG 12**).

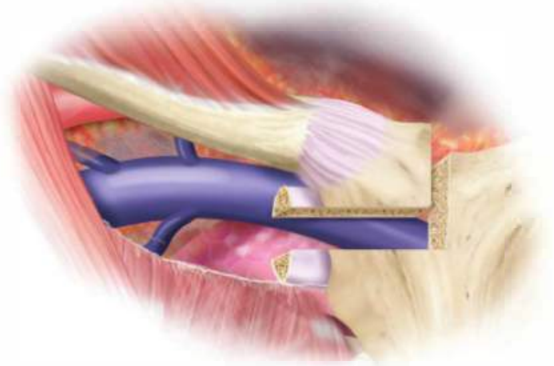

FIG 11 ● If more proximal exposure is needed to clamp for control, extension of the incision into the manubrium and toward sternal notch allows wider visualization of the origin of subclavian vein and junction with jugular into the innominate.

Closure

- Careful attention to the stump of rib remaining for hemostasis is performed, as well as the region of vein after venolysis and/or reconstruction.
- If the pleura or lung parenchyma has been injured, a small-caliber (12 Fr) pediatric chest tube can be place in the anterior pleural space under direct visualization.

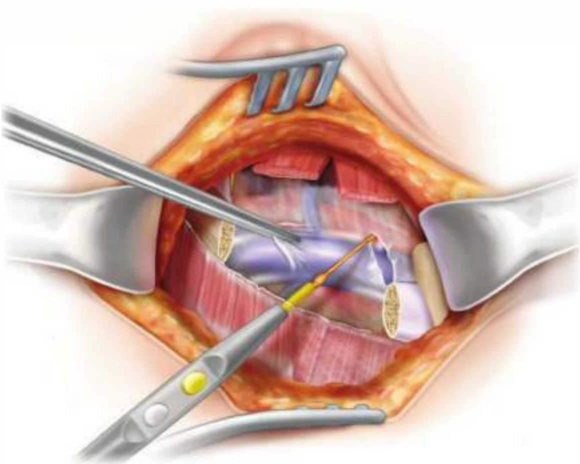

FIG 10 ● After 1st rib is resected, careful dissection around vein with venolysis and takedown of fibers surrounding vein allows adequate visualization to check for stenotic regions.

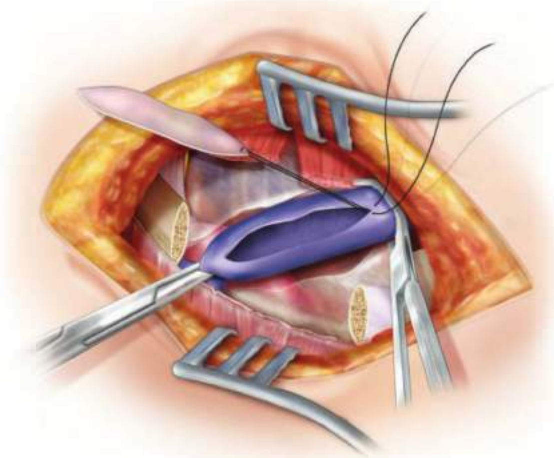

FIG 12 ● Stenotic region of the subclavian vein repaired with patch venoplasty using greater saphenous vein.

ARTERIAL THORACIC OUTLET SYNDROME

Supraclavicular Approach

- A 7-cm incision is made one fingerbreadth above the clavicle, starting lateral to the palpable edge of the sternal head of the sternocleidomastoid muscle and carried through the platysma. This exposes the clavicular head of the sternocleidomastoid, which is transected with a cuff to sew back together later, which now exposes the anterior scalene fat pad (**FIG 13**). The fat pad is dissected along three borders, inferiorly, laterally, and medially, to allow it swing northward to expose the anterior scalene muscle and the phrenic nerve (**FIG 14**). When operating on the left side, extra care is taken to visualize the thoracic duct when present, which is suture ligated to prevent postoperative chyle leaks if it becomes injured.
- With the phrenic nerve slung and protected, transection of the anterior scalene muscle off the superior edge of the 1st rib is done using bipolar scissors. Care is taken to stay on the bone during this portion so as not to injure the underlying subclavian artery. After the inferior edge of the anterior scalene is removed, a portion of muscle can be transected to allow room for further visualization and subsequent dissection around the brachial plexus (**FIG 15**). The long thoracic nerve is identified laterally, and the entire nerve structures are slung around a thick clear silastic loop.
- A cervical rib, when present, is often visualized at this time, with abnormal vasculature or musculature surrounding it, and can be fused to the 1st rib (**FIG 16**). Care is taken to dissect nerves and vessels away from the abnormal rib or its osseus portions that may not have appeared on radiography.
- The 1st rib is visualized by maneuvering the subclavian artery and the nerve bundle back and forth while dissecting middle scalene fibers and intercostal musculature off the 1st rib (**FIG 15**). This can be done sharply with bipolar scissors or by using a periosteal elevator. One should

FIG 14 ● With the scalene fat pad retracted superiorly, the anterior scalene muscle and phrenic nerve are clearly seen. The nerve is slung with a silastic loop.

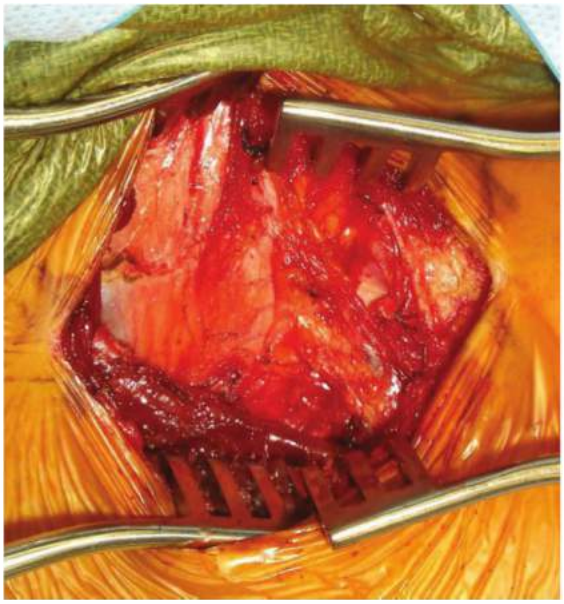

FIG 13 ● Supraclavicular incision one fingerbreadth above the clavicle continues after transecting clavicular head of the sternocleidomastoid and exposure of the anterior scalene fat pad.

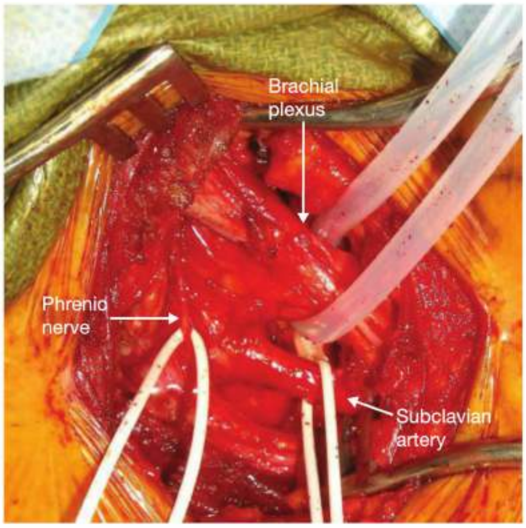

FIG 15 ● The 1st rib is cleared on both sides of the subclavian artery and the brachial plexus fibers, which are all slung to allow easy mobilization.

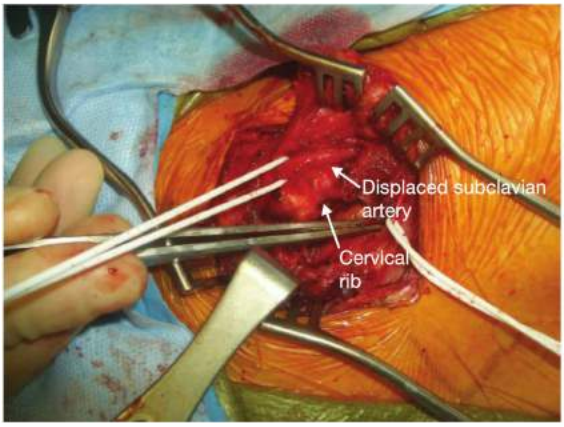

FIG 16 ● In this case, a fused cervical rib to the 1st rib is prominently tenting up the subclavian artery and brachial plexus fibers.

FIG 17 ● Removal of the congenitally fused cervical rib to the 1st rib as an en bloc piece, allowing the neurovascular bundle to return to its normal position without being kinked or displaced.

avoid the use of cautery in this area as it is likely to transmit to the brachial plexus or phrenic nerve.

- When the rib is clear from the region inferior to the subclavian artery and superior to the upper aspect of the brachial plexus, a power saw can be used to transect the rib. If there is a fused portion of cervical rib, it should be attempted to be removed as a single piece (FIG 17) to assure that all bony abnormalities have been freed up to allow for adequate decompression.

Arterial Reconstruction

- Subclavian aneurysm resection, when needed, consists of appropriate bypass principles and replacement with an autogenous or prosthetic interposition graft or extraanatomic bypass of carotid to distal subclavian or carotid to axillary graft. Typical sizes and types required for prosthetic grafts include 6- or 8-mm ringed polytetrafluoroethylene (PTFE) or Dacron.

PEARLS AND PITFALLS

Indications	■ vTOS definitive therapy consists of prompt diagnosis, venography and subsequent thrombolysis, and appropriate selection of patients to undergo thoracic outlet decompression. ■ aTOS patients often present with hand ischemic symptoms that will have some delay in management due to a wide differential. Abnormal bony or muscular anatomy along with presence of subclavian aneurysmal disease requires definitive repair including arterial reconstruction.
Preoperative workup	■ Venous duplex, venography, and pharmacomechanical thrombolysis provides the optimal reduction of clot burden to restore functional venous patency in patients with vTOS. Timing of rib resection and definitive thoracic outlet decompression are somewhat variable and the approach should be individualized. ■ aTOS patients should undergo plain radiography to search for a cervical rib and CT-A to determine the portions of diseased subclavian artery that might need resection.
Patient setup	■ Prepping the affected arm in the vTOS patients affords the ability to move the arm and, from the infraclavicular approach, gain access to the majority of the rib that is responsible for venous compression. ■ For cervical rib and arterial reconstructions, the supraclavicular approach gives numerous options for reconstructive purposes as well as the possibility of the carotid artery as an inflow source.
Infraclavicular approach	■ Visualization of the subclavius tendon and its fibers as well as the costoclavicular ligament is paramount in decompressing the region that compresses the subclavian vein in vTOS. ■ Liberal patching of the subclavian vein and extensive venolysis provide the best long-term patency results after vTOS decompression.
Supraclavicular approach	■ Carefully mobilizing the anterior scalene fat pad allows good visualization of the anterior scalene muscle and phrenic nerve. ■ When performing left-sided supraclavicular TOS decompression, one must be careful to identify and ligate the thoracic duct. ■ Slinging the subclavian artery and brachial plexus fibers allows gentle traction back and forth to expeditiously dissect free the entire 1st rib.

POSTOPERATIVE CARE

- At the conclusion of the procedure, patients are extubated and an immediate chest x-ray is obtained to ensure there is no pneumothorax. A small pneumothorax can be treated with oxygen and incentive spirometry, but a 25% lung volume reduction requires a chest tube to suction for 24 hours.
- Patients do not need a sling for their arms. They are given range-of-motion exercises immediately to encourage strengthening and are given a taper of muscle relaxant and opioid narcotics for pain control. Most patients are discharged the following day after surgery.
- Anticoagulation for vTOS patients is usually resumed 3 to 4 days postoperatively at home, typically consisting of Lovenox for a week, then they return for postoperative venography to see if further balloon venoplasty is necessary.[8]
- Anticoagulation for aTOS patients, especially if arterial reconstruction was performed, consists of antiplatelet therapy with aspirin.

OUTCOMES

- Patients treated for vTOS with lysis and subsequent thoracic outlet decompression have a very low recurrence rate of thromboembolic disease. Morbidity and mortality is minimal, as these are often young and healthy patients, but typically revolve around wound issues and bleeding given the need for a short course of anticoagulation. Satisfactory quality of life scores and return to full function are reported in the 80% to 90% range, and most patients can be counseled to expect a near full return to sport.[9]
- aTOS and the cervical rib patients often have the most dramatic recovery, as they are often the most symptomatic to begin with. Although the literature is much sparser with regard to this entity, results are uniformly positive with resolution of hand ischemic symptoms and lack of significant disease recurrence.

COMPLICATIONS

- Perioperative complications related to either form of thoracic outlet decompression revolve around lung injury and wound issues. Pneumothoraxes are often self-limited and treated effectively with chest tubes. Wound complications can include chyle leaks, seromas, and skin breakdown. Most of these are managed expectantly. Brachial plexus injuries may also occur, most commonly as a function of not recognizing important anatomic structures or not providing sufficient exposure to eliminate collateral damage during rib transection and removal.
- Timing of restarting anticoagulation in vTOS patients can lead to postoperative bleeding, which can manifest as delayed hemothorax. The cause of this bleeding is often related to recent thrombolysis and raw surfaces of muscle and cut bone, and this has led to the general recommendation of holding off on restarting anticoagulation until 3 or 4 days postoperation.

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Chapter 10

Proximal to the Wrist: Upper Extremity Reconstruction/ Revascularization

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DEFINITION

- The content discussed in the following text assumes the reader has familiarity with standard upper extremity arterial anatomy and its most common variations. For additional information, the reader may refer to excellent existing references.[1,2]
- Various occlusive and/or aneurysmal disease processes in the upper extremity arterial system may necessitate revascularization or reconstruction (Table 1).
- Acute upper extremity ischemia is less common than in the lower extremity due to the rich preexisting collateral circulation in both the upper arm and forearm. The majority (~50%) of acute ischemic complications in the upper extremity occur in elderly females as a result of embolic phenomenon rather than primary vessel thrombosis (which accounts for ~25% of acute ischemic events).[3] The differential diagnosis for embolic sources includes intracardiac sources, proximal arterial atherosclerotic plaque, proximal arterial aneurysm thrombus, endocarditis, or paradoxical embolus from venous circulation.
- Chronic arterial occlusive disease is rarely symptomatic. Associated comorbid conditions include diabetes, chronic atherosclerotic occlusive disease, subclavian or arteriovenous steal syndromes, or failure of prior arterial repair or grafting.[4,5]
- Venous occlusive disorders in the upper extremity are common and are usually associated with iatrogenic injury, indwelling catheters, or thoracic outlet pathology. For further information regarding venous thoracic outlet disorders. Distal to the thoracic outlet, venous occlusive disorders are for the most part managed expectantly with anticoagulation therapy. Open surgical and endovascular therapies are rarely used and, due to high recurrence and failure rates, are not enthusiastically recommended. For further recommendations regarding upper extremity venous disease management, please refer to additional references.[6,7]

Table 1: Upper Extremity Vascular Disease

Pathology	Etiology
Arterial stenosis or occlusion	• Atherosclerosis • Dissection/trauma • Extrinsic compression • Vasculitis • Hypercoagulable state
Arterial aneurysmal degeneration	• Atherosclerotic degeneration • Blunt or penetrating trauma • Connective tissue disorder • Iatrogenic injury
Venous stenosis or occlusion	• Deep venous thrombosis • Hypercoagulable state • Extrinsic compression

PATIENT HISTORY AND PHYSICAL FINDINGS

- Initial evaluation should include an assessment of associated comorbidities, including cardiac pathologies (myocardial infarction, arrhythmia, heart failure, or prior coronary artery revascularization), hypertension, hyperlipidemia, diabetes, hypercoagulability, smoking, prior upper or lower extremity arterial intervention, or index extremity trauma.
- Symptoms and signs of acute arterial ischemia include pain, paresthesia, pulselessness, paralysis, and/or poikilothermia. A thorough vascular, sensory, and motor examination will help assess the severity of arterial insufficiency. Although dated, the Rutherford classification system remains useful for prognostic determinations.[8] For classes 5 and 6 ischemia, urgent or emergent intervention may be necessary to preserve limb function and viability. Prompt removal of embolic debris in limbs with sufficient residual viability produces excellent long-term results.[3]
- Chronic limb ischemia may also present with symptoms of rest pain, pain with extremity use, paresthesia, pulselessness, poikilothermia, and/or ulcerations/wounds/gangrene of fingers or fingertips. Subjects should be asked to describe what, if any, activities exacerbate these potential symptoms (i.e., lifting or carrying material with affected arm/hand, arm raising, or repetitive arm/hand movement). Patients with vocational or recreational activities that require regular or frequent use of their upper extremities should describe convincing symptoms they experience in relation to these activities. More commonly, chronic upper extremity arterial ischemia is asymptomatic, particularly in older and less physically active individuals. In general, revascularization is not necessarily indicated in these circumstances. Discrepancy in upper extremity pulses, or brachial blood pressure differential of more than 15 mmHg, is a hallmark of chronic upper extremity arterial insufficiency with or without accompanying symptoms.
- Traumatic or iatrogenic injury accounts for 25% of patients presenting with acute upper extremity arterial insufficiency. Consideration of the mechanism of injury (blunt, penetrating, hyperextension, or avulsion) will help delineate the likely nature of the resulting arterial disruption (transection, dissection, or thrombosis, with or without ongoing extravasation). Following completion of the trauma primary survey, determination of extremity arterial continuity should be performed following reduction of obvious ipsilateral upper extremity fractures and dislocations. In complex injuries, including avulsions and crush injuries, baseline sensory and motor status should be documented early to formulate the most appropriate course of therapy. When severe arterial injury is associated with transection or avulsion of the brachial plexus and compound long bone fractures, meaningful functional recovery, despite ultimately successful revascularization, may not be possible.[9]

- More commonly, upper extremity arterial injuries can be more subtle and are frequently missed on primary or secondary surveys. The extensive collateral network present around the elbow often masks the presence of brachial artery thrombosis following posterior elbow dislocation, or dissection and thrombosis following brachial artery catheterization. When physical signs suggest asymmetric or reduced upper extremity arterial perfusion, objective imaging should be obtained promptly to direct therapy and maximize long-term function. Depending on hand perfusion and viability, occasionally, immediate revascularization can be at least temporarily deferred to allow for more urgent resuscitation and stabilization procedures to proceed. Similarly, non–flow-limiting dissections may be monitored without immediate intervention, particularly when the patient's overall condition merits observational management.

IMAGING AND OTHER DIAGNOSTIC STUDIES

- Depending on clinical circumstances, revascularization may be undertaken on the basis of clinically apparent injuries and limb ischemia. More commonly, physiologic assessment is indicated and necessary to determine the most efficacious method of revascularization. Arteriography, typically performed during or immediately prior to revascularization, remains an essential tool to guide intervention and confirm procedural success. As a general observation, physiologic testing helps determine when intervention is necessary, whereas arteriography provides the necessary anatomic information to ensure procedural and functional success.
- Computed tomography (CT) arteriography can potentially add useful information to surgical planning for upper extremity revascularization. However, unlike in the abdomen and lower extremities, significant insight into disease localization and severity in the upper extremities can be gleaned from physical examination and nonionizing imaging modalities such as ultrasound. The potential additional diagnostic benefit associated with CT angiography needs to be balanced with the not insignificant radiation dosage delivered with this imaging modality, particularly in regard to the longer life expectancy of younger patients. When vascular disease is known to be limited to the extrathoracic upper extremity arterial system, CT angiography provides little additional, useful information over diagnostic arteriography alone, especially when the latter can be paired with a therapeutic intervention.
- Noninvasive vascular testing for evaluation of the upper extremities includes segmental systolic pressure measurements using a Doppler flow detector, digital plethysmography, and arterial duplex scanning.
- Serologic tests are the basis for the workup of patients with suspected vasculitic pathologies (e.g., Takayasu's arteritis, giant cell arteritis, Buerger's disease, and/or scleroderma). Customary tests include baseline complete blood count, platelets, fibrinogen, C-reactive protein (CRP), and erythrocyte sedimentation rate (ESR).[10,11] In certain circumstances, color duplex evaluation may also provide additional clues to aid in the diagnosis.[12] Additional serial serologies and rheumatologic consultation may be necessary depending on the severity and progression of the suspected vasculitic disease process.
- Young patients with acute primary arterial thrombosis, patients with recurrent arterial thrombosis, or patients with a prior history of unprovoked deep venous thrombosis preceding an arterial event should be considered for a hypercoagulability workup and hematology consultation. Initial testing may include protein C function, free protein S, antithrombin III activity, anticardiolipin antibodies, factor V Leiden mutation, prothrombin mutation, and homocysteine level.[13]

SURGICAL MANAGEMENT

Preoperative Planning

- Prior to attempted upper extremity arterial repair or revascularization, a clear understanding of the extent and location of arterial pathology is essential. This knowledge guides the location of arterial exposure or optimal method of arterial access, the identification of optimal inflow sources and outflow targets, and the most effective and efficient methods of reconstruction. When uncertainty persists, intraoperative arteriography provides essential and timely guidance.
- As in all methods of peripheral arterial reconstruction, heparin is typically administered when an interventional sheath is first placed, or arterial control is anticipated. Typically, 100 units/kg of intravenous heparin is administered, with additional anticoagulation guided by the activated clotting time monitored during the course of the procedure.
- As discussed in Part 6, Chapter 2, the preferred extrathoracic method of innominate or proximal left subclavian artery surgical reconstruction is carotid subclavian bypass. Frequently, however, endovascular options are available and preferable in patients who cannot tolerate the risks or morbidity associated with open reconstruction. For example, in the setting of uncontrolled, life-threatening hemorrhage from penetrating or crush injuries or limb avulsion, bleeding may be controlled by insertion of covered, self-expanding stents across the area of injury in the subclavian or axillary arteries. However, with few other exceptions (such as lesions associated with giant cell or Takayasu's arteritis), angioplasty and stenting of arterial lesions at or distal to the clavicle is poorly tolerated and ill advised. Stents placed in this area are at high risk for fragmentation and subsequent arterial thrombosis, pseudoaneurysm formation, or stent migration.
- Surgical management of arterial pathology distal to the subclavian artery (surgical management of arterial disease of the arch vessels and subclavian artery are discussed in Part 6, Chapters 1, 2, and 9) and proximal to the wrist (surgical management of arterial disease distal to the wrist is discussed in Part 6, Chapter 11) will depend on acuity, cause/type of pathology (penetrating trauma, blunt trauma, occlusion, stenosis, or aneurysm), severity of patient symptoms, patient comorbidities, and required durability of the planned repair.
- Axillary artery exposure is guided by the nature of the planned reconstruction. The proximal artery is most easily exposed via a transverse infraclavicular incision. Exposure of the second and third portions requires deltopectoral or axillary approaches, respectively.[1]
- Acute symptomatic embolic occlusion of the axillary or brachial arteries are best managed by open, preferably image-guided, balloon catheter or direct thromboembolectomy.[1,2] Essential elements required for thromboembolectomy include (1) determination of the optimal treatment environment (operating room [OR] with portable vs. fixed imaging), (2) arterial access (level of incision), (3) acquisition of catheters and guidewires

required to transverse the embolus and accumulated luminal thrombus, (4) availability of balloon and over-the-wire embolectomy catheters, (5) need for adjuncts such as aspiration catheters (Export™ catheter, Medtronic, Minneapolis, MN) and thrombolytic agents (tissue plasminogen activator [tPA]), (6) options for managing postischemic hyperemia and elevated compartment pressures, and (7) consideration of treatment alternatives should preexisting atherosclerotic occlusive disease preclude or complicate catheter-directed thromboembolectomy.

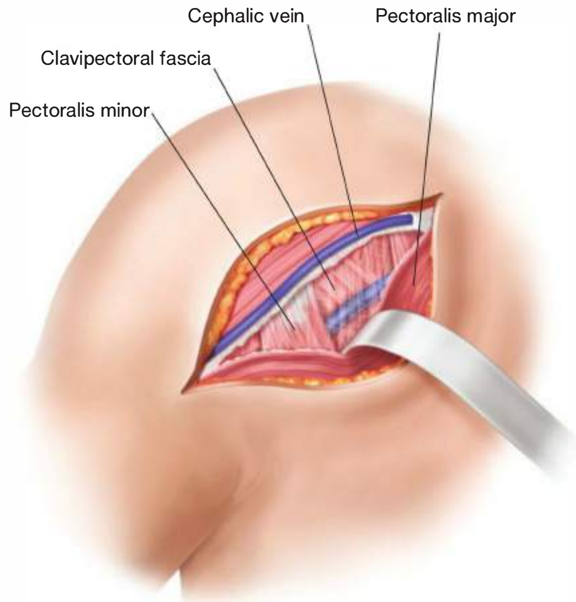
- For symptomatic axillary or brachial artery thrombosis not amenable to direct or catheter-based, image-guided thromboembolectomy, open surgical bypass or interposition grafting is the preferred method of repair. When considering open bypass or interposition grafting distal to the clavicle, key planning elements include (1) determination of optimal inflow and outflow, (2) conduit (almost exclusively autogenous vein), and (3) assessment of distal compartment pressures and potential need for fascial release. Commonly, more vasospasm is engendered by injury and surgical manipulation in the upper extremity arteries as compared to those of the lower extremities, and accommodations may need to be made to ensure graft and bypass patency in this context.
- Branch vessel injuries and aneurysms, particularly those arising from the axillary and brachial arteries, are best treated with ligation and excision.[14] Preoperative planning of these procedures involves selection of an appropriate exposure through the muscles of the upper extremity that will facilitate rapid recovery and minimize risk of disability in a usually young and active patient cohort.
- The relatively superficial location of the brachial artery in the antecubital fossa increases its vulnerability to traumatic and iatrogenic injury.[15] Most brachial injuries are associated with penetrating trauma; however, blunt injuries also occur, particularly in the distal brachial artery, following posterior elbow dislocations and supracondylar fractures (the latter more commonly in children).[16] In these situations, key elements for repair will include inspection of injured arterial segment on preoperative imaging for possible intimal disruption, short segment thrombosis, or thrombosis extending distally into the forearm.
- An increasing number of cardiac catheterizations and coronary interventions are performed via radial or brachial access.[17] Cannulation site complications, including thrombosis or pseudoaneurysm formation, often necessitate operative repair.[17,18] For these patients, preoperative planning will include identifying the extent of injury, options for graft conduit (smaller diameter vein), and alternative management options including arterial ligation in extenuating circumstances.
- The ulnar artery at the wrist is the dominant hand artery in the majority of patients. Achieving or maintaining sufficient arterial outflow at the wrist is essential to the hemodynamic and clinical success of forearm revascularization procedures. The status of the radial and ulnar arteries at the wrist should be confirmed in the course of evaluating all patients for upper extremity revascularization options.

Operating Room Setup

- The majority of upper extremity revascularization procedures are suited for a hybrid operating environment, or an OR equipped with a radiolucent, floating-point carbon fiber operating table and fluoroscopy radiation source and image intensification system, preferably equipped with digital subtraction angiography and last-image hold capabilities. When optimal x-ray penetration and resolution is not available, or in circumstances when diagnostic angiography alone is anticipated, less sophisticated portable imaging systems may suffice.
- Elective and emergent upper extremity surgical revascularization procedures may be performed with either regional or general anesthesia. Considerations include the overall status of the patient, ability to tolerate the specific challenges associated with either anesthetic techniques, and the abilities of the anesthesiologist responsible for anesthetic management.
- For the majority of upper extremity procedures, the operative limb is typically extended at 90 degrees. For optimal surgical exposure, we prefer arm positioning systems that move freely with the OR table rather than those with separate floor extensions. To avoid exacerbation of potential brachial plexus injuries in appropriate clinical settings, care should be taken to avoid hyperabduction and extension of the limb. The operative field should include, at a minimum, the ipsilateral axilla, chest, and neck, with the head rotated and extended to the contralateral side. A shoulder roll may be positioned under the ipsilateral shoulder to aid with neck and shoulder extension (**FIG 1A**). Alternatively, for optimal deltopectoral exposure of the axillary artery, the arm can be externally rotated and abducted at 30 degrees relative to the lateral chest.
- In situations where venous interposition conduit may be needed, a lower extremity should also be prepared into the surgical field to allow for greater or lesser saphenous vein harvest as indicated by the estimated diameter of the target artery. In the setting of extensive traumatic injuries, vein should be harvested from the least affected lower extremity.

A

FIG 1 • **A.** With the patient supine, the arm of interest is pronated and extended at 90 degrees relative to the chest. The head is externally rotated to the contralateral side to expose the ipsilateral neck segment. *(continued)*



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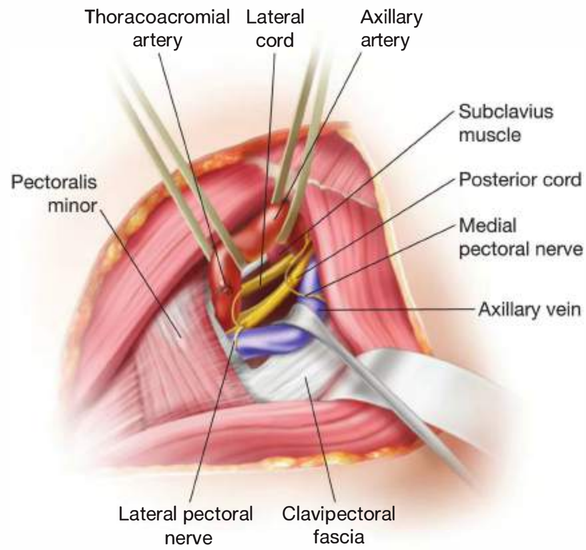

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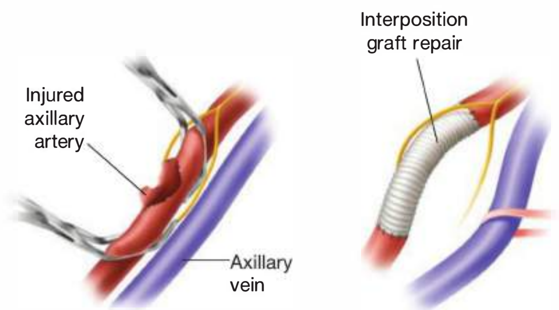


D

FIG 1 ● *(continued)* **B.** Infraclavicular exposure of the proximal axillary artery. **C.** Components of the infraclavicular axillary sheath. **D.** Interposition graft repair of a proximal axillary artery traumatic partial transection.

- Systemic anticoagulation should be considered whenever major open or endovascular revascularizations are undertaken. Exceptions include profound systemic coagulopathy or concern related to concomitant risks such as occult intracranial hemorrhage. Sufficient intravenous unfractionated heparin should be administered to achieve an activated clotting time of more than 250 seconds.
- Open surgical revascularization and repair techniques are described in the sections in the following text relative to upper extremity anatomic location.
- The last section describes general endovascular techniques used for upper extremity interventions.

PROXIMAL AXILLARY ARTERY

First Step

- Exposure of the proximal (first) portion of the axillary artery is best achieved through an incision placed one fingerbreadth below the middle third of the clavicle (**FIG 1B**). Deep to the subcutaneous tissue, the pectoral fascia is opened longitudinally. The pectoralis major muscle is divided with a muscle-splitting incision. The underlying clavipectoral fascia is then sharply incised to expose the proximal axillary sheath. Additional exposure is aided by lateral retraction or division of the pectoralis minor muscle.

Second Step

- Fine dissection should be used to expose and control the axillary artery deep to the clavipectoral fascia. Careful dissection and retraction minimizes injury to the cords of the brachial plexus surrounding the artery. The lateral pectoral nerve and proximal cephalic vein are also prone to injury during dissection or traction from misplaced self-retaining retraction devices.

Third Step

- The axillary vein lies anterior and caudal to the artery within the axillary sheath. Mobility of the vein is achieved with gentle dissection, ligation of associated venous tributaries, and mild caudal retraction with a circumferential vessel loop or small handheld retractor (**FIG 1C**).
- In smaller patients, division of the thoracoacromial artery and vein may be required to facilitate proximal axillary exposure. Once again, injury to the lateral pectoral nerve is avoided by gentle, deliberate dissection.

Fourth Step

- Once circumferential dissection and exposure of the proximal axillary artery is complete, the artery is optimally controlled with silastic vessel loops (**FIG 1C**).
- Familiar anatomic relationships may be less recognizable during redo or complex exposures, or in the setting of traumatic injuries, ongoing extravasation, and hematoma formation. The risk of associated brachial plexopathy is heightened in these situations. Extending exposure through the deltopectoral groove may help delineate otherwise indistinct tissue planes. Repositioning the arm throughout the range of available abduction may also reduce position-related anatomic distortion.

Fifth Step

- For axillofemoral bypass grafting, the first or most proximal axillary segment is chosen for anastomotic access to minimize the risk of traction and potential graft disruption from shoulder and arm movement. Locating the anastomosis as proximate to the clavicle as possible optimizes long-term performance and durability. Based on the patient's body habitus and planned graft configuration (uni- or bifemoral), an appropriately sized (6, 8, or 10 mm) externally supported expanded polytetrafluoroethylene (ePTFE) is employed. For most patients, in most situations, an 8-mm diameter, removable ring graft is optimal. The axillary arteriotomy is always created proximal to the overlying pectoralis minor muscle, which is itself usually divided to further minimize undue traction on the graft.
- When considering direct ipsilateral axillo–axillo or axillo-brachial bypass grafting, conduit choice depends on surgical context. In contaminated fields (with open penetrating or avulsion injuries of the axillary artery), vein is preferred and is sourced from the long or short saphenous or superficial femoral veins in the (least involved) lower extremity, or contralateral arm vein. For elective revascularization procedures, depending on the age of the patient, bypass length, target artery diameter, and indications for reconstruction, ePTFE or knitted polyester prosthetic grafts may provide acceptable alternatives. However, in nearly all situations requiring upper extremity bypass at or distal to the clavicle, autogenous vein is optimal and highly preferred.
- For ipsilateral revascularization, graft is tunneled parallel to the existing axillary artery beneath the pectoralis major and minor muscles to the anterior axillary line.
- For upper extremity revascularization procedures, tunneling is extended distally through subcutaneous planes along the arm and forearm as necessary to reach the target artery. In the case of axillofemoral bypass grafting, the ePTFE graft tunnel is created retrograde, extending from the femoral incision superiorly to the exposed axillary artery, with care being taken to position the graft anterior to the anterior superior iliac crest and advanced upward along the anterior axillary line. The tunnel must not breach the abdominal fascia or thoracic cavity. With a tunneling device of sufficient length, a counterincision is not usually necessary to reach the axillary artery. At the inferior border of the pectoralis muscle, the tunnel transitions to a subfascial plane extending below the pectoralis major muscle to reach the exposed axillary artery medial to its intersection with the pectoralis minor muscle. Use of a purpose-specific tunneling device for this maneuver will not only obviate the need for a counterincision but also minimize risks of kinking, twisting, or graft compression.
- The conduit should be beveled appropriately for end-to-side anastomoses at both ends. At the axillary anastomosis, slightly more graft length redundancy is needed to prevent excessive traction on the anastomosis and late graft or arterial injury. The use of stretch polytetrafluoroethylene (PTFE) is also preferred for this reason.

Sixth Step

- Traumatized, thrombosed, or aneurysmal proximal axillary artery segments may be transected or resected as necessary, reconstituted by interposition grafting with venous or prosthetic conduit (**FIG 1D**).
- For interposition grafting, the damaged or diseased arterial segment is fully transected and removed. The lumen within the proximal and distal arterial segments should be inspected for trauma, dissection, or thrombus formation. In the case of the distal artery, flushing with heparinized saline may help confirm patency and sufficient runoff. Retrograde flushing of diseased or damaged brachial, axillary, or subclavian arteries is not recommended given the potential risk for vertebral artery embolization of residual luminal detritus and subsequent central nervous system (CNS) infarction or injury.
- When uncertainty exists regarding the extent of axillary injury, further exposure may be necessary to ensure success. In rare and extenuating circumstances, clavicular resection and replacement (or removal) may be required for satisfactory arterial exposure. Similarly, when fragmented or chronically infected, the clavicle should be removed as necessary to optimize long-term graft patency and limb viability.
- For upper extremity arterial reconstruction, once exposure is complete and the appropriate tunnel is created, the appropriate conduit is selected for use and prepared for interposition grafting (**FIG 1D**). The conduit should be fashioned to an appropriate length to avoid potential kinking during future arm motions. Proximal and distal anastomoses are performed end-to-end or end-to-side depending on the respective diameters of the inflow and outflow segments.

Seventh Step

- Catheter embolectomy should be performed as necessary, often using over-the-wire, image-guided techniques, to remove luminal thrombus from inflow or outflow arterial segments as necessary. Care should be taken with proximally directed embolectomy to avoid dislodging clot fragments into the vertebral artery.
- To minimize iatrogenic injury from embolectomy catheters, proximal embolectomy is best initiated at the level of the axillary rather than brachial artery. Attempting antegrade embolectomy proximally from an antecubital brachial access incision risks traumatic injury to the axillary or brachial artery at the origin of the deep brachial artery, where the diameter of the brachial artery decreases significantly, just distal to the axillary fossa.
- Appropriately sized Fogarty thrombectomy catheters for upper extremity embolectomy include sizes 2 through 5 Fr, depending on the diameter of the artery being instrumented and the technique (antegrade or retrograde) being employed.

MID-DISTAL AXILLARY ARTERY

First Step

- The mid-distal axillary artery may be exposed via an axillary or deltopectoral incision. For distal exposure, the incision is extended through the posterolateral border of the pectoralis major muscle to allow for partial mobilization and medial retraction of that muscle (**FIG 2A**). In the superior aspect of the surgical incision, the coracobrachialis muscle will be visualized at 90 degrees relative to the medially retracted pectoralis major muscle. Within this angle, gentle blunt dissection is applied to identify the axillary sheath running along the inferoposterior border of the coracobrachialis muscle.
- For deltopectoral exposure, dissection is performed along the anterior border of the deltoid muscle, extending

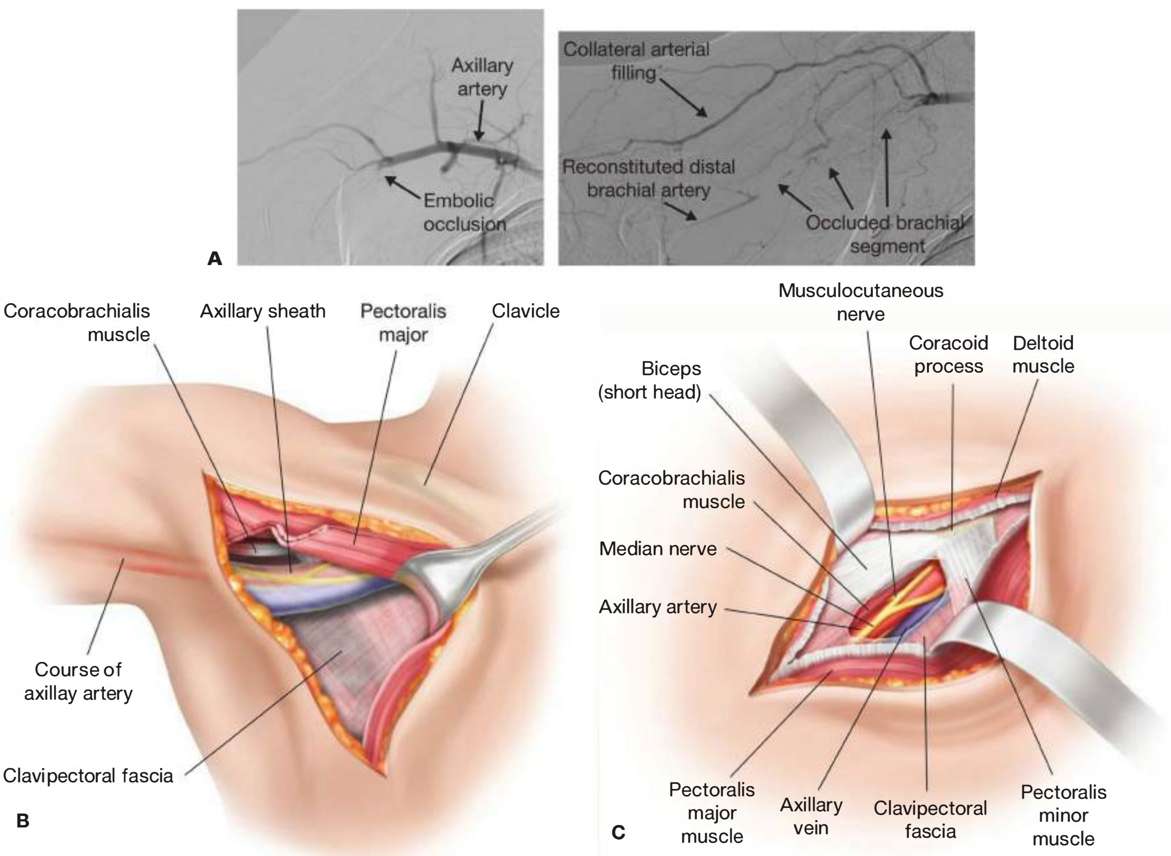


FIG 2 ● **A.** Right upper extremity arteriogram demonstrating distal axillary and brachial artery occlusion, with substantial filling of unnamed collateral arterioles. **B.** Axillary exposure of the mid-distal axillary artery. **C.** Deltopectoral exposure of a long segment of axillary artery. *(continued)*

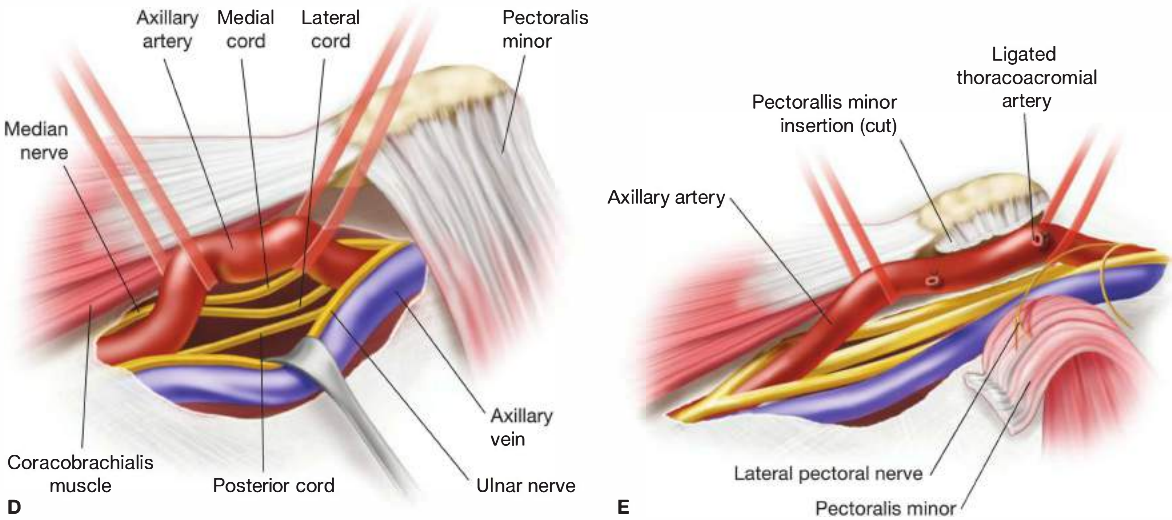


FIG 2 ● *(continued)* **D.** Exposure of the distal axillary artery and associated axillary sheath structures. **E.** Exposure of the midaxillary artery via reflection of the pectoralis minor muscle.

through the subcutaneous tissue in the deltopectoral groove (**FIG 2B**). With medial retraction of the pectoralis major, the neurovascular bundle is then exposed in the underlying clavipectoral fascia.

Second Step

- Upon entry of the axillary sheath, the axillary artery is visualized directly under the median nerve. At the lateral border of the pectoralis major muscle, the medial and lateral cords form the median nerve form over the anterior surface of the axillary artery. The ulnar nerve and axillary artery are visualized along the inferoposterior border of the mid-distal axillary artery in this exposure. Identification of surrounding structures during axillary exposure minimizes risks of inadvertent injury. Elevation and caudal retraction of the exposed axillary artery with vessel loops also augments exposure and reduces risk of adjacent nerve injury during arterial clamping (**FIG 2C**).

Third Step

- When further exposure of the second portion of the axillary is required, the pectoralis minor muscle is divided near its insertion on the coracoid process. The pectoral nerves should be identified and protected during this maneuver. Caudal retraction of the muscle allows for exposure of the underlying neurovascular bundle (**FIG 2D**).
- In the second portion, the axillary artery is surrounded on three sides by brachial plexus nerves, leaving the anterior surface of the artery uncovered. For sufficient circumferential exposure of the vessel, the thoracoacromial artery can be ligated and divided at its origin. However, during mobilization of the axillary artery segment, care should be taken to not injure the lateral thoracic artery and the lateral and medial cords as they join over the distal axillary artery to form the median nerve.

Fourth Step

- Similar to the steps outlined for reconstruction of injuries to the first or second portion, traumatized, thrombosed, or aneurysmal segments in the second or third portions of the axillary artery may be transected or bypassed, with interposition grafting or bypass as necessary.
- Repair of axillary branch injuries and aneurysms requires sufficient segmental exposure of the axillary artery itself, as well as the branch artery of concern. Subscapular, medial humeral circumflex, or lateral humeral circumflex branch artery aneurysms can be exposed through the axillary fossa and divided free from the axillary artery once ligated to prevent persistent distal arterial embolization and hand ischemia in the setting of chronic overuse or athletic injuries. Occasionally, aneurysmal degeneration of the branch compromises the integrity of the axillary artery itself, and interposition grafting may be required for optimal reconstitution of distal limb blood flow. Autogenous vein (or artery harvested from the distal internal iliac circulation in the pelvis) is the optimal conduit choice for this application (**FIG 3**).
- Axillary or branch artery injuries resulting in substantial distal and symptomatic upper extremity arterial emboli and digital ischemia may benefit from a trial of intraarterial thrombolytic therapy, administered preoperatively, to improve runoff, graft patency, hand perfusion, and functional status.

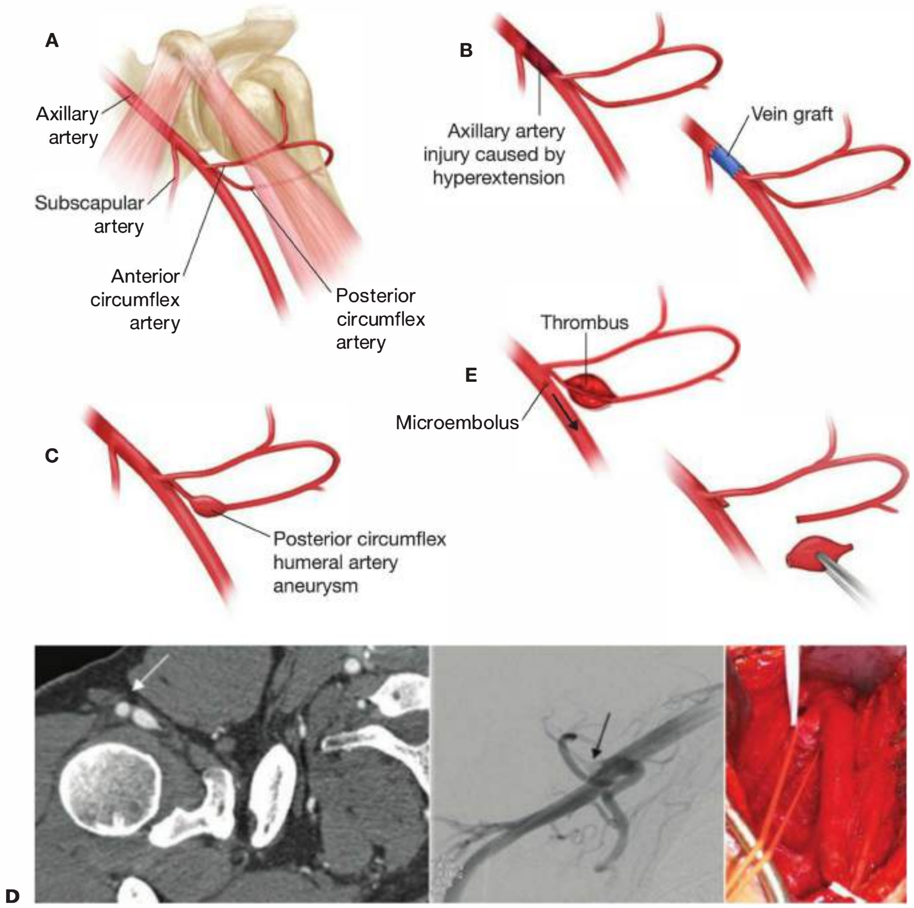


FIG 3 ● **A.** Relative anatomy of the distal axillary artery and associated anterior and posterior circumflex humeral arteries. **B.** Axillary artery injury at the origin of a circumflex humeral branch repaired with an interposition vein graft. **C.** Circumflex humeral branch aneurysm. **D.** CTA of right upper extremity circumflex humeral branch artery aneurysm *(arrow)*. Catheter-based angiogram demonstrates hypodensity in the circumflex humeral branch, consistent with intraluminal thrombus *(middle panel)*. Open operative exposure of the circumflex humeral branch originating from the axillary artery *(isolated by red silastic sling)*. **E.** Branch aneurysm thrombus causing distal microemboli can be treated with resection and interval ligation of the branch vessel.

BRACHIAL ARTERY

First Step

- In the upper arm, the proximal brachial artery is optimally exposed via a 5- to 8-cm longitudinal incision in the medial groove between the biceps and triceps muscles (**FIG 4A**).
- As the subcutaneous tissue is dissected, care should be taken to visualize and avoid injury to the basilic vein as it crosses near the brachial sheath in the distal upper arm. To aid in exposure, the basilic vein can be retracted into the posterior wound, and vein branches crossing over the brachial artery sheath can be ligated and divided. Significant plexus of sensory nerves are also encountered in this dissection and should be protected from injury.

Second Step

- By incising the deep fascia at the medial border of the biceps muscle, the neurovascular bundle may be further exposed. The median nerve will be the first structure to be encountered in the brachial sheath with this exposure. Wide mobilization of the nerve allows for its gentle retraction into the anterior wound (**FIG 4B**).
- Just deep to the median nerve, the brachial artery will be visualized along with two flanking brachial veins. Interconnecting communications between these veins may be ligated to aid in further exposure of the brachial artery.

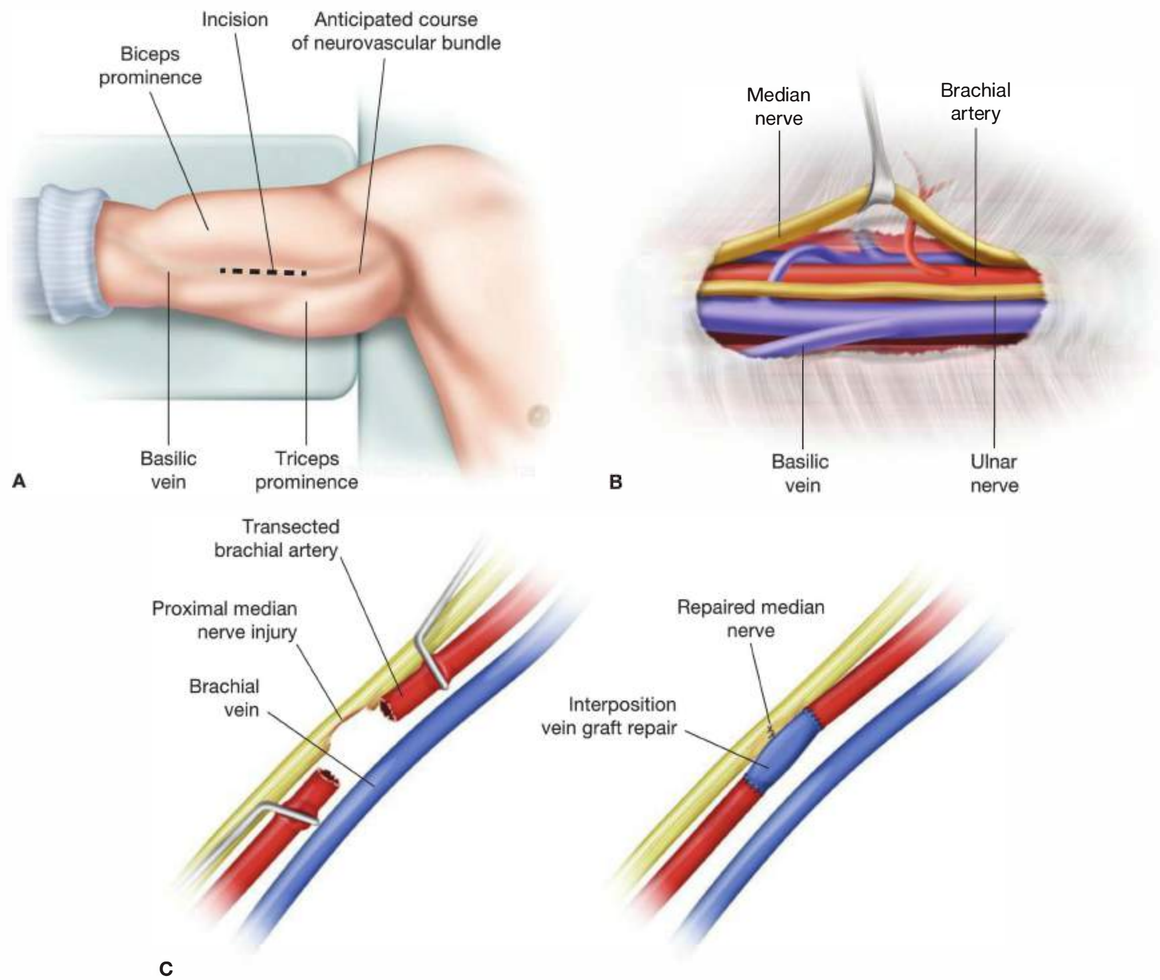


FIG 4 ● **A.** Incision created for exposure of the proximal brachial artery in the upper arm. **B.** The brachial artery in the upper arm is adjacent to the median and ulnar nerves. **C.** Traumatic transection of the brachial artery with associated intimal damage, along with partial injury to the median nerve. Subsequent repair is performed with a brachial artery interposition graft using a vein conduit and median nerve repair.

Third Step

- Exposure of the brachial artery in the mid-upper arm may require identification and control of the deep brachial artery, which arises on the posteromedial surface of the brachial artery, just distal to the lateral border of the teres major muscle in the distal axillary fossa. In the distal upper arm, the superior and inferior ulnar collateral arteries may also require control during brachial artery exposure.

Fourth Step

- Alternatively, the brachial exposure can be gained through an oblique incision along the anticipated course of the brachial artery in the distal upper arm proximal to the antecubital fossa.
- Once again, care should be taken to avoid injury of the median nerve, which can be found posteromedial relative to the brachial artery in this area (FIG 5). Elevation of the brachial artery with vessel loops prior to clamping can decrease the chance of nerve injuries during this process.

Fifth Step

- Pseudoaneurysm or transection of the brachial artery can be repaired following proximal and distal brachial artery exposure and control. In the setting imminent rupture or exsanguination, proximal control in this area may be obtained with a proximal sterile tourniquet. Following tourniquet control, the injured brachial artery segment or pseudoaneurysm sac can be isolated and explored with confidence. This technique is particularly useful in preventing catastrophic rupture and contamination of the OR environment with blood-borne pathogens in the setting of iatrogenic or self-inflicted mycotic aneurysms.
- Puncture wounds may be amenable to primary suture repair or minimal resection of the injured segment and primary reapproximation. Larger defects and partial

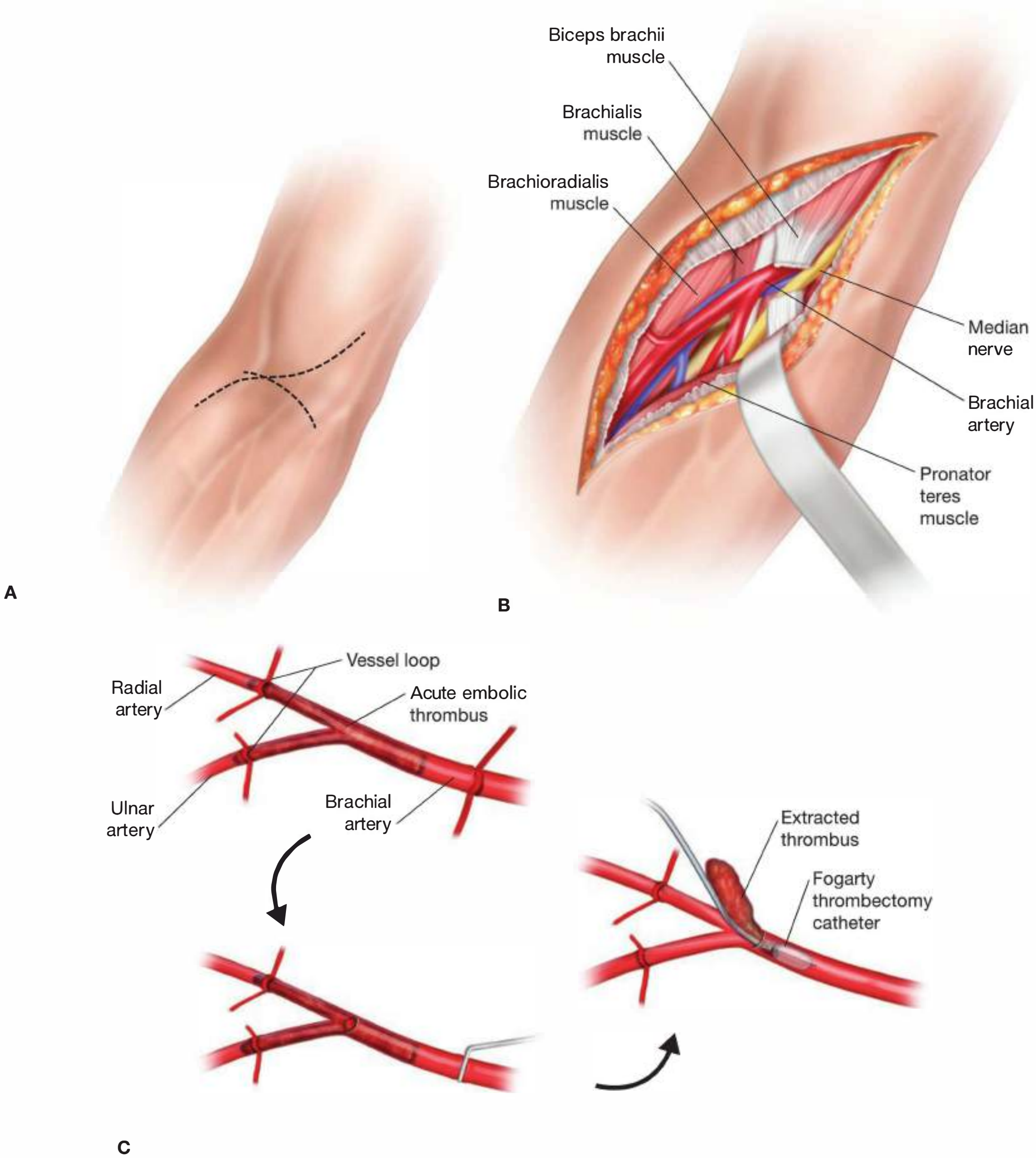


FIG 5 ● **A.** Typical incisions used for exposure of the distal brachial artery and proximal radial and ulnar arteries at the antecubital fossa. **B.** Relative anatomy of the brachial, radial, and ulnar arteries and adjacent median nerve. **C.** Acute embolic occlusion of the brachial artery bifurcation can be treated following proximal and distal control of the brachial, radial, and ulnar arteries. Arteriotomy is created over the occluded vascular segment. Following distal thrombectomy of the ulnar and radial arteries, a Fogarty thrombectomy catheter can also be used to extract thrombus from the brachial artery.

transections may require patch angioplasty for satisfactory repair (FIG 4C).

- When uncertain as to whether a primary repair is indicated or even possible, the most reliable course of action is interposition vein grafting, usually harvested from a long saphenous vein, with care taken to account for differences in length based on movement at the elbow (e.g., avoid kinking while limiting tension). Risk of kinking is also reduced by reconstructing other injured structures in the antecubital fossa (e.g., biceps brachialis tendon) to limit graft motion during elbow flexion.
- Distal forearm thrombectomy is best performed through a brachial incision created in the antecubital fossa. Exposure of the distal brachial artery may be necessary to sequentially catheterize the individual forearm arteries. Alternatively, proximal sheath access in the axillary fossa may facilitate image-guided access of the forearm arteries and over-the-wire embolectomy.
- In the antecubital fossa, distal thromboembolectomy may be performed with a 2- or 3-Fr Fogarty catheter (FIG 5C). Further endovascular imaging and treatment (see in the following text) may be required to optimally restore distal arterial perfusion.
- Apropos the prior discussion regarding axillary exposure and embolectomy, attempting removal of proximal emboli from antecubital brachial access (e.g., "retrograde" positioning of the embolectomy catheter into the proximal brachial and axillary arteries) carries a significant risk of catheter-related injury to the proximal brachial artery at the origin of the deep brachial artery, where a significant diameter reduction occurs due to the bifurcation of superficial and deep brachial arteries. For proximal embolectomy, the safer approach is to generally gain access in the axillary rather than antecubital fossa.
- Brachial occlusion associated with elbow or shoulder dislocation typically results from intimal disruption or dissection beginning at the point of injury and extending distally. Accordingly, when focal arterial injury is present in the setting of complete occlusion, the injured segment is optimally repaired by resection and replacement rather than attempts at anticoagulation or embolectomy alone.

RADIAL ARTERY

First Step

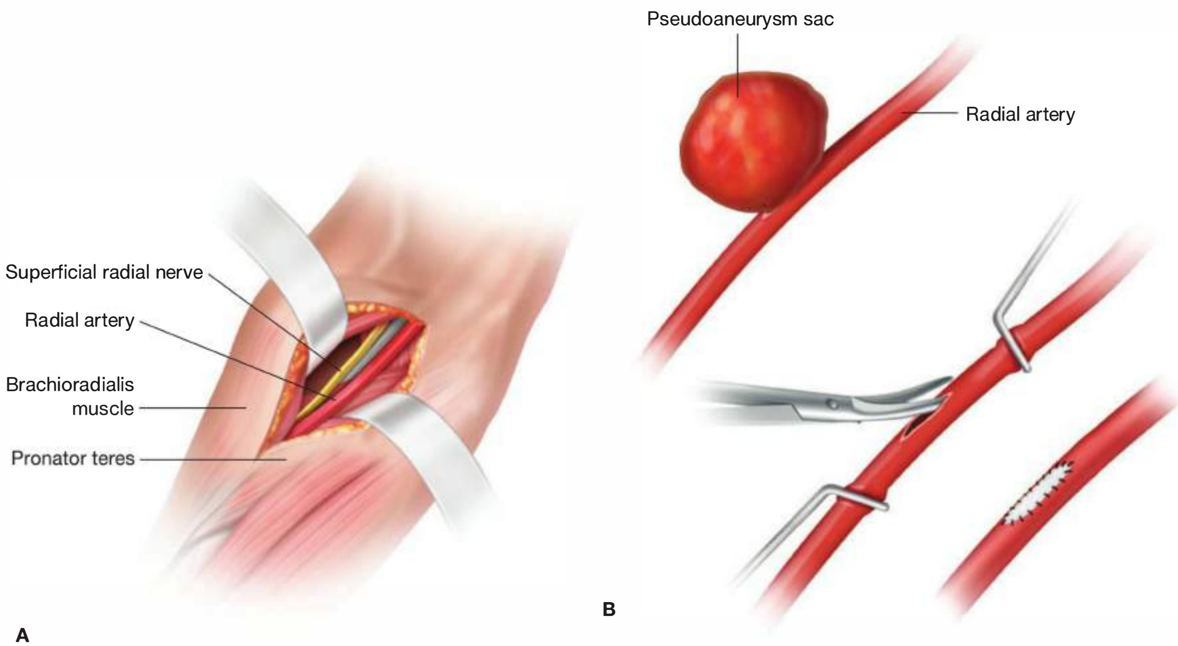
- Direct open exposure of the radial artery can be performed at almost every level proximal to the wrist. As with other arterial segments, exposure of the radial artery should be sufficient to allow both proximal and distal arterial control.
- The brachial artery typically bifurcates to give rise to the radial artery and ulnar/interosseus trunk at the level of the radial tuberosity (FIG 5B). However, not infrequently, the radial artery originates from the upper arm brachial artery or even the axillary artery (up to 15% incidence in cadaveric studies).[19] Several clinical circumstances highlight the significance of this anomaly, including the need to base distal bypass or arteriovenous access procedures off the "brachial" artery in the antecubital fossa. To ensure adequate arterial inflow, it is essential to identify which arterial conduits are present and identified in the antecubital fossa. Preoperative CT angiography, catheter-based contrast arteriography, or ultrasonography can provide essential information in this regard.
- Alternative exposure options exist for the brachial bifurcation and proximal radial artery in the antecubital fossa. A 4- to 5-cm transverse incision, two fingerbreadths distal to the antecubital crease, provides optimal exposure for the distal brachial artery as well as the origins of the forearm arteries (interosseus, radial, and ulnar). Alternatively, for more extensive brachial artery exposure, an S-shaped incision is employed extending from the medial aspect of the biceps muscle tendon, through the midpoint of the antecubital fossa, and toward the lateral aspect of the volar forearm (FIG 5A).
- Exposure of the mid- or distal radial artery can be performed through 4- to 5-cm longitudinal incisions along the lateral aspect of the volar forearm (FIG 6A). A useful landmark for these incisions is the imaginary line extending from the midpoint of the antecubital crease to the styloid process of the radius, which often anatomically corresponds to the groove of the medial edge of the brachioradialis muscle.

Second Step

- Superficial, subcutaneous veins overlying the target arteries (medial antecubital vein in the antecubital fossa and cephalic vein branches in the forearm) may be mobilized or ligated to aid with the exposure process. Prior to ligation, care should be taken to consider the totality of remaining forearm runoff veins, especially in the setting of blunt or avulsive traumatic injuries.
- In the proximal forearm, the antebrachial fascia will need to be excised along the medial edge of the brachioradialis muscle along the length of the incision. The radial artery can then be visualized with lateral retraction of the brachioradialis muscle.
- Similarly, in the midforearm, the radial artery can be visualized following excision of the overlying antebrachial fascia and retracting apart the brachioradialis and pronator teres muscles (FIG 6A).
- During exposure maneuvers, care should be taken to visualize and avoid injury to closely associated radial artery structures. This includes the paired radial artery veins that accompany the radial artery throughout its course in the forearm. The superficial radial nerve is also closely associated with the lateral aspect of the radial artery in the midforearm and can be preserved with gentle lateral retraction.

Third Step

- Given the dominance of the ulnar circulation in most patients, isolated distal radial reconstruction may be optional, depending on the totality of coexisting conditions and injuries. Superimposed acute or chronic traumatic injury,



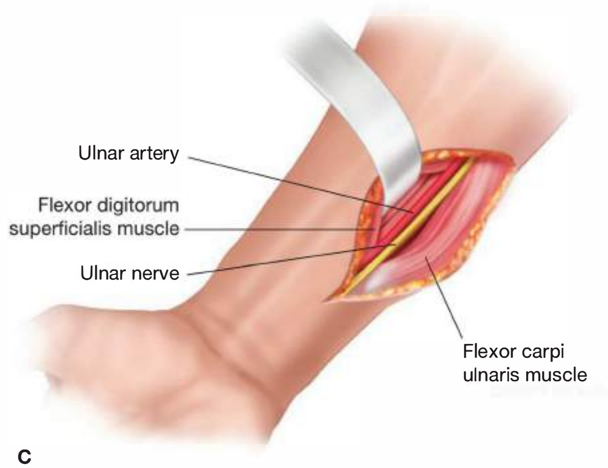


FIG 6 ● **A.** Exposure of the radial artery in the proximal and distal forearm. **B.** Following proximal and distal radial artery control, a primary repair of a radial artery pseudoaneurysm is performed. **C.** Exposure of the proximal midulnar artery in the forearm.

renal failure, diabetes mellitus, or chronic embolization may justify radial reconstruction, particularly in circumstances where hand viability is at significant risk.

- Radial artery transections or pseudoaneurysms, like all types of arterial reconstruction, are best approached following adequate exposure and proximal/distal control. Detailed exploration and arterial exposure follows shortly thereafter. Depending on extent of injury and integrity of the arterial lumen at the site of injury, either primary repair or interposition grafting may be considered (FIG 6B).
- Acute embolic occlusions of the radial artery can be removed through retrograde embolectomy, performed through a controlled proximal, transverse arteriotomy. Given the caliber of the forearm arterial system, a 2-Fr Fogarty catheter is best suited for this purpose. As was the case more proximally in the upper extremity arterial system, image-guided, over-the-wire embolectomy, combined with judicious use of intraarterial thrombolytic agents such as tPA (see "Upper extremity angiography and stenting" section in the following text), may be necessary to achieve satisfactory runoff and hand and digital perfusion. Thus, arrangements should be made preoperatively to initiate the embolectomy procedure in an operating environment that can support image-guided intervention.
- Both forearm arteries at the wrist may provide appropriate inflow for dialysis access procedures. Considerations for arteriovenous access creation and maintenance are beyond the scope of this chapter. Interested readers are referred to other references for options regarding dialysis access creation.

ULNAR ARTERY

First Step

- Similar to the radial artery, the ulnar artery may also be exposed along its course in the forearm, and the extent of exposure will depend on the site and type of pathology as well as ability to obtain adequate proximal and distal arterial control (FIG 6C).
- The proximal ulnar artery can also be exposed at the brachial bifurcation in the antecubital fossa through an S-shaped incision (see "Radial artery" earlier; FIG 5A,B).
- Although more challenging, the proximal ulnar artery may also be exposed in the medial aspect of the proximal forearm. Four fingerbreadths below the medial epicondyle, a 7- to 9-cm longitudinal incision can be created along a line extending from the medial epicondyle to the pisiform bone. Incising the deep fascia facilitates exposure of the ulnar artery through the space between the flexor carpi ulnaris and flexor digitorum superficialis muscles (FIG 6C).
- The distal ulnar artery, proximal to the wrist, is optimally exposed through a longitudinal incision just lateral to the flexor carpi ulnaris muscle. The ulnar nerve lies medial to the artery at this level and is prone to injury with this exposure. Care should be taken to identify and mobilize it safely. The superficial palmar branch of the ulnar artery and nerve also crosses superficial to the antecubital fascia at the wrist level, and care should be taken to prevent traction or compression injuries to these structures during ulnar artery exposure.

Second Step

- Thrombectomy of the ulnar artery proceeds in a fashion similar to that previously described for the radial artery.
- Ulnar artery traumatic transections may be repaired primarily or with an appropriately sized interposition vein graft. Vein harvested from the dorsum of the foot frequently serves this purpose well.
- Ulnar artery arteriovenous dialysis accesses are rarely performed due to this vessel's relative difficulty in exposure compared to the radial artery, its close proximity to the ulnar nerve throughout its length, and its relative dominance in maintaining adequate perfusion to the hand.

UPPER EXTREMITY ANGIOGRAPHY AND STENTING

First Step

- Access depends largely on the area and type of anticipated arterial pathology. For innominate or proximal subclavian artery disease or injury, retrograde transbrachial or transfemoral artery approach may both suffice. For distal diagnostic or interventional procedures, retrograde radial or antegrade access may be considered.
- Standard Seldinger technique is used for percutaneous arterial access, using either ultrasonographic or fluoroscopic guidance. Placement of a 4-Fr microsheath may help stabilize the initial cannulation site and allow for preliminary diagnostic imaging.

Second Step

- Intraarterial pharmacologic adjuncts may be administered through appropriately positioned arterial infusion systems.
- For arterial thrombosis, catheter-directed, limb-specific, intraarterial tPA is administered in doses related to the extent of thrombus load, ranging from 0.25 to 2.0 mg per hour, following an initial "seeding" dose of 4 mg across the region in question over 10 to 30 minutes. Combined pharmacologic/mechanical thrombus disruption systems useful in other arterial and venous beds, including the Trellis™ system (Covidien, Mansfield, MA), may be too large or unwieldy for the upper extremity arterial vasculature. Newer low-profile systems, however, such as the MicroLysUS™ infusion catheter (EKOS Corporation, Bothell, WA), may be more useful and appropriate in this application. Care should always be taken to account for risk of particulate embolus in the vertebral artery when planning embolectomy or thrombectomy procedures in the upper extremity.
- Similarly, the upper extremity arterial system is particularly prone to vasospasm during catheterization. During diagnostic examinations, particularly in younger patients, care should be taken to avoid catheterization distal to the antecubital fossa to minimize artifactual degradation of the angiographic image due to vasospasm. Similarly, using warm flush solutions may minimize this effect. When the radiographic appearance of vasospasm is encountered ("string sign" or "string of beads" appearance), direct intraarterial infusion of papaverine (10 to 50 mg) or nitroglycerine (50 to 200 μg) may improve image resolution in hand or digital arteries. Papaverine will precipitate out of solution when exposed to heparin and may not be optimal for all potential clinical applications for this reason.

Third Step

- If further endovascular diagnostic or interventional procedures are planned, wire access with a 0.018-in or 0.035-in guidewire to the arterial segment of interest must be achieved.
- From a brachial artery approach, a short guide sheath and a guide catheter combination usually allows for successful catheterization of adjacent proximal upper extremity arterial segments.
- From a femoral artery approach, a long (90 cm) 6- or 7-Fr sheath is typically advanced over the guidewire to facilitate stable catheterization of innominate or proximal left subclavian artery. Long, curved 5-Fr catheters (i.e., angled, JB 2, headhunter, or vertebral catheter) may be used to aid in successful cannulation and subsequent catheterization of the arch vessel of interest. Confirmatory angiograms will help confirm successful cannulation and aid in identifying the arterial segment of interest (FIG 7A).
- Once stable catheterization of the target vessel is achieved, magnified angiograms may be obtained in the

appropriate obliquities to accurately assess the arterial segments of interest. Additional runoff imaging may be necessary to evaluate the arterial outflow distal to the diseased segment. The operator should inspect these angiograms to determine once again the candidacy for endovascular treatment and obtain additional measurements to facilitate appropriate device selection.

Fourth Step

- Successful wire advancement across the lesion of interest is the next step in order to facilitate any planned treatments with angioplasty or stenting.
- With the guidance of a 4- or 5-Fr guide catheter, a 0.018-in or 0.035-in hydrophilic wire can be advanced across a hemodynamically significant stenosis (e.g., innominate artery, proximal subclavian artery, or upper arm brachial artery). During advancement, care should be taken to remain intraluminal as much as possible to minimize the risk of dissection and reentry. Adequate wire purchase should be acquired past the stenosis after crossing the lesion of interest to decrease the chance of losing subsequent wire access across the lesion.
- In situations where stenoses or occlusions preclude access from a "preferred" side, crossing the lesion from the alternate side and advancing a wire from the opposite direction using a snare technique may be required.
- Simultaneous antegrade and retrograde, through and through ("body floss") cannulation may facilitate lifesaving management of traumatic subclavian artery injuries. In dire circumstances where arterial continuity has been completely lost, and transluminal wire passage is not possible, advancing snare and wire from opposite directions simultaneously, employing multiple-angled view may allow for successful snaring in perivascular soft tissue and subsequent spanning of the arterial tissue defect with a flexible covered stent (e.g., Viabahn™). This technique may generate immediate and effective hemostasis while maintaining luminal patency and limb viability, especially as an alternative to ligation or emergency embolization (FIG 7).

Fifth Step

- Proximal subclavian artery and innominate stenoses are typically well managed by precise placement of stiff, balloon-expandable stents or stent grafts. Compared to the axillary artery, proximal to the costoclavicular junction, there is little or no movement in the proximal subclavian artery. In the setting of a prior internal mammary-to-coronary artery revascularization, or a history of vertebral–basilar insufficiency, precise stent placement is tantamount to procedural success. For this reason, appropriately sized covered (e.g., Atrium iCAST) or bare metal (e.g., Omnilink, Abbott, Redwood City, CA; Palmaz, Cordis Endovascular, Warren, NJ.) balloon-expandable stents are generally preferred.
- Appropriately size-matched, covered stents are also essential adjuncts for management of proximal subclavian artery injuries or chronic pseudoaneurysms (FIG 7).
- As noted earlier, however, stents of any kind should not be deployed in proximity to the junction of the 1st rib and clavicle, as chronic traumatic damage from compression between these bony structure will cause certain stent failure and further compromise limb viability.

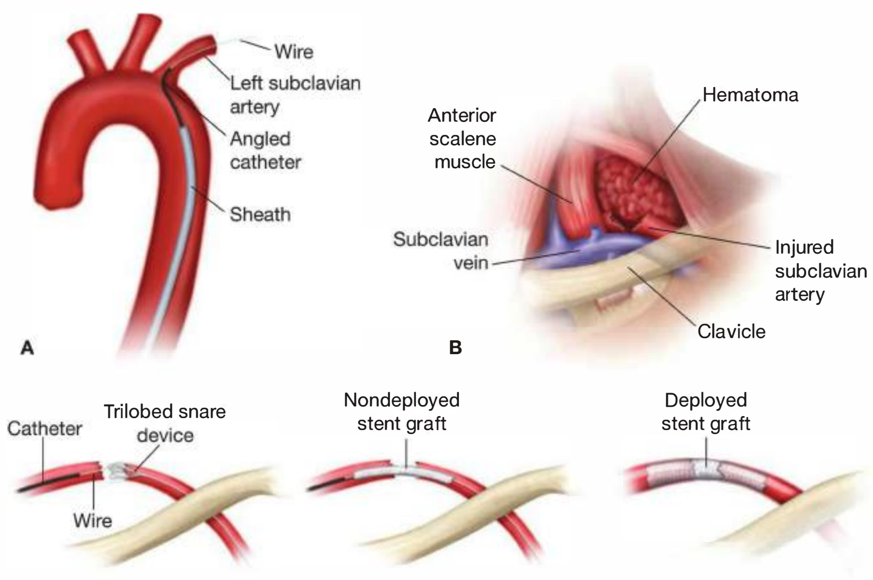


FIG 7 ● **A.** Retrograde cannulation of the proximal left subclavian artery using a triaxial flexible sheath, angled catheter, and glidewire combination. **B.** Traumatic injury to the left subclavian artery. **C.** Through and through (body floss) wire accesses the injured subclavian artery. **D,E.** Positioning and deployment of a covered stent to seal the subclavian arterial wall disruption while maintaining luminal flow.

PEARLS AND PITFALLS

Upper extremity nerve injuries	■ Upper extremity arterial injuries frequently are associated with concomitant nerve injuries.[20] Early recognition and diagnosis of these associated injuries is paramount to long-term functional restoration. ■ When nerve injury is identified or suspected, prompt repair in the same setting is recommended. Plastic surgery consultation in these circumstances is usually required.
Iatrogenic nerve injury during axillary artery exposure	■ As a general rule of thumb, whenever possible, axillary exposure proximal to the axilla should be acquired as proximal as possible, to limit the risk of nerve injury, as the cords of the brachial plexus become more intimately related to the axillary artery as it proceeds laterally from the clavicle. Also, the amount of axillary artery displacement and traction as a result of arm movement is minimized with far proximal anastomotic positioning. ■ Unless repair of the axillary artery requires a deltopectoral exposure, the preferred choices for axillary artery exposure are proximal or distal to the second portion of the axillary artery.
Arterial repair following segmental resection	■ In the setting of arterial trauma, the extent of arterial injury should be precisely determined prior to attempts at reconstruction. Failure to completely delineate the extent of injury will complicate attempts at repair. ■ As a general rule of thumb, all involved arterial segment should be resected and/or bypassed prior to attempts at reconstruction. Although primary repair with native arterial preservation is often appealing, long-term success typically requires interposition vein grafting for anything more than the simplest of injuries.[15,21]
Inflow assessment	■ Prior to completion of an upper extremity arterial repair, the operator must ensure that arterial inflow is adequate. ■ This can be confirmed on preoperative CTA if available, or alternatively, with an intraoperative angiogram.
Outflow assessment	■ Adequate arterial outflow is paramount to maintain patency of proximal repairs and help alleviate potential extremity ischemic symptoms. ■ Some authors recommend routine outflow assessments following upper extremity revascularization.[22] However, if this strategy is not regularly employed, intraoperative outflow assessment should be performed in circumstances where the distal arm and/or wrist vascular examination is abnormal following operative revascularization. ■ Because the ulnar artery is the dominant vessel of the distal forearm and hand, restoration of flow to this outflow vessel is often necessary to avoid subsequent complications.
Compartment syndrome of the upper extremity	■ With prolonged acute ischemia (>4–6 hours), upper extremity compartment release via fasciotomies is highly recommended. ■ Upper arm fasciotomies include two incisions into the brachium's two compartments. ■ Forearm fasciotomies are performed with three or more discrete incisions to decompress the volar forearm, dorsal forearm, and mobile wad.[23] ■ The hand may also require decompression via multiple incisions.[24] A carpal tunnel release may be necessary if median and ulnar nerve dysfunction is evident. Consultation with hand or plastic surgeons is recommended when considering the potential benefit of hand fasciotomy to maximize compartmental release and long-term functional and cosmetic recovery.

POSTOPERATIVE CARE

- At the conclusion of arterial reconstructive procedures, reversal of heparin-induced coagulopathy with protamine may or may not be indicated, depending on the status of the limb, the patient, and the reconstructive procedure itself. Care should be taken to provide a test dose of protamine before full reversal, if indicated, to minimize associated hypotension when antiprotamine antibodies are present.
- Motor and sensory examination as well as determination of upper extremity arterial status (including a Doppler and pulse examination) should be performed immediately postoperatively to determine the new baseline for subsequent serial examinations and to document improvement.
- Patients are typically observed for an extended period (at least several hours) following upper extremity arterial intervention to ensure procedural success and recovery from anesthesia. During this period, the patient is observed for bleeding, hematomas, or change in serial vascular examinations.
- Patients treated for primary thrombosis or occlusion of an arterial segment are typically managed with long-term, adjunctive systemic anticoagulation. The length of treatment period is debated and is variable between practitioners but may be directed by severity of presenting symptoms, frequency of prior occurrences, or history of a hypercoagulable condition.[25]
- Patients who presented with a presumed embolic occlusion of an arterial segment should undergo a medical workup for possible cardiac, proximal arterial atherosclerotic, endocarditis, paradoxical, or tumor embolic sources.
- Patients who underwent angioplasty or stenting of an arterial segment in the upper extremity are typically initiated on a single-agent antiplatelet regimen with either aspirin or clopidogrel.

- Patients who had a concomitant nerve injury or required fasciotomy compartment release should be engaged in rehabilitation activities promptly to aid in restoration of extremity function.[23]
- Postoperative surveillance of patients with upper extremity arterial interventions is necessary. Duplex evaluation of the repaired arterial segment 1 to 3 months following intervention is usually recommended followed by serial duplex evaluations every 6 months for at least 1 to 2 years. Patients with no evidence of repair site compromise may then be imaged on a yearly basis. If there is evidence of arterial segment compromise (stenosis, decreased flow, or occlusion), primary assisted patency and secondary patency may be enhanced with reintervention.

OUTCOMES

- Upper extremity revascularization with open arterial bypass has a reported average primary patency of 82% to 87% and excellent limb salvage rates.[26]
- Some series suggest arterial graft patency is lowest in female smokers with long bypass segments that cross multiple joints.[27]
- Because acute embolic episodes more commonly occur in elderly patients, the perioperative mortality and morbidity in this patient cohort is higher compared to age-matched background populations.[28]
- Catheter-based revascularization of the proximal subclavian artery and innominate artery have a high reported technical success rate (>98%), with excellent primary rates and low associated procedure morbidity.[29]
- Percutaneous treatment of upper extremity traumatic arterial injuries of subclavian artery are associated with decreased operative time and intraoperative blood loss while maintaining equivalent patency rates to standard open repairs.[30,31]
- Axillary artery branch vessel repair outcomes are met with high success rates of symptom resolution and lack of recurrence if distal emboli are lysed and proximal branch vessel embolic source is completely isolated from the circulation.[14]

COMPLICATIONS

- Intraoperative arterial vasospasm or occlusion
- Missed concomitant venous or nerve injuries during traumatic arterial injuries
- Iatrogenic brachial plexus, median, or ulnar nerve injuries from intraoperative electrocautery, traction, or accidental transection
- Iatrogenic injury to the brachial artery when attempting retrograde catheter embolization, especially when failing to take into account the significant taper present in the proximal brachial artery
- Arterial bypass graft stenosis or thrombosis
- Repair site bleeding
- Wound or graft site infection
- Digital or vertebral artery embolization, complicating thromboembolectomy
- Postrevascularization compartment syndrome in the arm or hand
- Stent failure when deployed in proximity to the clavicle/1st rib

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Chapter **11**

Upper Extremity Arterial Reconstruction and Revascularization Distal to the Wrist

Michael G. Galvez   James Chang

DEFINITION

- Arterial reconstruction and revascularization distal to the wrist requires reconstituting the complex vascular supply to the hand. This includes the ulnar and radial arteries, superficial and deep palmar arches, and common and proper digital arteries. This reconstitution is performed with either end-to-end primary vascular repair, interposition vascular graft bypass with proximal and distal anastomoses, or addressing the digital arteries individually. Additionally, fasciotomy for compartment syndrome following trauma or reperfusion injury may be a necessary adjunct.

DIFFERENTIAL DIAGNOSIS/PRECIPITATING CAUSES OF HAND ISCHEMIA

- Arterial injury
  - Traumatic (laceration, high energy or crush injury, etc.) or iatrogenic injury (including inadvertent or intentional cannulation for vascular access).
- Proximal embolization
- Intraluminal thrombosis
  - Hypothenar hammer syndrome occurs when the base of the hypothenar eminence sustains repeated blunt trauma resulting in chronic injury to the distal ulnar artery and the superficial palmar arch. In this scenario, compression occurs between the roof of Guyon's canal and the hook of the hamate bone, resulting in aneurysmal degeneration of the ulnar artery, luminal thrombus accumulation, and digital embolization (typically the ring and small finger). This typically occurs on the dominant hand of individuals participating in vocational or avocational activities involving repeated palmar impact (e.g., pipe fitters and mountain bike riders).
  - Spontaneous radial artery thrombosis may be associated with Buerger's disease and is not as common as ulnar artery thrombosis.
- Chronic digital ischemia secondary to vasospastic and rheumatologic disease:
  - Primary Raynaud's syndrome refers to cold-induced vasospasm present in the absence of concomitant disease. The etiology of this condition remains uncertain but is likely due to an exaggerated adrenergic receptor–mediated response to cold exposure.
  - Secondary Raynaud's syndrome refers to digital vasospasm which occurs in the setting of known autoimmune collagen vascular diseases and related rheumatologic disorders (such as rheumatoid arthritis). In this circumstance, a normal vasospastic response to cold or environmental stimuli is superimposed on chronic digital artery occlusive disease. Differentiation from primary Raynaud's syndrome is most commonly made based on digital ulceration and tissue loss, conditions which uniformly develop in secondary Raynaud's syndrome.
  - CREST syndrome encompasses the most common phenotypic presentation of systemic scleroderma/sclerosis: calcinosis, Raynaud's phenomenon, esophageal stenosis, sclerodactyly, and associated telangiectasias.
  - Buerger's disease, or thromboangiitis obliterans, represents a progressive, recurring necrotizing arteritis of small and medium vessels closely linked to tobacco exposure.
- Compartment syndrome occurs in response to increased pressure within a fixed osteofascial anatomic space, leading to decreased arterial perfusion, irreversible myonecrosis, neuropathy, and potential limb loss. In the hand, compartment syndrome most commonly develops following crush injuries; however, intravenous infiltration, external compression, and other mechanisms may also induce increased compartment pressure.

PATIENT HISTORY AND PHYSICAL FINDINGS

- Determine the hand dominance of the patient and relevant history of trauma, tobacco use, medical history (coagulopathic disorders), and occupational exposures. Additionally, the presence of palpable masses, pain, sensory changes, or color changes should be evaluated.
- An Allen's test may provide additional information regarding the relative contribution of the ulnar and radial arteries to hand perfusion. This test is performed by manual compression of both the radial and ulnar arteries, with elevation and successive opening and closing performed to drain venous blood from the hand. The time differential to reperfusion, following respective arterial release, provides qualitative insight into relative radial or ulnar dominance. In most cases, however, the ulnar artery is dominant, and modern quantitative arterial perfusion assessment by duplex imaging and digital plethysmography has largely supplanted subjective physical exam findings in the assessment of adequacy of arterial inflow.
- Patients with hypothenar hammer syndrome can have complaints of pain and tenderness of the hypothenar mass, with cold sensitivity and numbness of the ring and small finger secondary to digital embolization and direct ulnar nerve compression. A pulsatile mass may, on occasion, be appreciable in the palm. Discoloration of the lateral three fingers of the hand may also be present as a result of chronic digital embolization.
- Patients with spontaneous radial artery thrombosis present with pain, numbness, and discoloration of the tips of the

radial-sided digits. The area of occlusion is commonly beneath the first and third extensor compartments and can be related to compression of the radial artery by the extensor pollicis longus.[1]

- Patients with Raynaud's syndrome report ischemic symptoms and digital discoloration on exposure to cold. Cold-induced vasospasm may be elicited by cold emersion testing in an ice bath. A positive test is elicited by the elimination of plethysmographic pulsatile phasicity on exposure to cold, in addition to the onset of symptoms. Most patients, however, cannot tolerate this provocative test, and the clinical use of eliciting vasospastic symptoms, particularly in the presence of existing digital ulceration, is uncertain.
- Compartment syndrome is a clinical diagnosis. Cardinal signs include persistent and progressive pain unrelieved with immobilization/elevation, tightness of skin, pain with passive extension, and decreased sensation. Reduced skin temperature, pallor, and pulselessness are often late findings.
  - The intrinsic compartments are tested for pain with passive adduction and abduction of the fingers. The thenar compartment is tested by adduction of the thumb. The adductor of the thumb is tested by passive palmar abduction. The hypothenar compartment is tested by adduction of the small finger.
  - Normal intracompartment pressures are less than 10 mmHg; between 10 and 20 mmHg is considered high but not enough to cause muscle necrosis. An acute compartment syndrome is assumed if the measured interstitial tissue pressures are within 30 mmHg of the mean arterial pressure or 20 mmHg of the diastolic blood pressure.[2] Hand pressures are typically difficult to assess on the basis of direct measurement, given the extensive septation of the fascial compartments, underscoring the importance of clinical diagnosis. When in doubt, it is prudent to proceed with operative fasciotomy.

IMAGING AND OTHER DIAGNOSTIC STUDIES

- As previously mentioned, noninvasive vascular imaging and physiologic assessment are essential to establishing the diagnosis of hand and digital ischemia as well as providing a physiologic corollary to subsequent arterial imaging studies obtained to outline the relevant anatomy. Noninvasive testing informs and should always precede anatomic imaging studies regardless of modality.
- Imaging provides essential identification of normal and variant arterial anatomy, recognition of the location and extent of obstructive and aneurysmal disease, and operative planning.
- The vascular anatomy of the hand includes the ulnar artery, radial artery, and sometimes a persistent median artery (5% of the population). The ulnar and radial arteries anastomose to form the superficial and deep palmar arches, with the ulnar artery being the main contributor to the superficial arch and the radial artery the main contributor to the deep palmar arch (**FIG 1**). There is significant variation in the vascular patterns of the superficial and deep palmar arches.
- The superficial palmar arch is completed by either the branches of the deep palmar arch, radial artery, or median artery in about 80% of patients. The deep palmar arch is completed by the superior branch of the ulnar artery, the inferior branch of the ulnar artery, or both in about 97% of patients.

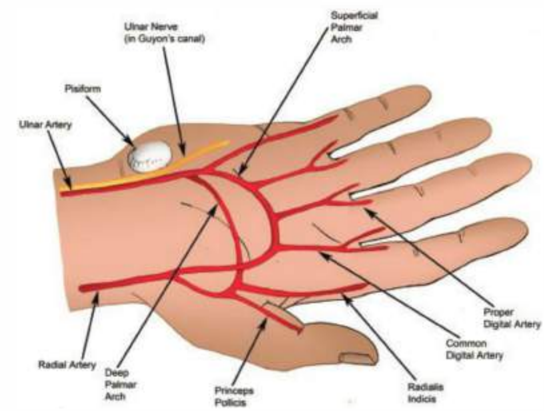

FIG 1 ● Anatomy of the hand illustration: schematic drawing of the vascular supply of the hand, demonstrating the ulnar artery as it passes Guyon's canal and becomes the superficial palmar arch, radial artery as it becomes the deep palmar arch, the common digital arteries, and the proper digital arteries.

- The main branches from the superficial palmar arch are the three common digital arteries, which go to the index-middle, middle-ring, and ring-small finger webspaces, as well as the proper digital artery to the ulnar aspect of the small finger. Each digit has a dual blood supply from the radial and ulnar proper digital vessels.
- The thumb has blood supply from the princeps pollicis artery, which variably arises from the radial artery, the deep palmar, or superficial palmar arch.
- Catheter-directed, contrast-enhanced, digital subtraction hand arteriography provides highly detailed anatomic information and represents the gold standard in vascular imaging (**FIG 2**). However, there are risks from this invasive procedure, which include contrast allergic reaction, vasospasm, contrast-induced nephropathy, thromboembolic events including digital embolization and stroke, and drug reactions precipitated by intraarterial injection of vasoactive agents including Priscoline and nitroglycerin. Hence, catheter-based arteriography is best suited to operative planning in patients already determined to need reconstructive surgery.

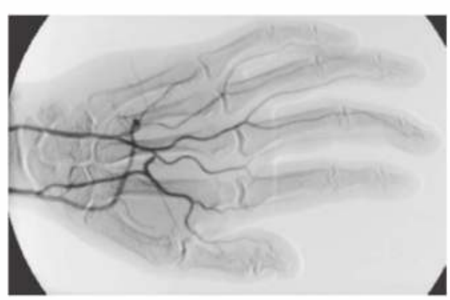

FIG 2 ● Hand angiogram: normal hand angiogram demonstrating complete superficial and deep palmar arches.

- Magnetic resonance arteriography (MRA) is another option for imaging that is noninvasive, eliminating risks of radiation, contrast reaction, and vasospasm. However, the resolution of MRA is not sufficient for detailed surgical planning.
- Computed tomographic arteriography (CTA) is also noninvasive, although contrast and (significant) radiation exposure are required for image acquisition. Similar to MRA imaging, the resolution of CTA is typically not sufficient to support detailed surgical planning.
- Measuring compartment pressures of the hand can be performed with the Stryker Intra-Compartmental Pressure Monitor (Kalamazoo, Michigan), which involves placing the device needle perpendicular to the skin and evaluating individual compartments including sites of maximum swelling of the thenar, hypothenar, and interosseous compartments. The compartment being measured should be at the level of the heart. In an intensive care unit setting, using an arterial pressure line connected to a strain gauge, zeroed at the level of needle entry into the hand, can also provide rapid and accurate compartmental measurements. A 20-gauge needle is inserted into the compartment and flushed, with measurement acquired after the flush bolus has disseminated in the compartment and the pressure spike from the flush returns to baseline.

SURGICAL MANAGEMENT

Preoperative Planning

- The overall goal is to restore distal blood flow to baseline/maximal levels, given anatomic constraints, available arterial conduit, central arterial perfusion pressure and cardiac output, and end-organ (hand) viability.
- Treatment of thromboembolic disease can include medical management and catheter-based chemical and mechanical thrombolysis, angioplasty, and stenting to maximize arteriolar outflow and arterial inflow, respectively. Upper extremity revascularization techniques are discussed in Part 6, Chapter 10.
- End-to-end primary vascular repair can be performed if arteries are tension free after mobilization, and the zone of injury is accurately identified to be uninvolved in the site of anastomosis. If there is any difficulty in approximating the vessels ends, then vascular grafts are preferred.
- In ulnar or radial artery thrombosis, reconstruction is preferred over ligation. Proximal reconstructions are attempted even in the setting of more distal occlusions, based on the rationale of augmenting collateral flow via direct or indirect means.[3]
- Determining venous or arterial graft harvest site is important for preoperative planning. Dorsal hand or foot veins provide the most appropriate size match for intrinsic arteries of the hand (and feet). Donor sites for arterial graft conduits include the deep inferior epigastric artery, subscapular artery, thoracodorsal artery, or descending branch of the lateral femoral circumflex artery. Typically, arterial grafts patency rates are superior to those obtained with venous grafts.[4]
- For chronic ischemia, medical management including pharmacologic treatment with vasodilators, topical nitroglycerin, calcium channel blockers, or botulinum toxin should be attempted first, prior to surgical management.[5] Evidence of gangrene, osteomyelitis, and so forth of the involved digit may require debridement or digital amputation.
- Periarterial sympathectomy in the hand, which involves stripping the adventitial layers from affected arteries, removes sympathetic nerve input to the media and has proven effective in promoting distal finger lesion healing in scleroderma patients. In scleroderma specifically, the thickened adventitia apparently contributes to decreased digital arterial flow.[6,7]

Positioning

- Hand surgery is usually performed with the patient in the supine position. The operated hand is placed on a hand surgery table, which is stabilized by two legs. Reconstructive surgery may be performed under tourniquet, depending on systemic comorbidities and the adequacy of arterial inflow. For tourniquet control, the upper arm is well padded with Webril (cotton) wrapped circumferentially, and then an 18-in (or appropriately sized) pneumatic tourniquet is secured around the upper arm (**FIG 3**). Alternatively, depending on inflow status, the tourniquet may be placed at the forearm or wrist. Finally, an impervious barrier (3M Steri-Drape 1000) is placed circumferentially just distal to the tourniquet to prevent see page of the sterile prep solution. The arm/hand are then sterilely prepped and draped.
- Intraoperatively, the arm is exsanguinated with an elastic bandage (Esmarch bandage) wrap and elevation immediately prior to tourniquet inflation. In adults, the tourniquet is typically inflated to 250 mmHg; in children, it is set 100 mmHg above the systolic pressure. The tourniquet inflation should last no more

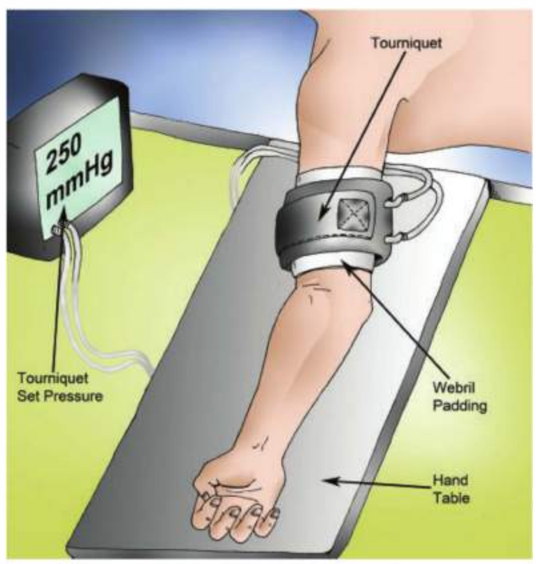

FIG 3 ● Positioning illustration: supine positioning of patient with arm being operated on placed out on hand table. Webril gauze is wrapped circumferentially around the arm and followed by tourniquet placement. Appropriate tourniquet pressure is set. Finally (not pictured) a 3M Steri-Drape 1000 is wrapped circumferentially.

than 2 hours and must be deflated for a 20-minute interval to allow reperfusion prior to reinflation, if needed. Consideration should be made to establishing systemic anticoagulation prior to tourniquet inflation when indicated.

- Appropriate concurrent sterile prep should be performed on graft harvest sites as necessary.
- Microsurgery prep includes ensuring that the operating scope is working properly and sterilely draped. Positioning is extremely important to reduce surgeon fatigue, which includes ensuring good table height, working height (with appropriate padding support of the wrists with stacks of surgical towels), and sitting position. Microsurgery instruments should be available as necessary, depending on the level of revascularization considered. 9-0 and 10-0 sutures are employed for more distal reconstructive procedures and digital reimplantation. For proximal radial and ulnar reconstruction procedures, at or immediately adjacent to the wrist, 2.5× to 3.5× surgical loupe magnification will provide adequate anatomic resolution and suture placement for operators with normal visual acuity.

ULNAR ARTERY RECONSTRUCTION

Placement of Incision

- Identify the ulnar artery aneurysm (FIG 4A), and incise the skin longitudinally over the ulnar artery as it crosses Guyon's canal. Extension across the midpalmar crease may be necessary to expose the distal ulnar artery as it curves radially to become the superficial palmar arch.
- The volar carpal ligament, the roof of Guyon's canal, is a continuation of the deep palmar fascia and fibers of the flexor carpi ulnaris and must be carefully incised for access to the ulnar artery and nerve.
- The ulnar nerve, particularly the motor branch, must be carefully protected.

Resection of Ulnar Aneurysm

- Once the deep palmar fascia is incised, the aneurysm is generally recognizable (FIG 4B AND FIG 5A). The aneurysm itself may be thrombosed or tortuous or elongated as a result of chronic posttraumatic remodeling. Microvascular clamps are placed on the ulnar artery proximal and distal to the aneurysm.
- Preserve the common digital arteries and other large branches distal to the thrombosed segment. Place microvascular clamps and vessel loops as needed on vessels that will require revascularization.
- Resect the affected artery and trim the ends sharply.
- The adventitia is excised as needed, and the intima inspected at the proximal and distal end of the anastomoses to ensure

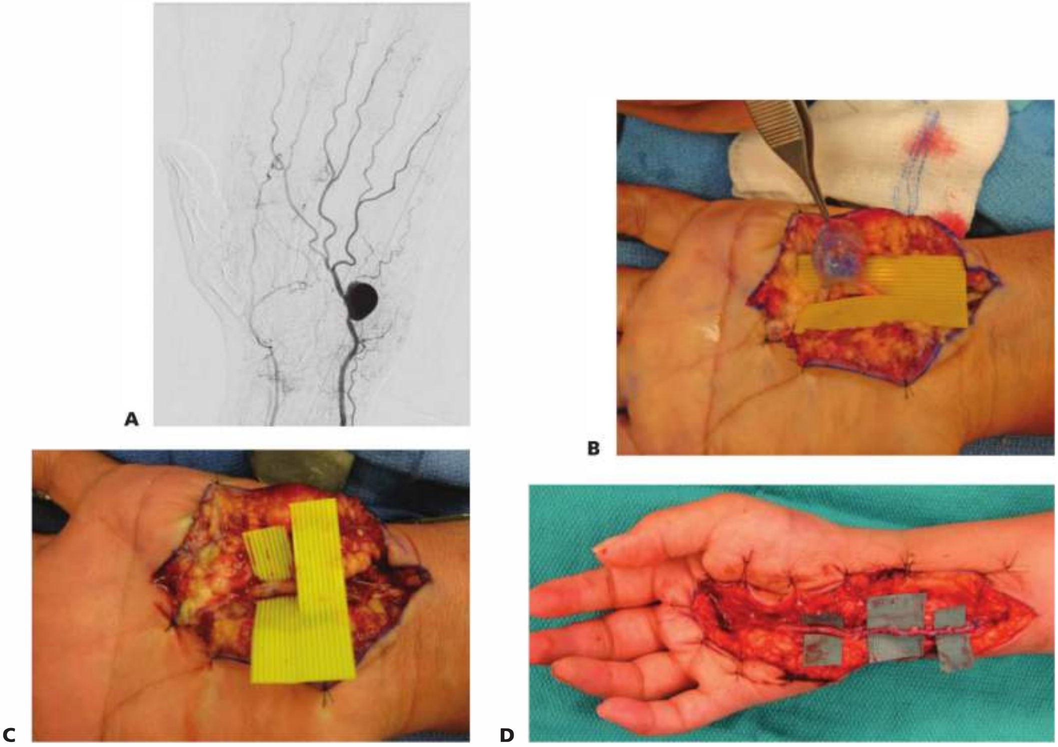

FIG 4 ● Ulnar artery reconstruction: **A.** Hand angiogram demonstrating a large ulnar artery aneurysm in Guyon's canal. **B.** Ulnar aneurysm segment is isolated proximally and distally. **C.** A direct end-to-end anastomoses was performed. **D.** In another patient, a long vein graft is used to extend from a more proximal ulnar artery.

that the entire disease segment is removed. Failure to remove the entirety of diseased artery may precipitate early graft thrombosis and recurrent digital embolization.

Vein Graft Interposition

- Occasionally, sufficient redundancy is present in the ulnar artery to allow direct primary repair (FIG 4C); in most cases, interposition vein grafting (FIG 4D) is required to complete the reconstruction without tension.
- When the superficial palmar arch and adjacent common digital arteries are involved, then a more complex "palmar arch" reconstruction may be necessary to restore perfusion to the dependant digits (FIG 5B), with end-to-side anastomoses of the common digital arteries into the distal extent of the vein graft.
- Vein harvest is typically chosen from the hand and foot veins. Length of vein harvest should be several centimeters longer to allow for trimming.
- Marking the superficial surface of the vein helps avoid twisting or kinking of the vein graft. Marking one end (typically distal) provides a reminder to reverse the graft prior to implantation. If needed, ends with valves are excised. Arterial graft may also be used when available and of suitable diameter and length.
- Longer grafts may also be used (FIG 4D) when more proximal arterial inflow is required.
- Microvascular anastomosis of vessel graft.
    - Anastomosis completion may require microsurgical technique, given that common digital arteries may be 1 to 2 mm in diameter.
    - Both ends of the vessels are held in place by an appropriately tensioned microvascular double-armed clamp.

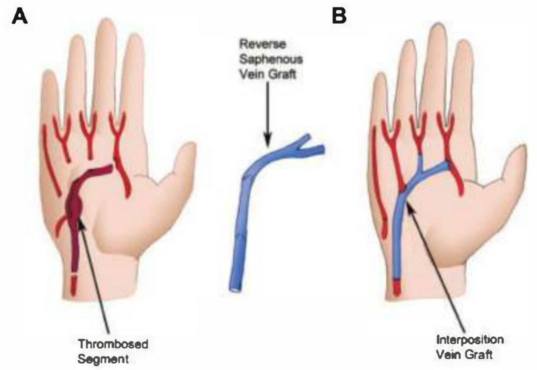

FIG 5 ● Ulnar artery reconstruction illustration. Exploration of the ulnar artery confirms findings of angiogram demonstrating **(A)** ulnar artery thrombosis to the origin of the common digital arteries. Reconstruction requires harvesting a Y branch of a saphenous vein graft, which is then reversed prior to interposition. **B.** End-to-side distal anastomosis, end-to-end anastomosis of the vein branch to the common digital artery, and end-to-side anastomosis to common digital artery are performed.

- After irrigation with heparinized saline, interrupted sutures are placed circumferentially using a triangulation technique.
- The proximal anastomosis is performed first, then flushed with heparin and clamped to allow the vein graft to extend to length before preparing and completing the distal anastomos(e)s.

SNUFFBOX RADIAL ARTERY RECONSTRUCTION

Placement of Incision

- At the level of wrist, the radial artery turns dorsally underneath the first extensor compartment (containing the abductor pollicis longus and extensor pollicis brevis), then runs between the first and third extensor compartments (extensor pollicis longus) in the area known as the "anatomic snuffbox." The diseased segment and distal targets should be confirmed by reference to the specific preoperative imaging studies (FIG 6A,B). A skin incision is made on the dorsum of the hand directly over the anatomic snuffbox parallel to the second metacarpal (FIG 7A).
- The superficial radial nerve is identified and preserved.

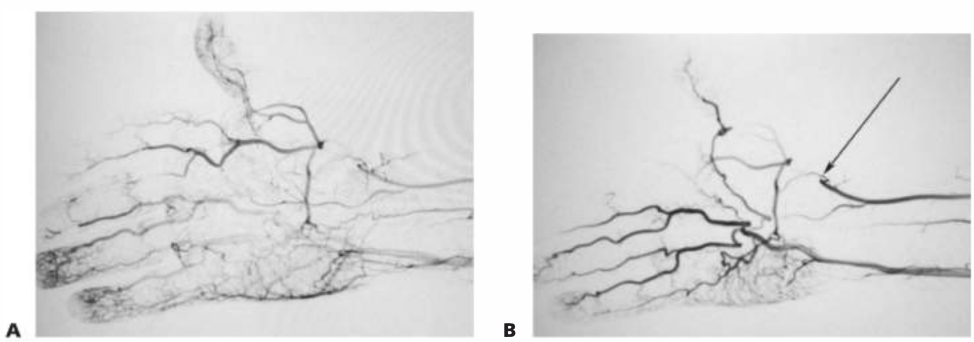

FIG 6 ● Snuffbox radial artery reconstruction angiograms: **A,B.** Angiograms demonstrating cutoff of radial artery (*arrow* demonstrates filling defect corresponding to occluded segment) at the level of the anatomic snuffbox.

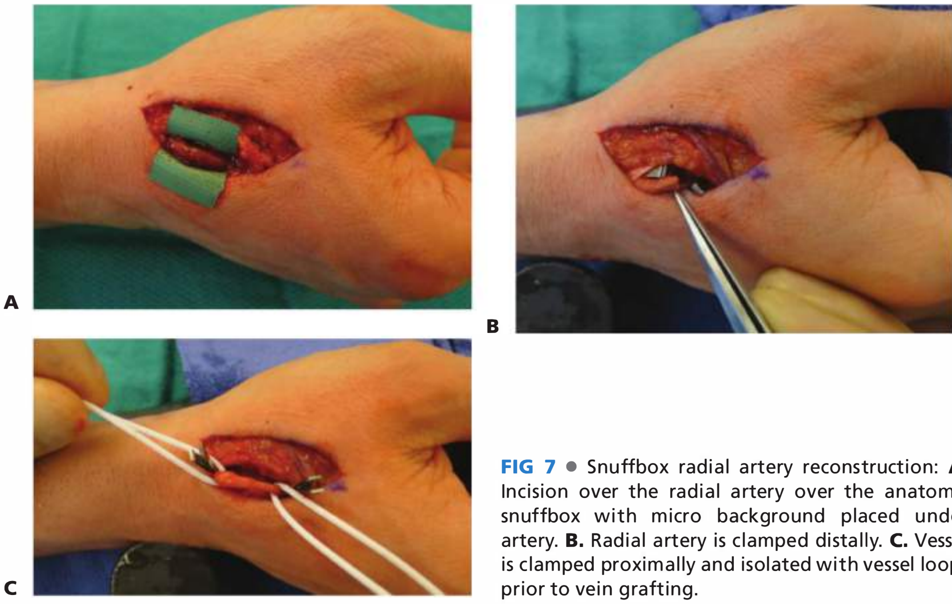

FIG 7 ● Snuffbox radial artery reconstruction: **A.** Incision over the radial artery over the anatomic snuffbox with micro background placed under artery. **B.** Radial artery is clamped distally. **C.** Vessel is clamped proximally and isolated with vessel loops prior to vein grafting.

Resection/Bypass of Diseased Segment

- This dissection is continued distally between the heads of the first dorsal interosseous muscle, allowing further mobilization of the distal radial artery and visualization of the origin of the deep palmar arch.
- Microvascular clamps are placed proximal and distal to the thrombosed segment of the radial artery.
- All branches from the thrombosed segment should be ligated and removed en bloc (**FIG 7B**).

Vein Graft Interposition

- The vein graft should be reversed and placed superficial to the extensor pollicis longus and extensor pollicis brevis (making the graft immediately beneath the skin) and then sutured end-to-end to the radial artery proximally and end-to-end to the deep arch distally (**FIG 7C**). See the "Ulnar Artery Reconstruction" section for further description on vein harvest and microvascular anastomosis technique.

HAND FASCIOTOMY

Placement of Incisions

- The 10 compartments of the hand include the thenar, hypothenar, adductor, and 4 dorsal and 3 volar interossei compartments. Four incisions are required to release all 10 compartments.
- The dorsal and volar interosseous compartments are decompressed with two dorsal incisions over the index finger and ring finger metacarpal (**FIG 8A**). These incisions are carried down to either side of the metacarpal to release the dorsal interossei. Dissection along the ulnar and radial aspects of the index metacarpal must be sufficiently deep (**FIG 8C**) to release the first dorsal palmar interosseous and the adductor compartments. Similarly, to release the remaining palmar interossei, deep dissection is required along the ulnar and radial aspects of the ring metacarpal. Meticulous release along the length of the metacarpal is essential to ensure adequate decompression.
- The thenar compartment is bound by thenar fascia and contains the abductor pollicis brevis, flexor pollicis brevis, and the opponens pollicis. This compartment is decompressed with a longitudinal incision along the radial/volar (**FIG 8A**) aspect of the thumb metacarpal.

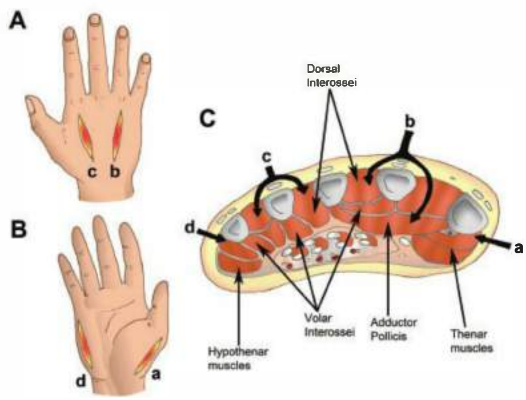

FIG 8 ● Hand fasciotomy illustration: fasciotomy incisions of the hand. **A.** Dorsal incisions over the index **(c)** and ring **(b)** finger metacarpal. **B.** Volar incisions over the hypothenar **(d)** and thenar **(a)** muscles. **C.** Cross section at the level of the metacarpals of the hand demonstrating that both dorsal and interosseous compartments and the adductor compartment to the thumb can be released through these four incisions with appropriate direction and depth as outlined **(a–d)**.

- The hypothenar compartment is bound by the hypothenar fascia and contains the abductor digiti minimi, flexor digiti minimi, and opponens digiti minimi. This compartment is decompressed with a longitudinal incision along the ulnar/volar (**FIG 8B**) aspect of the small metacarpal.
- The finger can also have compartment syndrome if there is excessive swelling and depending on clinical assessment. Here, the fascial compartments are bound by Cleland's and Grayson's ligaments. The finger fasciotomy is performed by making midaxial incisions along the ulnar aspect of the index, ring, and long fingers and on the radial aspects of the thumb and small finger. Once incisions are made, blunt dissection is continued through Cleland's ligament (firm fascia bands that run from side of the phalanges to the skin and are dorsal to the neurovascular bundle), retracting the neurovascular bundles in a volar direction and remaining volar to the flexor tendon sheath.

Carpal Tunnel Release

- If any compartment pressure is elevated in the hand, then all compartments should be released including the carpal tunnel.
- A longitudinal palmar incision is made just distal to the volar wrist crease and extending distally for 3 to 4 cm in the proximal palm along the course of the radial aspect of the ring finger.
- The palmaris fascia is divided longitudinally to expose the underlying transverse carpal ligament, which is then incised under direct visualization.
- The incision is extended at least 2 cm into the forearm to ensure release of the deep antebrachial fascia.
- The carpal tunnel release incision is closed primarily with interrupted nylon sutures.

Wound Care

- Fasciotomy wounds are left open for a minimum of 48 hours or until swelling has resolved.
- Secondary closure with wet-to-dry dressings may occur over open incisions.
- Eventually, these wounds may need split-thickness skin grafting.
- The hand should be splinted in a safe position (70 to 90 degrees of metacarpophalangeal [MCP] flexion and proximal interphalangeal [PIP] joints straight).

PEARLS AND PITFALLS

- Although a thrombosed ulnar artery can be ligated, reconstruction of the ulnar artery can reconstitute normal flow and should be attempted.
- Hand vascular repair and grafting requires meticulous microvascular technique.
- The dorsal sides of the hand and foot have veins of similar size that are ideal for vein graft reconstruction.
- Periarterial sympathectomy is particularly effective in scleroderma because the vessels are encased in adventitial scarring.
- Early diagnosis and treatment for hand compartment syndrome is critical: When in doubt, release all compartments.

POSTOPERATIVE CARE

- Postoperative monitoring of the hand after vascular reconstruction is similar to finger replantations and can be performed with pencil Doppler monitoring or with pulse oximetry (**FIG 9**).
- Aspirin 81 mg is given for 6 weeks postoperatively after vessel reconstruction.
- For periarterial sympathectomy, immediate digital range of motion is encouraged, and cold temperature and vasoconstrictive drugs or substances (smoking, caffeine, etc.) are avoided for at least 6 weeks.
- For compartment syndrome, aggressive strengthening and range of motion should be started once wounds have stabilized.

OUTCOMES

- Radial artery reconstruction patency in a study of 13 patients found that all vein grafts were patent after mean follow-up of 22 months, with a significant decrease in pain; however, no difference in numbness was seen.[3] In another study of 145 patients, an overall patency of vein grafts of 85% over

FIG 9 • Hand postoperative monitoring: Revascularization of digits can be monitored with basic pulse oximetry at the tip of the digits.

an average follow-up period of 34 months was found as well as 100% with arterial grafts.[4]

- Long-term recovery after compartment syndrome release depends on the extent of injury and requires long-term hand therapy for recovery of hand function. Compartment release of the hand can result in normal function; however, contractures can develop, which may need eventual reoperation for contracture release.

COMPLICATIONS

- Infection
- Dehiscence of incisions and other wound healing complications
- Failure of revascularization
- Distal emboli
- Thrombosis at anastomosis
- Long-term patency
- Stiffness of the fingers
- Continued ischemia, pain, and ulcerations

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Chapter 12

Exposure and Open Surgical Reconstruction in the Chest: The Thoracoabdominal Aorta

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Roberto Chiesa

DEFINITION

- A thoracoabdominal aortic aneurysm (TAAA) involves the aorta at the diaphragmatic crura and extends variable distances proximally and/or distally from this point (**FIG 1**).[1] TAAAs can be classified in terms of their causes, the two most common being medial degeneration and dissection.
- Open treatment of TAAAs consists of graft replacement with reattachment of the main aortic branches: The inclusion technique was introduced by S. E. Crawford in the 70s and refined by subsequent surgeons in the following decades. TAAA repair, especially in extensive aortic disease, is associated with greater operative risk than repair of other aortic segments. The main sources of morbidity are spinal cord (SC) ischemia and renal as well as respiratory and cardiac complications.
- Experienced surgical centers now report lower mortality and morbidity rates for TAAA repair,[2] largely due to multimodal approaches to reduce surgical trauma and maximize organ protection.[3]

IMAGING AND OTHER DIAGNOSTIC STUDIES

- To plan the best possible treatment strategy for each patient, our preferred modality is computed tomographic arteriography (CTA). The acquisition of computed tomography (CT) data in particular has benefited from spectacular progress, including multirow detectors, higher rotation and translation speeds with reduced scan times (single breath-hold), cardiac cycle synchronization, and better postprocessing capabilities.
- Digital Imaging and Communications in Medicine (DICOM) slices of adequate thickness (≤1 mm) should be postprocessed on a digital workstation using a multiplanar reformatting (MPR) tool to visualize a scan which angulation matches that of the aorta or the vessel under investigation. Postprocessing may be performed on a dedicated workstation (AquariusNet®, TeraRecon, Inc) or desktop computer with open source software (OsiriX and others) in a user-friendly and time/resources-efficient way (**FIG 2**).
- Beyond analysis of aortic diameter and the extent of pathologic involvement, reformatted images are particularly useful for evaluating the presence, extension, and characteristics of dissection and thrombus, particularly at proposed sites of clamp placement and the infradiaphragmatic aorta when direct aneurysm cannulation is considered for distal aortic perfusion. The exact location and geometry of aortic branches is obtained to reveal possible anatomic variations or anomalies, which are particularly common at the level of the renal arteries and arch vessels. Vessel patency is also routinely evaluated; in particular, obstruction of the superior and inferior mesenteric artery and the hypogastric arteries and dominance of one vertebral artery are assessed.
- Three-dimensional rendering tools such as maximum intensity projection (MIP), volume rendering, surface rendering, and so forth produce realistic imaging of the anatomic structures that may expand anatomic understanding, including, for instance, the most appropriate intercostal space to perform thoracotomy (**FIG 3**).
- Perioperative SC ischemia may precipitate paraparesis or paraplegia. Prior knowledge of the SC arterial supply informs both procedural planning and risk stratification.

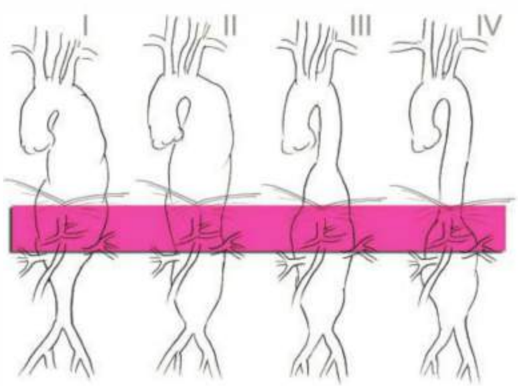


FIG 1 ● An aneurysm is defined as thoracoabdominal when the highlighted region is involved. Crawford's classification was developed to improve stratification of perioperative paraplegia risk. Subclassifications include the following: Extent I includes the thoracic and abdominal aorta, from the left subclavian artery to the level of the renal arteries; extent II includes the entire descending aorta from the level of the left subclavian artery to the aortic bifurcation; extent III includes aorta beginning at the T6 level extending to the bifurcation or lower; extent IV includes the entire abdominal aorta starting at the level of the diaphragm (T12) to the aortic bifurcation or lower.

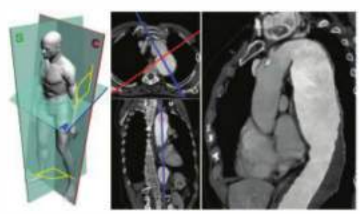


FIG 2 ● MPR tools allow the sagittal reconstruction to properly follow the major axis of the thoracic aorta. In this reformatted image, the entire thoracic aorta is included despite significant tortuosity.

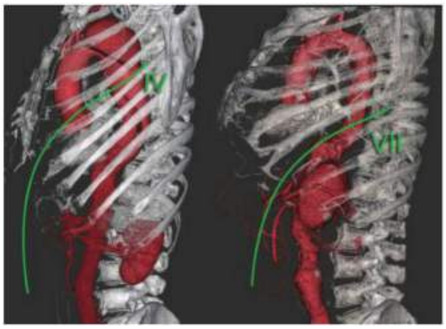


FIG 3 ● Beyond aortic imaging, the CT provides extensive anatomic information to guide exposure and surgical decision making.

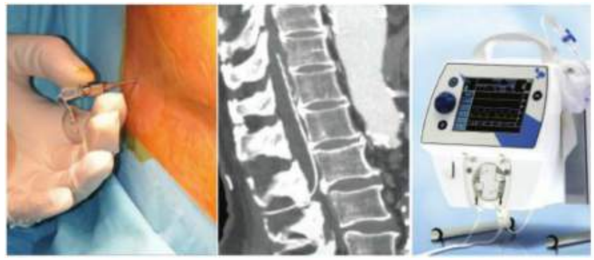


FIG 5 ● Once the dura has been punctured with the introducer needle, a drainage catheter is inserted 8 to 10 cm along the intradural space. The catheter is then connected to a pressure transducer, and the fluid is drained to keep the pressure below 10 cm H_2O. Automated systems are available for this purpose.

Recent advances in imaging techniques, especially noninvasive techniques, increased the likelihood that patient-specific risk criteria may soon be recognized and be widely available[4] (**FIG 4**).

SURGICAL MANAGEMENT

Preoperative Workup and Patient Optimization

- Preoperative transthoracic echocardiography is a satisfactory noninvasive screening method to evaluate both valvular and biventricular function. Stress testing identifies patients who require coronary catheterization and possible intervention.[5] Electrocardiographically (EKG) gated CT has recently emerged as a less invasive method of visualizing coronary anatomy. For severe, symptomatic coronary disease requiring percutaneous transluminal angioplasty prior to aneurysm repair, use of drug-eluting stents requiring prolonged double antiplatelet therapy should be avoided to reduce subsequent perioperative bleeding.
- The use of estimated glomerular filtration rate (eGFR), rather than serum creatinine levels alone, is recommended to assess renal function.[6] Based on the eGFR metric, chronic kidney disease has been shown to be a strong predictor of death following open or endovascular thoracic aneurysm repair, even in patients without other clinical evidence of preoperative renal disease.[7]

Pulmonary function evaluation with arterial blood gases and spirometry is used to evaluate the respiratory reserve of all patients undergoing open surgery of the descending aorta. In patients with a forced expiratory volume in 1 second (FEV_1) of less than 1 L and a partial pressure of carbon dioxide (PCO_2) greater than 45 mmHg, operative risk may be improved by cessation of cigarette smoking, treatment of chronic bronchitis (if present), weight loss, and participation in a supervised exercise program for a period of up to 6 months prior to surgery. However, in patients with aneurysm-related symptoms, this type of respiratory rehabilitation may not be practical or possible.

Positioning

- After inserting a cerebrospinal fluid drainage (CSFD)[8] catheter into the subarachnoid space between L2 and L3 or L3 and L4 (**FIG 5**), the patient is turned to a right lateral decubitus position, with the shoulders at 60 degrees and the hips flexed back to 30 degrees.
- Preparation should allow for access to the entire left thorax, abdomen, and both inguinal regions. Patient position is maintained with a moldable beanbag attached to a suction line for vacuum creation. A circulating water mattress is placed between the beanbag and the patient in order to modify body temperature as necessary (**FIG 6**).

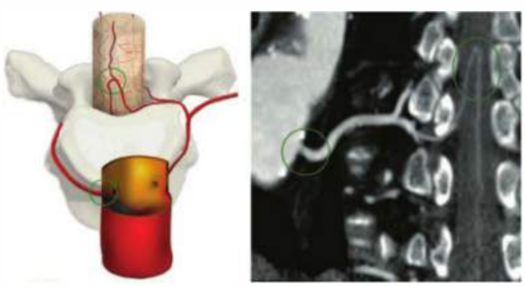


FIG 4 ● Using a customized curve plan, the whole path of the arterial feeder to the spinal cord (arteria radicularis magna) can be visualized from the aorta to the anterior spinal artery.

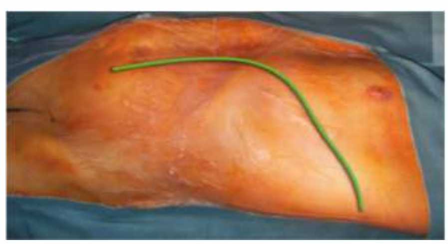


FIG 6 ● Prepping and draping for TAAA. Posterolateral aspect of the left thorax, the abdomen, and left groin are included in the sterile operatory field. Please note the gentle curvature of the line indicating the skin incision to avoid flap necrosis.

THORACO-PHRENO-LAPAROTOMY

- The thoracic incision varies in length and level, depending on exposure requirements. Usually, the 5th, 6th, or 7th intercostal space is employed according to the aneurysm anatomy. The posterior section of the ribs is gently spread to reduce thoracic wall trauma and fractures; anterolaterally, the incision curves gently as it crosses the costal margin to minimize subsequent tissue necrosis. The pleural space is entered after single right lung ventilation is initiated. Monopulmonary ventilation is maintained throughout thoracic aorta replacement (**FIG 7**).
- Paralysis of the left hemidiaphragm contributes significantly to postoperative respiratory failure; therefore, a limited circumferential rather than radial section of the diaphragm is routinely performed, sparing the phrenic center. Under favorable anatomic conditions, this approach reduces respiratory weaning time[9] (**FIG 8**).
- Special care must be taken when isolating the proximal aneurysm neck. The insertion of a large caliber esophageal probe makes it easier to distinguish the esophagus at this level. The vagus nerve and the origin of the recurrent laryngeal nerve must also be identified because they can also be damaged during isolation and clamping maneuvers (**FIG 9**). Identification and clipping of some "high" intercostal arteries can sometimes facilitate the preparation for the proximal anastomosis, thus reducing aortic bleeding.
- The upper abdominal aortic segment is exposed via a transperitoneal approach; after entering the peritoneum, medial visceral rotation is performed to retract the left colon, spleen, and left kidney anteriorly and to the right (**FIG 10**). Use of a transperitoneal approach allows direct assessment of the abdominal organs at the end of procedure. Extra care must be taken to avoid damage to the spleen, which is particularly prone to bleeding after capsular injuries regardless of size.

FIG 7 ● Thoraco-phreno-laparotomy in the 6th intercostal space. A circumferential incision of the diaphragm is carried out (dotted line).

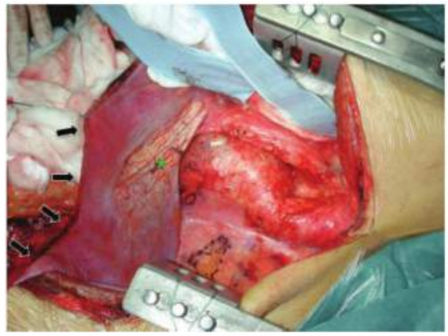


FIG 8 ● The diaphragm is circumferentially divided *(arrows)* for several centimeters near its peripheral attachment to the anterior chest wall sparing the phrenic center *(asterisk)*.

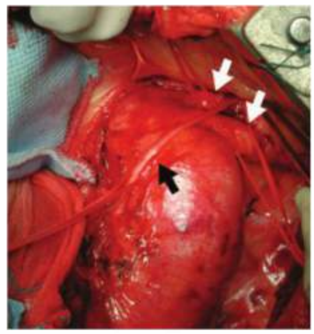


FIG 9 ● The vagus nerve *(black arrow)* and the origin of the recurrent laryngeal nerve are mobilized and identified with vessel loops to prevent injury during aortic clamping maneuvers or suture placement. When an aortic cross-clamping between left carotid and subclavian artery is required, these vessels are also identified and controlled with vessel loops *(white arrows)*.

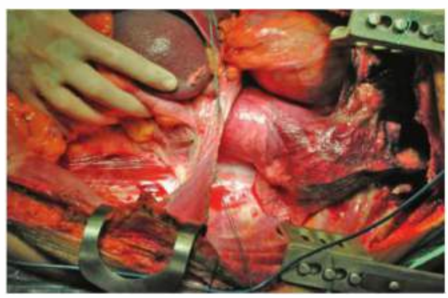


FIG 10 ● Medial visceral rotation: The left colon, the spleen, and the left kidney are retracted anteriorly and to the right to visualize the visceral and infrarenal aorta. Transperitoneal approach allows direct evaluation of the abdominal organs throughout the procedure.

DISTAL AORTIC PERFUSION

- Cross-clamping of the descending thoracic aorta produces immediate and significant increases in left ventricular afterload, myocardial oxygen consumption, and visceral and renal ischemia. Techniques incorporating distal aortic perfusion with left heart bypass (LHBP) have significantly improved outcomes in thoracic aortic surgery.[10] In preparation for LHBP and aortic cross-clamping, low-dose intravenous heparin is administered. If cessation of pump support is anticipated during the case, additional heparin should be administered at that time to provide full anticoagulation.
- The upper left pulmonary vein is usually cannulated for inflow of oxygenated blood, which is routed through a centrifugal pump (Bio-Medicus®) into the left femoral artery (**FIG 11**). A "Y" connector included in the circuit provides two occlusion/perfusion catheters (9 Fr) for selective visceral perfusion when necessary.

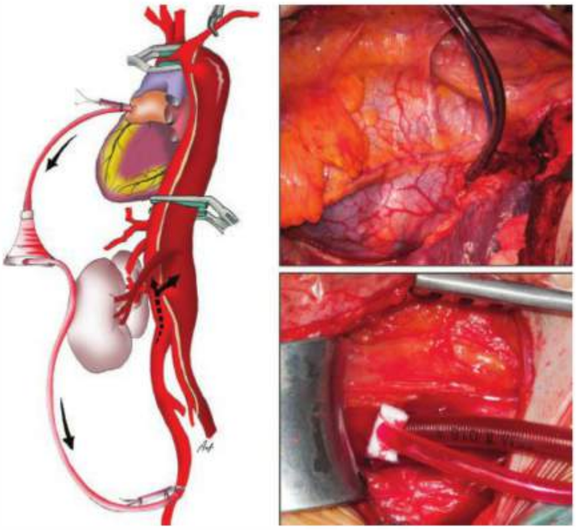


FIG 11 ● Schematic view of distal aortic perfusion. A 20-Fr cannula is inserted in left superior pulmonary vein for the arterial blood drainage **(up)**. Nonocclusive femoral cannula (14 to 18 Fr) allows synchronous proximal and distal perfusion from the femoral axis **(down)**.

AORTIC REPAIR

- Once the neck of the TAAA is isolated and controlled between clamps, the descending thoracic aorta is transected and separated from the esophagus (**FIG 12**). The graft is sutured proximally to the descending thoracic aorta using 2-0 polypropylene suture in a running fashion. The anastomosis is reinforced with Teflon felt (individual pledgets or single strip) (**FIG 13**). An additional aortic clamp is applied onto the abdominal aorta above the celiac axis before the proximal aortic clamp is removed (sequential cross-clamping).
- Intercostal artery reimplantation into the aortic graft plays a critical role in SC protection. Patent intercostal arteries from T7 to L2 are temporarily occluded to prevent backbleeding/maximize cord perfusion pressure[11] then selectively reattached to the graft by means of aortic patch or graft interposition (**FIG 14**). When ready, the distal clamp

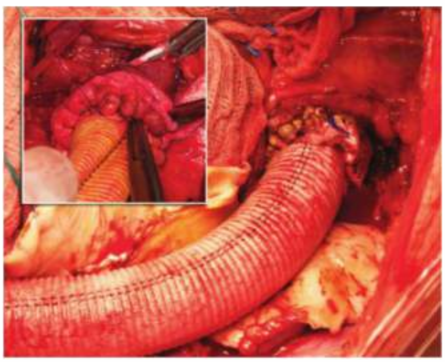


FIG 13 ● The proximal anastomosis routinely reinforced with a Teflon strip.

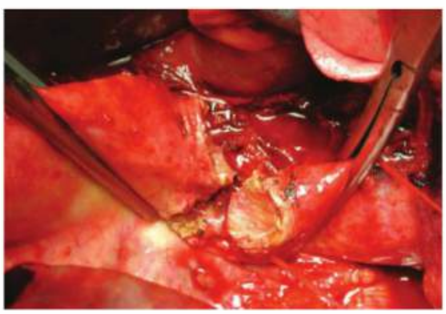


FIG 12 ● The proximal descending thoracic aorta is controlled and completely transected to avoid accidental injury to the adjacent esophagus.

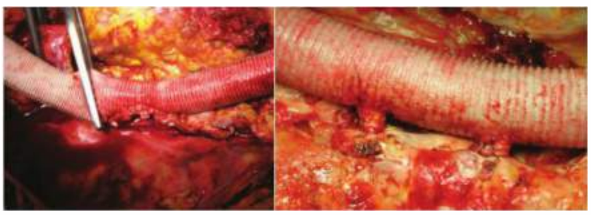


FIG 14 ● Critical intercostal arteries reattachment. Here visualized are two different techniques: On the **left**, an aortic island including the origin of several intercostal arteries is reattached to a fenestration created on the aortic graft; on the **right**, intercostal arteries are reattached selectively to the graft via 6/8-mm interposition grafts.

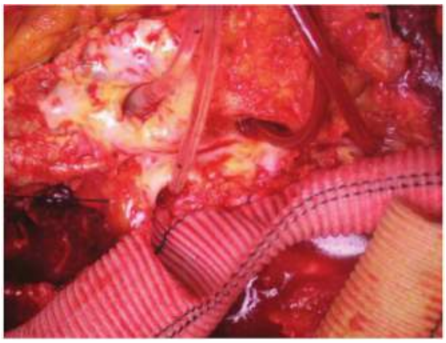


FIG 15 ● Visceral arteries perfusion with blood, renal perfusion with cold Custodiol® solution during branch artery reimplantation.

FIG 17 ● A modified technique to separately reattach the left renal artery is detailed here: The use of a hybrid tube graft that includes a self-expandable covered stent allows for a sutureless anastomosis. The advantages are the reduced ischemia time of the kidney and kink prevention of the graft after visceral derotation at the end of the aortic repair.

is moved below the renal arteries, and the aneurysm is opened across the diaphragm. The centrifugal pump maintains visceral perfusion (400 mL per minute) following insertion of the 9-Fr irrigation-perfusion catheters (LeMaitre Vascular) into the celiac trunk and the superior mesenteric artery. Cold perfusion of Custodiol[12] (histidine-tryptophane-ketoglutarate) is directed into the renal arteries (**FIG 15**). For visceral artery reimplantation, a fenestration is created in the graft and the visceral vessels are reattached as a single patch. Usually, the left renal artery is reconnected with an 8-mm polyester interposition graft. If visceral artery orificial stenosis is encountered, before placing the irrigation perfusion catheter, the stenosis may be resolved by direct placement of an appropriate-sized balloon-expandable stent within the artery[13] (**FIGS 16** and **17**). If creation of the visceral patch requires retaining a large segment of native aorta, we prefer to place a multibranched graft instead. This prosthesis, although somewhat more time consuming, significantly reduces the risk of recurrent aortic patch aneurysm (**FIG 18**). Finally, the distal end-to-end anastomosis with the distal aorta is performed, the graft flushed, and clamps removed (**FIG 19**).

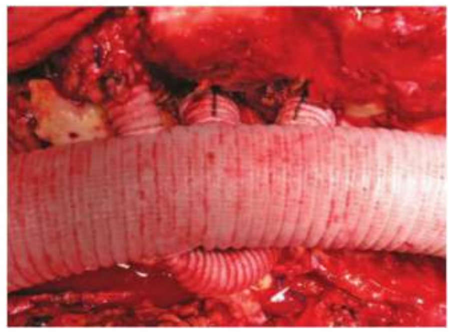


FIG 18 ● Visceral vessels and renal arteries are reattached separately in this patient with Marfan syndrome to reduce as much as possible the aortic native tissue and prevent recurrent aortic aneurysm formation.

FIG 19 ● End-to-end distal anastomosis at the aortic bifurcation.

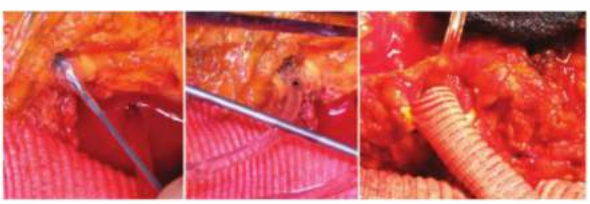
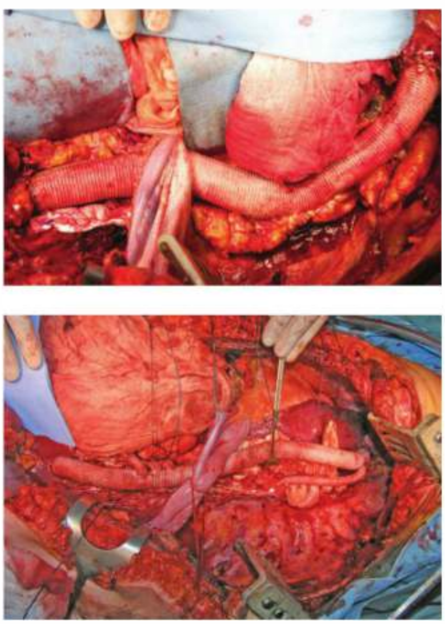


FIG 16 ● From left to right. In case of orificial stenosis, intraluminal stents are placed under direct visualization before insertion of the perfusion catheter and ultimate reimplantation.

CLOSURE

- The entire aortic repair (**FIG 20**) is inspected. All exposed aortic branch pulses are palpated after derotation and replacement of the abdominal viscera. Any bleeding or kinking of the aortic branches is addressed at this juncture. The atrial and femoral cannulae are removed; the purse-string sutures are tied and reinforced. Anticoagulation is reversed with protamine. The crus of the diaphragm is reapproximated to restore the aortic hiatus (**FIG 21**) and the left hemidiaphragm loosely sutured with a running polypropylene suture. The left lung is temporarily inflated to check for air leakage.
- A closed-suction abdominal drain is placed next to the aortic graft in the left retroperitoneal space, and two chest tubes are placed in the posteroapical and basal pleural space. Absorbable pericostal sutures are placed to approximate the ribs (**FIG 22**), and two steel wires are used to stabilize the costal margin. The lung is inflated, and the correct expansion of all the segments is carefully checked; the pericostal and diaphragmatic sutures are tightened and ligated. The steel wires are twisted and buried in the cartilaginous costal margin. The abdominal fascia is closed with a running suture. The abdominal and thoracic drains are connected to suction. The serratus and latissimus dorsi muscles are approximated with separate absorbable sutures. Subdermal layer is sutured, and the skin is closed with staples (**FIG 23**).



A

B

FIG 20 ● Final repair of a type II TAAA. **A.** Standard inclusion technique. **B.** Selective reimplantation with multibranched graft.

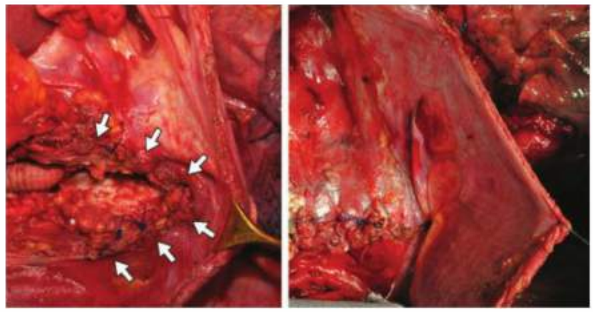


FIG 21 ● The pillars of the diaphragm (arrows) are approximated with absorbable sutures to reshape the aortic hiatus.

FIG 22 ● The thoracic wall is repaired with pericostal sutures. The left lung is inflated and checked for air leakage; two chest tubes are positioned to drain the upper and lower thoracic space.

FIG 23 ● The abdominal and thoracic walls are sutured; skin is closed with staples.

PEARLS AND PITFALLS

Indications	■ Aortic diameter and aneurysm morphology ■ Signs and symptoms of acute aortic syndrome
Preoperative planning	■ Level of intercostal incision ■ Graft selection ■ Identification of accessory renal arteries and other visceral anomalies (e.g., horseshoe kidney) ■ Potential need for multibranch graft vs. Carrel patch
Surgical access	■ Avoid skin flap necrosis. ■ Rib section ■ Limited phrenotomy (circumferential diaphragmatic incision) ■ Transperitoneal approach ■ Careful and limited lung manipulation ■ Nonocclusive femoral cannulation
Technical adjuncts for organ protection	■ Spinal cord drainage ■ Left heart bypass ■ Sequential aortic clamping ■ Critical intercostal artery reattachment ■ Visceral perfusion from left heart bypass cannulas ■ Renal perfusion with cold Custodiol® or similar solution ■ Direct stenting of renal and visceral orificial lesions as needed

POSTOPERATIVE CARE

- The main focus of immediate postoperative management is the early detection of neurologic or cardiovascular complication as prompt intervention may prevent substantial long-term morbidity. As soon as baseline blood pressure and body temperature are restored, sedation is lightened regardless of ventilatory status. When SC or cerebral neurologic injury is suspected, CT imaging is performed immediately to address the possibility of intracranial or intradural SC hematoma. In case of paraparesis or paraplegia, mean arterial pressure is chemically maintained above 80 mmHg, CSFD is drained in order to lower the cerebrospinal fluid pressure below 10 mmHg, and methylprednisolone (1 g bolus followed by 4 g per 24 hours continuous infusion) and 18% mannitol (5 mg/kg, four times a day) are administrated.
- If malperfusion develops in the lower limbs, renal or visceral circulation, efforts should be made to restore normal circulation immediately. For a precise visualization of visceral organ perfusion, emergency arteriography (catheter-based or CT) is required.
- Blood pressure fluctuations, including recalcitrant hypertension, is common in the early postoperative period, especially in the chronically hypertensive patient; prompt attention should be paid to regulating the mean arterial pressure in a physiologic range. Immediate intervention may be required to reduce the risk of anastomotic bleeding, especially in the setting of dissection.
- In uncomplicated cases, drainage tubes are removed at 36 to 48 hours postoperatively, whereas the intrathecal CSFD catheter is removed usually after 72 hours. A prolonged requirement for ventilatory support is not unusual, especially after emergency operations, in patients with significant blood loss and after longer periods of circulatory arrest (if necessary for concurrent arch or ascending aortic reconstruction). In case of severe chronic kidney disease, transient temporary renal replacement therapy may also be necessary in the early postoperative period.

COMPLICATIONS

- Bleeding
- Multiorgan failure
- Dialysis
- Paraplegia
- Stroke
- Death
- Aneurysm recurrence

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Chapter 13

Thoracic Aortic Stent Graft Repair for Aneurysm, Dissection, and Traumatic Transection

Brant W. Ullery Jason T. Lee

DEFINITION

- In 1994, Dake and colleagues,[1] at Stanford University, were the first to report the use of custom-designed thoracic aortic stent grafts for the treatment of descending thoracic aortic aneurysms in patients deemed high risk for conventional open surgery. Each of these devices was deployed through peripheral arterial access, successfully excluding the aneurysm from systemic pressurization. This groundbreaking minimally invasive technique thereby avoided many of the physiologic insults associated with open surgery, including the need for thoracotomy, aortic cross-clamping, reperfusion injury, and acute hemodynamic changes.
- Results from the first multicenter U.S. Food and Drug Administration–sponsored trial for thoracic aortic stent grafts demonstrated significantly less perioperative mortality, respiratory failure, renal insufficiency, and spinal cord ischemia in patients after thoracic endovascular aortic repair (TEVAR) compared to a matched cohort of patients undergoing open descending thoracic aortic aneurysm repair.[2]
- After two decades of surgeon experience and endovascular technologic advancement, TEVAR has evolved to serve as a primary treatment strategy for an increasingly diverse group of acute and chronic aortic pathologies including thoracic aortic aneurysms, dissections, and traumatic transections.

DIFFERENTIAL DIAGNOSIS

- Depending on the type and extent of pathology, TEVAR may include the use of fenestrated or branched stent grafts, advanced snorkel/chimney/periscope techniques, or the need for hybrid debranching procedures. The decision to treat thoracic aortic pathology with stent grafts is based on individual patient comorbidity burden, detailed analysis of thoracic aortic anatomy, and physician experience.
- Acute thoracic aortic pathologies often present with chest pain and therefore must be considered in the workup for acute coronary syndrome. The ubiquitous use of computed tomography (CT) scanning for pain, shortness of breath, trauma, and to "rule out" many pathologies has led to an increase in the recognition of thoracic aortic pathology potentially benefitting from TEVAR technology.

PATIENT HISTORY AND PHYSICAL FINDINGS

- Thoracic aortic aneurysms (TAAs) are defined as localized or diffuse dilation of 50% or more relative to the diameter of the adjacent normal-sized aorta. Common risk factors for aneurysmal degeneration include smoking, hypertension, chronic obstructive pulmonary disease, atherosclerosis, and connective tissue diseases. Indications for repair of descending TAAs are similar to those for conventional open repair: maximum aortic diameter greater than 6 cm, rapid aneurysmal growth (>5 mm of growth over 6 months), or symptoms such as persistent chest or back pain, rupture, or dissection. In most patients with TAA, the aneurysms were diagnosed following routine imaging ordered for other reasons and are therefore most commonly asymptomatic.
- Aortic dissection occurs when an intimal tear in the aorta causes blood to flow between the layers of the wall of the aorta and most often presents as tearing chest pain that radiates to the back. Potential etiologic factors leading to aortic dissection include poorly controlled hypertension, connective tissue disorders, trauma, or vasculitis. Medical management of uncomplicated type B thoracic aortic dissection serves as the current standard of care. These practice guidelines stem from the results of the INvestigation of STEnt grafts in patients with type B Aortic Dissection (INSTEAD) trial, the first prospective, multicenter randomized trial comparing optimal medical therapy (e.g., blood pressure control) to TEVAR for uncomplicated type B dissection.[3] This trial demonstrated no significant improvement in 2-year survival or adverse event rates with TEVAR despite favorable aortic remodeling, although recently reported 5-year data suggest improved long-term survival in patients undergoing TEVAR. In contrast, for patients with complicated type B dissections involving rupture, malperfusion (e.g., visceral or limb ischemia), or refractory back pain despite optimal medical management, TEVAR is indicated. The goal of TEVAR in this setting is to cover, or exclude, the primary entry tear and reexpand the true lumen while promoting thrombosis of the false lumen.
- Traumatic aortic transection results from a high-velocity or deceleration injury to the aorta. The tethering of the aorta by the ligamentum arteriosum makes this site most susceptible to shearing forces during sudden deceleration. A high index of suspicion is necessary to help make the diagnosis. Trauma workups most often involve whole-body CT scanning, which allows rapid triage for possible treatment. CT-A commonly demonstrates an irregular outpouching beyond the takeoff of the left subclavian artery at the aortic isthmus, which corresponds to the presence of an aortic pseudoaneurysm caused by the traumatic event. Extent of blunt traumatic aortic injury and the corresponding physiologic insult may range from clinically occult intimal injury to life-threatening complete transection and rupture (**FIG 1**).[4] Early diagnosis and endovascular treatment is generally recommended for those presenting with a traumatic aortic transection, particularly when there is a contour abnormality visualized on cross-sectional imaging.

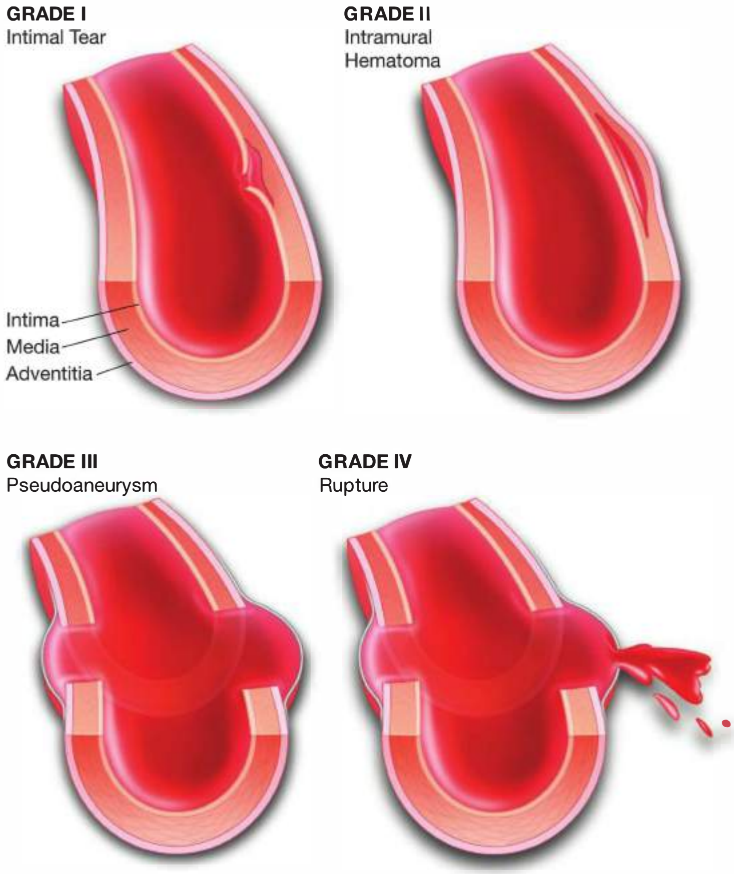


FIG 1 ● Society for Vascular Surgery classification of blunt traumatic aortic injury. (Adapted from Lee WA, Matsumura JS, Mitchell RS, et al. Endovascular repair of traumatic thoracic aortic injury: clinical practice guidelines of the Society for Vascular Surgery. *J Vasc Surg*. 2011;53:187–192.)

IMAGING AND OTHER DIAGNOSTIC STUDIES

- Transesophageal echocardiography (TEE) may serve as a useful imaging tool, particularly in the setting of acute thoracic aortic pathology. TEE can confirm the presence of aortic dissection, distinguish between types A and B dissections, identify involvement of supra-aortic vessels, and assess for contained rupture.
- High-resolution computed tomography angiography (CT-A) with three-dimensional reconstructive software allows for the most complete anatomic analysis, including details regarding aneurysm morphology, diameter, dissection flap characterization, thrombus burden, calcification, angulation, and branch vessel orientation.
- Familiarity and routine usage of three-dimensional workstations and the ability to customize measurements provide an accurate road map to guide endovascular strategy, device selection, and stent graft sizing.

SURGICAL MANAGEMENT

Preoperative Planning

- Patients scheduled for elective TEVAR undergo routine preoperative cardiac evaluation. Based on cardiovascular risk profile, symptomatology, and presence of electrocardiogram abnormalities, selected patients undergo further evaluation in the form of an exercise stress test, dobutamine stress echocardiography, or Persantine thallium stress testing. Coronary angiography is pursued in cases involving extensive or symptomatic coronary artery disease.
- Aortic transections or symptomatic dissections and aneurysms should have early and aggressive blood pressure control using intravenous beta-blocker or calcium channel blocker medications. After obtaining a reliable clinical examination, refractory chest, back, or abdominal pain should be treated with narcotic analgesics.
- Renal protective strategies should be employed preoperatively to minimize the risk of contrast-induced nephropathy. Intravenous hydration is initiated preoperatively and, in the setting of baseline renal insufficiency, may warrant early hospital preadmission and concomitant administration of Mucomyst and bicarbonate infusion.
- Suspected blunt aortic injury should prompt a referral to a level I trauma center in order to facilitate early evaluation by a vascular specialist and other pertinent members of a multidisciplinary trauma team.
- General anesthesia is routinely performed in TEVAR cases. Prophylactic lumbar cerebrospinal fluid (CSF) drainage is

considered in every case based on the relative risk of spinal cord ischemia, hemodynamic status, and acuity of clinical presentation. Arterial monitoring is performed via a right radial artery approach. Peripheral intravenous lines are typically adequate; however, more intensive central venous monitoring may be required in cases involving unstable traumatic transections, patients with significant baseline cardiovascular comorbidities, or any case involving hemodynamic instability.

- Preoperative imaging should be heavily scrutinized for the adequacy of iliofemoral access anatomy. An iliac conduit may be required in cases involving small-caliber, tortuous, or heavily calcified access vessels. Anticipated use of a conduit should prompt consideration of an autotransfusion or cell saver machine to be available during the procedure.
- Numerous variables have been identified as risk factors for the development of spinal cord ischemia after TEVAR. Given that hypoperfusion represents the primary etiology of spinal cord injury following TEVAR, commonly cited risk factors involve those relating to the extent of impairment or exclusion of the collateral perfusion to the spinal cord. The European Collaborators on Stent/Graft Techniques for Aortic Aneurysm Repair (EUROSTAR) investigators reported results from the largest multicenter registry to date (N = 606).[5] In the EUROSTAR registry, the incidence of spinal cord ischemia was 2.5% and independent risk factors included left subclavian artery coverage without revascularization (odds ratio [OR], 3.9; p = .037), concomitant open abdominal aortic surgery (OR, 5.5; p = .037), and the use of three or more stent grafts (OR, 3.5; p = .043).
- Based on the principle that spinal cord perfusion pressure is approximated by the difference between the mean arterial pressure (MAP) and CSF pressure, placement of a prophylactic lumbar drain has the potential to increase spinal cord perfusion pressure by decreasing CSF pressure and may be beneficial in select patients at high risk for spinal cord ischemia. Percutaneous drainage of CSF is performed by inserting a silastic catheter 10 to 15 cm into the subarachnoid space through a 14-gauge Tuohy needle at the L3–L4 vertebral interspace. The open end of the catheter is attached to a sterile closed circuit reservoir and the lumbar CSF pressure is measured with a pressure transducer zero-referenced to the midline of the brain. Lumbar CSF can be drained continuously or intermittently in the operating room to achieve target CSF pressures of 10 to 12 mmHg. Postoperatively, intermittent or continuous CSF drainage can be continued in the intensive care unit for CSF pressures exceeding 10 mmHg or at the first sign of lower extremity weakness. In the absence of neurologic deficits, the lumbar CSF drainage catheter can be clamped 24 hours postprocedure followed by continued monitoring of CSF pressure together with serial neurologic assessments. The CSF drain can then be removed at 48 hours after operation. Although prophylactic or therapeutic lumbar CSF drainage has an established record of safety, complications have been reported to occur in approximately 1% of patients, which may include neuraxial hematoma, subdural hematoma, catheter fracture, meningitis, intracranial hypotension, chronic CSF leak, and spinal headache.

Selection and Sizing of Thoracic Stent Graft

Landing zones

- Proximal and distal landing zones must be of sufficient length (usually at least 2 cm) to enable safe and accurate deployment bracketing the area of thoracic aortic pathology, which often includes the subclavian artery proximally or the celiac artery distally.
- Intentional coverage of the left subclavian artery is sometimes required due to a very proximal extent of aortic pathology, especially transections. Left subclavian artery revascularization may be required in select cases. The celiac artery rarely requires intentional coverage.
- Significant tortuosity, circumferential mural thrombus, and extensive calcification can compromise the proximal or distal landing zone, thereby predisposing to inadequate fixation and subsequent development of endoleak or migration. Site of proximal and distal landing zones should be selected in order to minimize the impact of these anatomic features, even if it requires extending the length of aortic coverage.
- A variety of anatomic measurements are taken from preoperative CT-A imaging to assist in the sizing and selection of the thoracic stent graft (**FIG 2**). Interventionalists should be proficient in accurate sizing and measuring of key thoracic aortic locations that influence device selection and ultimately determine patient outcomes.

Sizing of stent grafts

- The degree of stent graft oversizing can vary based on the indication for intervention. Stent grafts are generally oversized by 10% to 20% based on the aortic diameter at the proximal and distal fixation sites for aneurysmal disease. Insufficient oversizing for the treatment of TAAs may predispose to inadequate exclusion and the potential for endoleak or migration. Aggressive oversizing, on the other hand, increases the risk for stent graft collapse, graft thrombosis, access arterial injury, and potential for peri- or postprocedural iatrogenic retrograde type A dissection.
- Chronic type B dissections are frequently characterized by a thick, nonmobile dissection flap, or septum, that separates true and false lumens into concave or convex discs of flow lumen. Such dissection flaps have limited compliance; therefore, minimal or no oversizing may be required in order to achieve a suitable proximal or distal seal.
- Aortic transections frequently occur in young trauma patients with normal or minimally diseased aortas. As such, minimal oversizing is needed to achieve an adequate seal and only recently did device manufacturers create devices meant for smaller diameter aortas. Note also that underrescucitated patients on admission will have smaller aortic diameters on their CT-A.
- Currently available stent grafts range in diameter from 22 to 46 mm. Given the traditional 10% to 20% rule of device oversizing, these devices are designed to safely treat aortas with landing zones ranging from 19 to 43 mm in diameter.

Access vessel anatomy

- Current thoracic aortic stent grafts require large-caliber delivery systems, ranging from 18 to 26 Fr in outer diameter. Small,

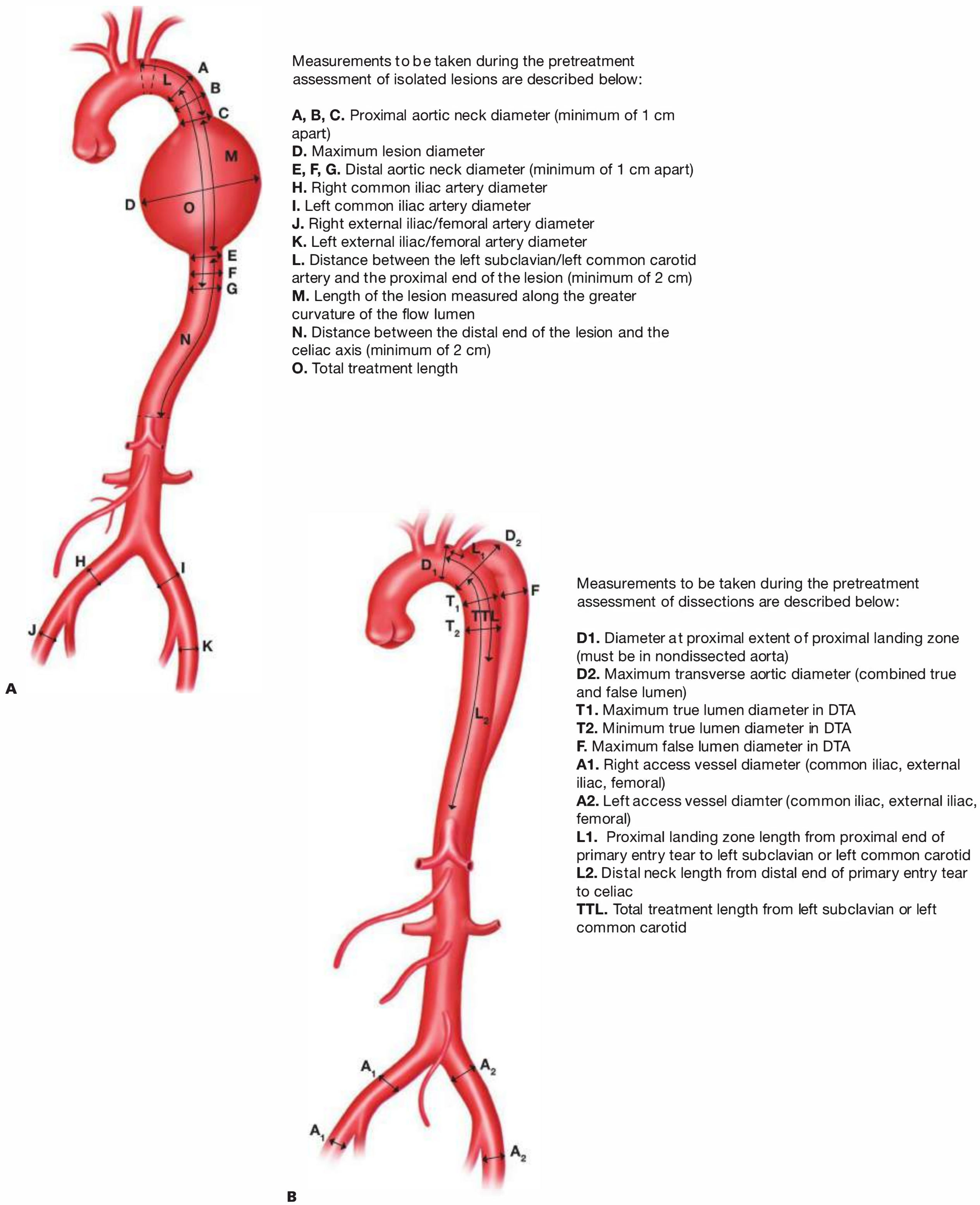


FIG 2 ● Anatomic measurements to assist in thoracic stent graft device sizing and selection for the treatment of aneurysms **(A)** and dissections **(B)**. DTA, descending thoracic aorta.

tortuous, and heavily calcified iliofemoral arteries may prohibit sheath advancement and predispose to access site–related complications, including groin hematoma, dissection, or rupture.

- Careful evaluation of access vessel anatomy on preoperative imaging should be performed in order to assess the caliber, tortuosity, thrombus burden, and extent of calcification of the iliofemoral arteries. Such anatomic information will serve as the basis for deciding laterality of femoral access as well as to determine the need for an iliac conduit.
- Serial dilation may be attempted for patients with small iliofemoral vessels. Iliac atherosclerotic lesions may be pretreated with balloon angioplasty and/or stent grafting in order to facilitate sheath advancement and introduction of the thoracic stent graft components.
- Iliac conduits serve as a safe and reliable technique to circumvent issues related to suboptimal access vessel anatomy. From either flank incision, a retroperitoneal exposure provides visualization of the common iliac artery or distal abdominal aorta. A 10- or 12-mm Dacron graft is commonly used as the conduit of choice. The conduit can be modified by creating a patch at the distal end in order to further facilitate the delivery of large-caliber sheath and enable additional degrees of torqueability (**FIG 3**). This modification involves creating a patch by cutting the Dacron graft along its long access, thereby enlarging the transition zone from the graft to artery.

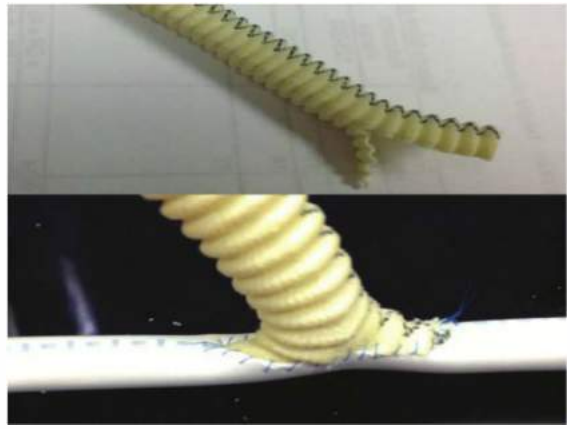


FIG 3 • **A.** 10-mm Dacron conduit bisected longitudinally to create a sewing patch. **B.** Dacron iliac conduit sewn to native iliac artery allows easy mobility of the conduit at multiple angles of entry for large-caliber device or sheath. (From Lee JT, Lee GK, Chandra V, et al. Comparison of fenestrated endografts and the snorkel/chimney technique [published online ahead of print April 27, 2014]. *J Vasc Surg*. doi:10.1016/j.jvs.2014.03.255.)

TECHNIQUES

EARLY PROCEDURAL CONSIDERATIONS

Positioning

- The C-arm is typically configured in the "head" position. The left arm may be abducted to 75 to 90 degrees and circumferentially prepped into the field if an embolization or snorkel/chimney procedure involving the left subclavian artery is anticipated. The chest, abdomen, and bilateral groins should be prepped. As frequently only one groin access is required for the performance of a routine TEVAR, laterality of the operator position may vary based on surgeon preference or anticipated access site location.

Establishing Vascular Access

- The ipsilateral femoral artery is accessed either percutaneously or from an open exposure. Secondary access may be obtained from the contralateral femoral artery or brachial artery as needed for a 5-Fr sheath and flush catheter. Surgical exposure is obtained from a small oblique incision at the level of the inguinal ligament. The common femoral artery is exposed, with proximal control obtained at the level of the external iliac artery and distal control at the level of the femoral bifurcation or proximal superficial femoral and profunda femoral arteries. Heavy calcification may require preemptive endarterectomy and patch angioplasty in order to facilitate safe sheath placement.
- The femoral artery is punctured using a standard micropuncture set, and if arterial access is obtained percutaneously, a sheathogram is performed to confirm adequate puncture site location (mid–common femoral artery). A standard length Bentson wire is inserted into the aorta through micropuncture sheath and exchange for a 7-Fr sheath is then performed using Seldinger technique. Wire exchange is then done for a 260-cm stiff Lunderquist wire. The Lunderquist wire should have a flexible, curved proximal end that should be advanced under fluoroscopy across the aortic arch to abut the aortic value. The location of the distal end of the Lunderquist wire should be marked on the operating table and this wire position should be maintained throughout the procedure.
- Over the stiff Lunderquist wire platform, the 7-Fr sheath is removed and serial dilators are advanced to gradually enlarge the subcutaneous tract and arteriotomy site in order to accommodate either the stent graft device itself or a larger 18- to 26-Fr introducer sheath required for device delivery.
- After placement of the larger sheath, systemic heparin is administered at a dose of 100 units/kg (goal activated clotting time of >250 seconds). Concomitant traumatic injuries, particularly intracranial hemorrhage, may alter the dose or decision to administer heparin.

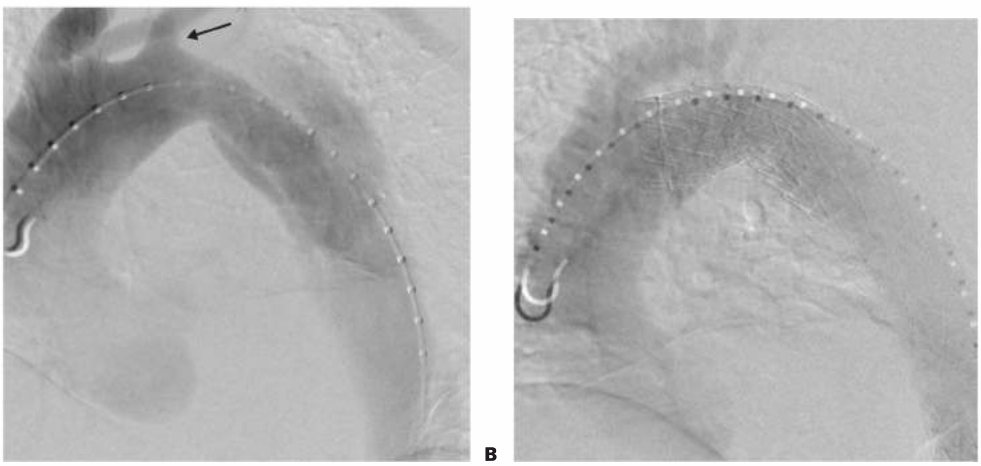
INITIAL AORTOGRAM

- A 5-Fr 100-cm Omniflush or pigtail catheter is inserted into aorta and advanced to the level of the aortic arch. This catheter may be advanced via a contralateral 5-Fr sheath or it may be inserted into an additional ipsilateral 5-Fr sheath placed distal to the arteriotomy for the main body delivery sheath.

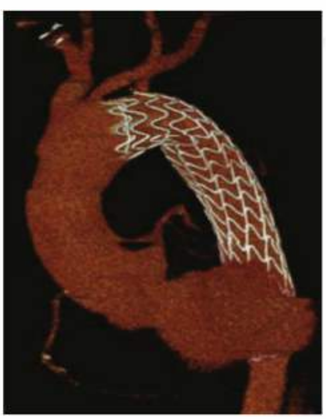
- If satisfied with stent graft sizing based on available preoperative imaging, the thoracic aortic stent graft may be advanced over the Lunderquist wire and be positioned in the proximal to midportion of the thoracic aorta prior to initial aortogram.
- Optimal angiographic imaging of the aortic arch is obtained by placing the fluoroscopic C-arm in a left anterior oblique orientation, often 35 to 65 degrees, and can be optimized by referencing the preoperative CT-A. The location of the supra-aortic vessels, particularly the left subclavian artery, should be noted and marked on viewing monitors (**FIG 4A**).
- Intravascular ultrasound (IVUS) may be used an adjunct in cases involving dissection to assist in the identification of true and false lumens, as well as to gain additional information on aortic diameter, branch vessel location, and morphology of proximal and distal landing zones. IVUS also aids in limiting intravenous contrast exposure in those patients with baseline impaired renal function.
- If necessary to guide distal extent of stent graft placement, the celiac artery is best imaged from a full lateral projection. Additional structures to note are large, patent intercostal arteries at the level of the aortic hiatus. Efforts should be made to avoid covering these if at all possible during the course of the repair.

Device Deployment

- Precise proximal positioning of the stent graft is facilitated by either marking the location of the left subclavian artery on the viewing screen and/or using the road-mapping feature. The distal radiopaque line of the endotracheal tube seen on fluoroscopy at about 45 degrees left anterior oblique can sometimes correlate to the position of the left common carotid artery, thereby serving as a convenient landmark in cases requiring left subclavian artery coverage.
- Immediately prior to stent graft deployment, systemic arterial blood pressure is reduced below 100 mmHg to reduce risk of caudal migration.
- The stent grafts are generally deployed in a proximal-to-distal sequence. However, a distal-to-proximal sequence may be preferred in cases involving precise deployment near the celiac artery or in aortas with significant diameter taper and a larger proximal landing zone compared to the distal landing zone (where devices of different diameter may need to be stacked up on each other).
- Deployed endografts will naturally extend toward the outer curvature of the aorta and precision deployment is facilitated by gently providing forward traction on the wire toward the outer curve during deployment. This



A B



C

FIG 4 ● **A.** Initial thoracic aortogram performed with C-arm in a 45-degree left anterior oblique orientation in a case involving a type B aortic dissection. Note how clearly the origin of the subclavian *(arrow)* is seen to accurately decide if there is adequate proximal neck length. **B.** Aortogram following deployment of thoracic stent graft with coverage of the ostium of the left subclavian artery. **C.** Postoperative three-dimensional imaging demonstrating successful exclusion of the proximal entry dissection tear.

maneuver also facilitates straightening out of the transverse arch, which can be helpful in minimizing the "bird-beaking" effect at the proximal graft margin, where the device may not fully oppose to the "inner" aortic wall. Bird beaking, when present, can predispose to proximal type I endoleaks, endograft collapse, and potential aortic occlusion.

- Additional graft components are added, when necessary, by exchanging the first device over the Lunderquist wire. A minimum overlap of 5 cm between pieces is recommended to ensure adequate apposition and minimize risk of junctional (type III) endoleak.

Balloon Molding

- Balloon molding is often required in cases involving TAAs. Under fluoroscopic guidance, a noncompliant molding balloon (Coda [Cook Medical, Bloomington, IN, USA] or Tri-Lobe [W. L. Gore, Flagstaff, AZ, USA]) is advanced up to the proximal edge of the stent graft and balloon molding is performed in a proximal-to-distal sequence. Balloon molding should be performed at the proximal and distal fixation sites, as well as at areas of stent graft overlap in those cases requiring multiple stent grafts.
- Aggressive ballooning can cause component fracture and aortic injury, and care must be taken during inflation with constant visualization and knowledge of the tension applied to the balloon.
- Balloon molding is not typically required in cases involving aortic dissection or transection, particularly in cases where no obvious endoleak is visualized. Balloon molding may increase risk for iatrogenic retrograde type A conversion if performed in a region of friable or fragile aorta and is generally not recommended during dissection cases.

COMPLETION AORTOGRAM

- After stent graft deployment, the pigtail catheter is withdrawn along the outside of the deployed device(s) over a wire to below the level of the stent graft. The catheter is then readvanced over a wire within the stent graft lumen and positioned at the level of the aortic arch.
- Additional aortograms may be performed at this time as necessary in order to ensure adequate stent graft position and patency of the supra-aortic and celiac arteries and to assess for the presence of endoleaks.

REMOVAL OF SHEATH AND ARTERIOTOMY CLOSURE

- In cases involving percutaneous access, the two previously placed Perclose ProGlide devices are used to close the arteriotomy site(s) (see Part 6, Chapter 23 for details). If open surgical exposure was obtained, proximal and distal vascular control is obtained in the respective groin. All wires and sheaths are removed. The arteriotomy is closed transversely using a polypropylene suture in either a running continuous or interrupted fashion. Antegrade and retrograde flushing maneuvers should be performed prior to completion of the arteriotomy closure.

LEFT SUBCLAVIAN ARTERY REVASCULARIZATION

- Endovascular procedures that require coverage of the left subclavian artery have the potential to increase the risk of spinal cord injury by compromising blood flow to the ipsilateral vertebral artery, an important collateral pathway for arterial flow to the anterior spinal artery. Subclavian artery revascularization therefore serves as an additional strategy to decrease the risk of spinal cord ischemia in select patients deemed high risk.
- Techniques to revascularize the left subclavian artery include transposition of the subclavian onto the left carotid artery or left carotid–subclavian bypass grafting with subsequent embolization of the left subclavian artery proximal to the bypass graft (**FIG 5**). These revascularization procedures may be performed as part of a staged repair or at the time of TEVAR.
- The existing clinical evidence to support the efficacy of routine left subclavian artery revascularization remains controversial; there are advocates for routine revascularization, selective revascularization, or no revascularization. A meta-analysis of published studies showed a trend toward increased risk of spinal cord ischemia when the left subclavian artery was covered, suggesting a potential benefit for left subclavian artery revascularization, but the finding was not statistically significant.[4–6]

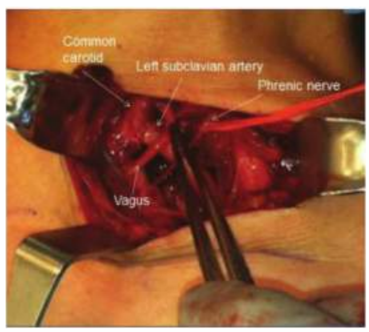


FIG 5 ● Left subclavian artery transposition is performed by ligating the left subclavian artery proximal to the vertebral artery and moving it cephalad in order to perform an end-to-side anastomosis between the left subclavian and left common carotid arteries. Alternatively, a Dacron graft can be used as a left carotid–subclavian bypass.

SPECIAL CONSIDERATIONS BASED ON AORTIC PATHOLOGY

Aortic Dissection

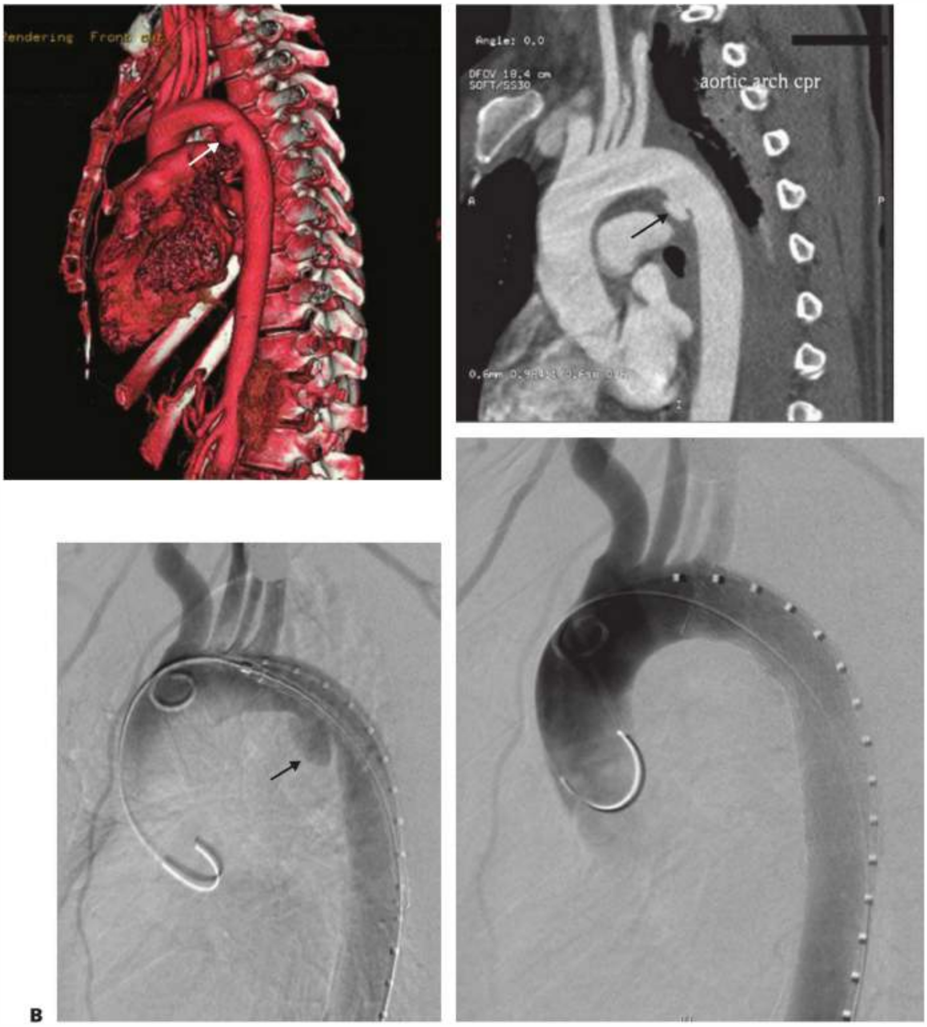
- The primary goal of TEVAR for the treatment of dissection is coverage of the proximal entry tear (**FIG 6A,B**). Stent graft sizing is based on the diameter of the adjacent nondissected thoracic aorta. Minimal or no oversizing of the stent graft is recommended.
- In acute type B dissections, the septum is relatively mobile and compliant. Therefore, the diameter of the small true lumen in the dissected portion often returns to normal diameter following successful exclusion of the proximal entry tear.
- Chronic dissections have thicker, less compliant septa, which may limit expansion of the true lumen despite adequate entry tear coverage. Often, these patients have chronic false lumen aneurysmal dilation, and entry tear and fenestration covering serve simply to decrease false lumen pressurization and promote thrombosis.
- IVUS serves as a useful adjunct in dissection cases, both in terms of initial identification of true and false lumen, as well as assisting in precise positioning of the device.

Aortic Transection

- Traumatic aortic injuries are typically located along the inner curve of the proximal descending thoracic aorta (**FIG 7**). Given the proximal location, left subclavian artery coverage is sometimes needed.[4]
- In the absence of concomitant hemorrhage or brain injury, routine heparin is recommended.
- Trauma patients are frequently hypovolemic and, as a result, may have an underdistended aorta on preoperative cross-sectional imaging. Initial cross-sectional imaging can underestimate true aortic morphology at the region of the subclavian by as much as 10% to 20%. In such settings, IVUS may assist in more accurate stent graft sizing performed in vivo.[7]

A B

FIG 6 ● **A.** CTA reconstruction demonstrating complex thoracoabdominal aortic dissection with proximal entry tear located in the proximal descending thoracic aorta. **B.** Initial aortogram documenting position of the supra-aortic arteries. Note the stent graft has been advanced into approximate position but is not yet deployed.



A B C

FIG 7 ● **A.** Three-dimensional reconstructed images showing the presence of traumatic aortic transection at the level of the ligamentum arteriosum *(arrow)*. **B.** Aortogram showing focal outpouching *(arrow)* along the inner curve of the proximal descending thoracic aorta, correlating to the traumatic transection observed on preoperative imaging. Note that the stent graft has been advanced into the proximal descending thoracic aorta but is not yet deployed. **C.** Aortogram following thoracic stent graft deployment with successful exclusion of the transection site.

PEARLS AND PITFALLS

Indications	■ TEVAR follows general recommendations for elective repair of descending thoracic and thoracoabdominal aortic aneurysms and should be offered to good anatomic risk patients with aneurysms >6 cm. ■ Patient selection should take into account the need for regular interval clinical and radiologic follow-up in order to monitor for stent graft–related complications and endoleaks.
Preoperative workup	■ High-quality imaging and ability to configure three-dimensional reconstructive software are essential for successful preoperative planning and device selection. ■ Pre- and perioperative hydration is a central part in the protection from contrast-induced nephropathy. ■ Patients should be stratified according to baseline risk of spinal cord ischemia. A prophylactic lumbar drain should be considered in those at high risk.
Patient setup	■ A hybrid endovascular suite provides optimal opportunity for accurate imaging and capability to perform necessary open surgical exposure or repair of access-related complications. ■ Anticipated adjunct procedures, including left subclavian artery embolization or revascularization, may require prepping the left neck and/or arm into the surgical field.
Thoracic aneurysms	■ Oversizing of stent grafts by 10% to 20% and balloon molding is generally recommended in order to maximize proximal and distal fixation. ■ Proximal and distal landing zones should be relatively free of stenosis, calcification, and thrombus to maximize durability of this minimally invasive technology.
Type B dissection	■ Accurate identification of true and false lumen is essential prior to deployment of the stent graft. IVUS may be a useful adjunct in this setting to confirm true or false lumen position. ■ Aggressive oversizing of stent grafts is not recommended in patients with aortic dissection. Balloon molding is generally reserved only for those with type I or III endoleak on completion angiography and not against the region where there is a mobile septum.
Traumatic transection	■ Routine heparin is recommended unless contraindicated by concomitant intracranial or solid organ injury. ■ Similar to dissections, aggressive oversizing and balloon molding is not routinely performed during the treatment of transections.

POSTOPERATIVE CARE

- Patients are typically extubated immediately following the procedure unless prohibited by concomitant physiologic insults (e.g., hemodynamic instability, trauma patient).
- Intensive care unit monitoring is required for patients who require a lumbar drain for 24 to 48 hours. Immediate and frequent neurologic assessments are critical in the early perioperative period to assess for spinal cord ischemia. Raising MAP goals are an additional way to minimize risk of cord ischemia.
- Durability of TEVAR is reliant on routine imaging to evaluate for stent graft–specific complications postoperation. Follow-up chest CT-A and plain x-rays are typically obtained at 1, 6, and 12 months and at intervals thereafter. Consideration should be made between balancing risks for cumulative lifetime iodinated contrast and radiation exposure versus the necessity for serial graft monitoring. In stable patients, chest x-rays may suffice to confirm device position, with CT scanning reserved for those with migration suggested by CT or evidence of progressive aortic enlargement or onset of recurrent symptoms such as chest pain.

OUTCOMES

- The largest published series, which has reported 1-year follow-up, included 443 patients treated with TEVAR for a variety of indications, both emergent and elective, as follows: TAA (n = 249), thoracic aortic dissection (n = 131), traumatic aortic injury (n = 50), and false anastomotic aneurysm (n = 13).[8] Technical success was achieved in nearly 90% of patients, with an all-cause mortality among patients treated for aortic aneurysm and aortic dissection of 20% and 10%, respectively.
- No randomized trials comparing TEVAR to open surgery have been published to date. However, multiple nonrandomized comparisons suggest equivalent or better outcomes with TEVAR. In a single-center, retrospective study of over 700 patients who underwent either TEVAR or open surgery, mortality was not significantly different at 30-day (5.7% vs. 8.3%, respectively) or 1-year (15.6% vs. 15.9%, respectively) follow-up.[9] Two smaller studies demonstrated a reduction in 30-day perioperative mortality with TEVAR compared with open surgery (1.9% vs. 5.7%).[10,11]

COMPLICATIONS

- Stroke continues to be a common complication following TEVAR and is associated with significant in-hospital mortality. Recent clinical series have reported an incidence of stroke after TEVAR to range from 2% to 8%.[12,13] The underlying mechanisms contributing to acute ischemic stroke after TEVAR and the temporal relationship of stroke to the procedure are not completely understood. However, the constellation of preoperative risk factors, neurologic examinations, and patterns of brain infarction observed in these patients has led most investigators to conclude that cerebral embolization and ischemic events are the primary mechanisms for perioperative stroke in TEVAR.[5,13,14] Embolic events are related to instrumentation of the aortic arch in patients with severe atheromatous disease, whereas ischemia is a result of the planned or inadvertent endovascular coverage of supra-aortic vessels.

- Spinal cord ischemia and subsequent acute or delayed paraplegia represents the most devastating complication of TEVAR. The pathogenesis of spinal cord injury after TEVAR is likely multifactorial but still poorly understood. The deployment of thoracic stent grafts results in rapid complete exclusion of varying lengths of segmental collateral vessels without the ability to surgically reimplant or revascularize the intercostal arteries. Stent deployment and catheter manipulation can predispose patients to dislodgement of thrombotic or atheromatous debris from the aortic wall into segmental vessels, with subsequent distal embolization and occlusion of arteries supplying the spinal cord. Moreover, endovascular coverage of the left subclavian artery may compromise spinal cord perfusion in patients with a dominant left vertebral artery, solitary vertebral artery, carotid artery disease, or an incomplete circle of Willis. Access site injuries to the iliofemoral vessels may further increase the risk of spinal cord ischemia by compromising collateral flow to the anterior spinal artery through the hypogastric and pelvic vascular plexus. Lastly, pharmacologic measures aimed at decreasing arterial blood pressure to enhance accuracy of device deployment in cases involving difficult aortic anatomy may lead to hypotension similar to that observed in open surgery.
- Due to the large sheath sizes required for the delivery of thoracic stent grafts, small-diameter, tortuous, or heavily calcified access vessels can predispose to iliofemoral arterial injury. Postoperative CT-A often documents arterial dissections and injury that can be followed with noninvasive duplex and managed expectantly until patients have claudication-like symptoms.
- Endoleaks are a relatively common finding after TEVAR, affecting nearly 15% of patients in the early or late postoperative periods. Type I or III endoleaks typically require additional stent placement or balloon molding in order to improve proximal, distal, or junctional fixation. Most type II endoleaks observed on completion angiogram or early follow-up cross-sectional imaging will resolve spontaneously. Persistent type II endoleaks, especially those with aneurysm sac expansion or failure to adequately seal a proximal entry tear or transection, warrant additional intervention. Retrograde flow from intercostal or left subclavian arteries can be treated using coil embolization or vascular plug placement.

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Chapter 14

Exposure and Open Surgical Management at the Diaphragm

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DEFINITION

- Thoracoabdominal aneurysms and complicated descending aortic dissections are the two most likely reasons for requiring surgical exposure of the diaphragm in vascular surgery. The need to expose the aorta both above and below the diaphragm requires an extended incision spanning the left thorax to the abdomen, the length and exact location of which depends on the location of the targeted aortic pathology. Often, the diaphragm must be divided, necessitating an awareness of the regional anatomy as well as various surgical management considerations.

DIFFERENTIAL DIAGNOSIS

- Thoracoabdominal aneurysm: The Crawford classification categorizes thoracoabdominal aneurysms according to the extent of the aneurysm and is the most widely used[1] (**FIG 1**). The classification is as follows: type I, from the left subclavian artery to just above the renal arteries; type II, from the left subclavian artery to the infrarenal aorta; type III, from the mid-descending thoracic aorta to below the renal arteries; type IV, from the diaphragmatic aorta to the iliac bifurcation; and type V (modified classification by Safi et al.[2]): from the mid-descending thoracic aorta.
- Descending (type B) aortic dissection: Two classifications systems are commonly used to describe the extent of aortic dissections (**FIG 2**). Stanford type A dissections involve the ascending aorta with or without involving the descending aorta, whereas type B dissections only involve the descending aorta beyond the left subclavian artery. The DeBakey classification includes type I, which involves both the ascending and descending aortas; type II, which involves only the ascending aorta; and type III, which involves only the descending aorta.

PATIENT HISTORY AND PHYSICAL FINDINGS

- Most patients who are referred for surgery for a thoracoabdominal aneurysm present with no symptoms. However, when they do have signs and/or symptoms, they may present with pain in the chest, abdomen, or lower back; a mass in the abdomen, which may be pulsatile, or rigid abdomen; and evidence of atheroembolism distally. The aforementioned symptoms, with signs of hypovolemic shock, may indicate a ruptured aneurysm.
- Uncomplicated descending aortic dissections are generally managed medically. However, if the dissection is complicated, such as when it is associated with significant symptoms or leads to visceral or distal malperfusion, rapid surgical intervention is warranted.
- A more complete discussion regarding indications for intervention in aortic dissections and thoracoabdominal aortic aneurysm can be found in a number of relevant reference textbooks.

IMAGING AND OTHER DIAGNOSTIC STUDIES

- Imaging is used to determine the proximal and distal extent of repair required. It impacts the type of exposure required (i.e., thoracotomy vs. laparotomy vs. thoracoabdominal incision) as well as the level of incision.
- If the exposure is for the repair of thoracoabdominal aortic pathology, all patients require adequate preoperative imaging, ideally consisting of a computed tomography aortography (CTA) with or without 3-D reconstruction. Magnetic resonance aortography (MRA) may also provide the necessary information, but this generally requires more time, is more expensive, and requires more extensive postprocessing. However, MRA is the study of choice when CTA is contraindicated or unsafe, such as in patients with a contrast allergy or renal insufficiency. Catheter-based invasive aortography has generally been supplanted by CTA and MRA as the primary preoperative imaging

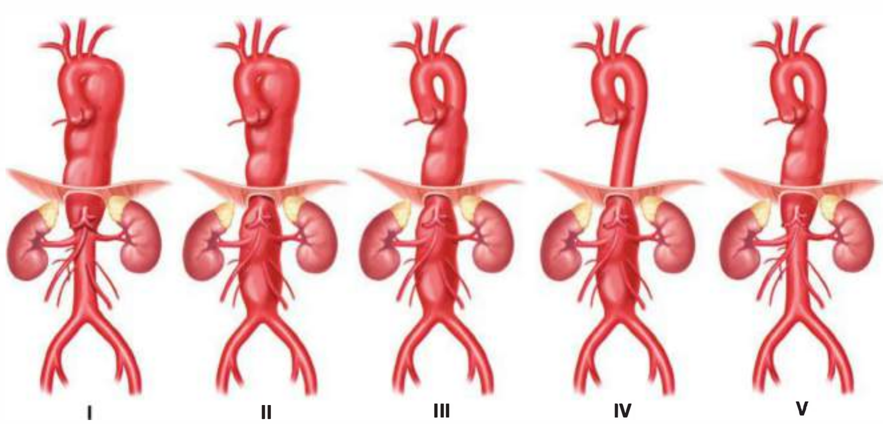

FIG 1 ● Modified Crawford classification.

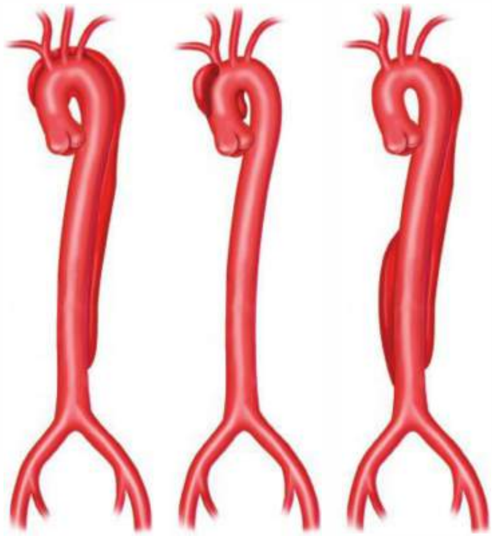

FIG 2 ● Stanford/DeBakey classification.

modality of choice, as it is more cumbersome and does not provide a complete assessment of the aneurysm, including thrombus volume and adjacent anatomic structures.

- If the surgery is elective, as in the case of an incidentally found aneurysm, extensive preoperative evaluations are necessary to minimize postoperative morbidity and mortality.
- Thorough evaluations of the cardiac, pulmonary, and renal systems are necessary, especially because these systems are most commonly affected when there are complications. Depending on the risk factors and prior history, further testing may be required and patients should be referred to appropriate specialists for proper evaluation. A good neurologic evaluation is also warranted, particularly if the patient has a prior history or symptoms suggestive of a lower extremity weakness or spinal injury.

SURGICAL MANAGEMENT

Preoperative Planning

- Determine the possible need for adjuncts such as cardiopulmonary bypass and neurophysiologic monitoring. In some instances, pulmonary artery catheters may be warranted for monitoring cardiovascular hemodynamics.
- Assess the need for spinal cord protection, including the use of lumbar drainage of cerebrospinal fluid (CSF), distal aortic perfusion, epidural cooling, and distal aortic perfusion.
- Given the expected amount of blood loss, a Cell Saver and rapid infuser should be available.
- Double lumen endotracheal tube should be used for single-lung ventilation of the right lung. Bronchial blockers are not reliable adjuncts for this purpose.

Positioning

- Initially, place the patient supine on a deflated beanbag (**FIG 3**). Roll the left chest upward and toward the right and place a shoulder roll under the right axilla and a bump under the left scapula while also gently pulling and securing the right arm over to the right side. Ideally, the upper back should be rotated about 60 degrees to the table with the pelvis remaining flat, such that the trunk is twisted to the right. Position the patient with the break located halfway between the left costal margin and the left iliac crest. Jackknife the table and then inflate the beanbag. Be sure to support and secure the arms ("airplane" splint for the left arm) and pad all pressure points on the body and extremities.
- Prep the left chest with the following boundaries: the axilla superiorly, the spine posteriorly, and the sternum and abdomen beyond the right of midline anteriorly. Keep the groins in the field for surgical access to the femoral vessels for possible cannulation if necessary.

FIG 3 ● Positioning.

PLANNING THE INCISION

- This chapter deals with distal thoracic aortic pathology requiring exposure of the diaphragm where a simple thoracotomy incision would not be adequate. Such more limited pathologies are described elsewhere.
- The proximal extent of the pathology and the anticipated location of the proximal clamp determine the level of the thoracic portion of the incision.
  - If the proximal clamp is to be placed between the aortic arch and just beyond the left subclavian artery, the chest is entered through the 4th or 5th intercostal spaces (e.g., Crawford types III and V aneurysms).

  - If the proximal clamp is to be placed just above or at the diaphragm, the 8th or 9th interspace should be entered (e.g., Crawford type IV aneurysms).
- Consider the possible use of parallel or "double" thoracotomy incisions if exposure of both the proximal and distal extent of the thoracic aorta is needed. In this case, the skin incision is placed between the levels of the two interspaces anticipated to be entered.
- The length and location of abdominal incision is determined by distal extent of the aortic pathology.
  - A modified thoracoabdominal incision that does not extend to midline is adequate if limited exposure of the abdominal aorta to the level of the celiac artery is required.
  - Extend the incision to the midline for exposure of the visceral aorta.
  - The incision should be extended down the abdominal midline for more extensive exposure of the infrarenal abdominal aorta (types II, III, and IV) to the aortic bifurcation or common iliac arteries (**FIG 4**).

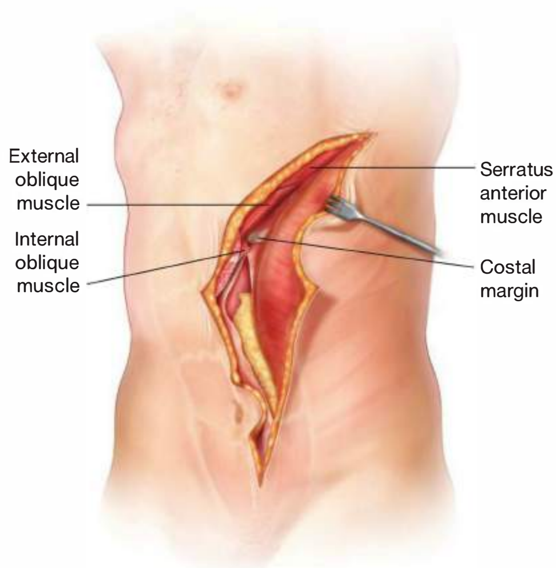

FIG 4 ● Thoracoabdominal incision.

THE INITIAL INCISION AND EXPOSURE

- Mark where the incision is to be made including finding the appropriate interspace and the extent of the abdominal incision as described earlier.
- Start with the thoracic incision over the appropriate interspace and then extend it across the costal margin. Depending on the degree of the abdominal exposure required, extend this incision obliquely to the midline of the abdomen. The midline incision can then be extended to the level of the symphysis pubis, if necessary.
- The abdominal incision is carried through the subcutaneous tissues, the external abdominal oblique aponeurosis, and the anterior rectus sheath.
- Split the external abdominal oblique muscle in the direction of its fibers.
- Divide the underlying internal oblique and transversus abdominus muscles between the costal margin and lateral edge of the rectus sheath.
- Divide left rectus muscle.
- The thoracic incision should provide adequate exposure posteriorly and should be extended to the erector spinae fascia.
- Expose the intercostal muscles by incising through the subcutaneous tissues and the external oblique fascia.

ABDOMINAL EXPOSURE

- Develop the abdominal portion of the incision before entry into the left pleural cavity
- The aorta may be exposed by an extraperitoneal or transperitoneal approach.
  - Extraperitoneal: This approach is ideal for repairing thoracoabdominal aneurysms, especially those involving the upper abdominal aorta (**FIG 5**).
    - Develop the plane between the transversalis fascia and the parietal peritoneum.
    - Separate the peritoneum from the lateral and posterior abdominal walls as well as from the diaphragm superiorly.
- Transperitoneal: This approach provides better exposure for visceral artery revascularization when required, especially when bypass is required to the right renal artery.
- Additional details of these approaches can be found elsewhere and are beyond the scope of this chapter.

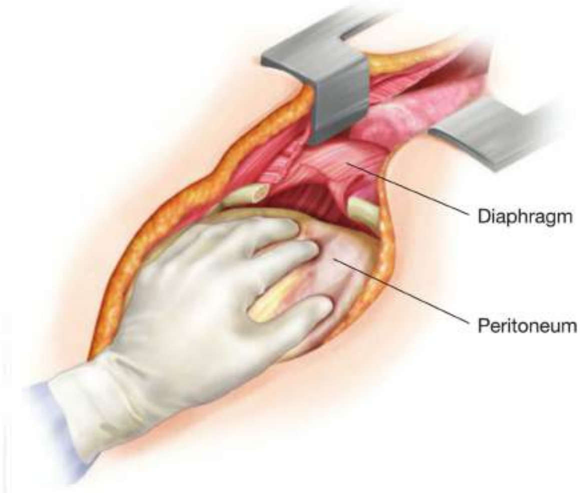

FIG 5 ● Abdominal aortic exposure via extraperitoneal approach.

THORACIC EXPOSURE

- Develop a plane superficial to the ribs and intercostal muscles.
- Hold ventilation to the left lung and allow it to collapse.
- Enter the left chest by opening the intercostal space along the superior edge of the lower rib, making sure not to injure the lungs.
- To maximize the exposure, it may be necessary to perform a subperiosteal resection of the rib above or below the interspace entered, depending on the target location.
- Additional exposure can be obtained from "notching" an adjacent rib. This is accomplished by excising a 2-cm segment of the rib posteriorly
- If two interspaces are being entered, develop an adequate plane anterior to the ribs. The skin and overlying muscles can be retracted to accommodate both thoracic interspace exposures.
- Use a self-retaining retractor to maintain exposure.
- Be aware that there can be extensive adhesions within the pleura that may predispose to lung injury. Usually, these adhesions can be mobilized bluntly if thin but may need bovie cautery or scissors if more substantial.

EXPOSURE AND DIVISION OF THE DIAPHRAGM

- Release any adhesions that may be present, mobilize the lung by dividing the inferior pulmonary ligament, and retract the lung cephalad to expose the diaphragm.
- Next, join the left thoracic cavity and the retroperitoneum or abdomen by dividing the diaphragm.
- The diaphragm can be incised partially or completely (**FIG 6**).
  - Partial incision: Incise the muscular portion of the diaphragm and preserve the central tendinous portion. This approach minimizes respiratory complications.
  - Complete division: This approach provides the best exposure of the aorta. This extends the incision from the divided costal margin to the aortic hiatus. Division can be accomplished either radially or circumferentially. Be sure to leave approximately 2 to 3 cm of diaphragm from the internal costal margin to aid in the later closure of diaphragm. The circumferential approach also theoretically minimizes disruption of the phrenic nerve and is generally preferred.

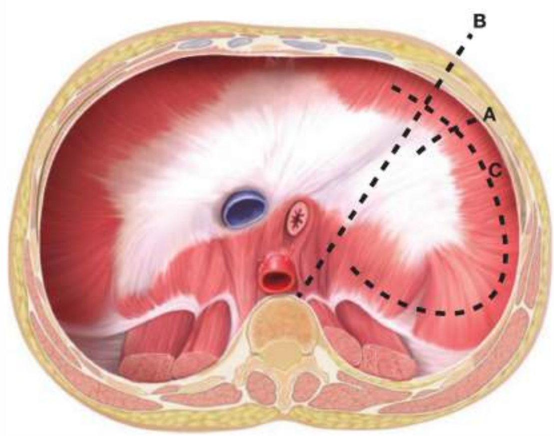

FIG 6 ● Division of the diaphragm.

CLOSURE

- After completion of the core surgical procedure, close the diaphragm.
- Take patient out of flexed position and close the diaphragm with heavy running suture.
- Place chest tubes.
- Reapproximate the interspace with multiple simple or figure-of-eight heavy (no. 1) nonabsorbable suture.
- Close the incision in layers, including the muscle with running Vicryl as well as the deep dermal layer. Close the skin with subcuticular sutures or staples.

PEARLS AND PITFALLS

Indications	■ Preoperative CTA or MRA is mandatory to determine the suitability of the aortic pathology for surgical repair.
Placement of incision	■ The placement of the incision should be carefully considered preoperatively based on imaging and the extent of the pathology. A single thoractomy incision can be placed even if two intercostal spaces need to be entered. To minimize morbidity, begin with a smaller incision because it can always be extended when necessary.
Injury to phrenic	■ A circumferential division of the diaphragm can provide the best exposure while also minimizing the risk of injury to the phrenic nerve.
Closure	■ When carrying out a circumfrential division of the diaphragm, leave 2 to 3 cm of diaphragm from the internal costal margin for the repair of the diaphragm when closing.

POSTOPERATIVE CARE

- Monitor in the surgical intensive care unit as necessary for the extent of the aortic reconstruction required.
- Remove chest tubes when drainage is adequately low.
- Continuous spinal cord protection and neurologic monitoring immediately postoperatively; continue CSF drainage for ~3 days.
- Follow-up imaging with CTA to establish a baseline
- Standard postoperative incision and wound care

OUTCOMES

- It is proposed that pulmonary dysfunction associated with thoracoabdominal aortic surgery is to a large part associated with diaphragmatic dysfunction. Stickley and Giglia[3] recommend a new technique using a gastrointestinal stapler to divide the diaphragm. This technique is proposed to be "rapid, hemostatic, and aids with reapproximation at the completion of the case" and that "this method of diaphragm division is quicker and less traumatic and has the potential to decrease the incidence of postoperative pulmonary dysfunction."
- Huynh et al.[4] conclude that renal failure, spinal cord deficit, and pulmonary complication were the major determinants of length of stay (LOS) in patients for thoracoabdominal aortic aneurysm (TAAA) repair. Their study has shown that the preservation of diaphragmatic function and the use of the adjunct distal aortic perfusion and CSF drainage may reduce hospital LOS.

COMPLICATIONS

- Bleeding; take back
- Phrenic nerve palsy or paralysis
- Diaphragmatic hernia
- Pulmonary complications, respiratory failure
- Wound complications
- Paralysis; spinal cord ischemic injury, associated with thoracoabdominal aortic surgery
- Stroke/transient ischemic attack (TIA), associated with thoracoabdominal aortic surgery
- Multiorgan failure, associated with thoracoabdominal aortic surgery
- Death, associated with thoracoabdominal aortic surgery

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Chapter 15

Retroperitoneal Aortic Exposure

Matthew Mell

IMAGING AND OTHER DIAGNOSTIC STUDIES

General Considerations

- Retroperitoneal aortic exposure may be desirable for a variety of vascular conditions, including abdominal aortic aneurysms, aortoiliac occlusive disease, and mesenteric or left renal artery occlusive disease.
- Retroperitoneal exposure may be preferred for patients with a hostile abdomen from previous intraabdominal infection, surgery, or radiation.
- Compared with transabdominal aortic exposure, retroperitoneal exposure may be associated with shorter postoperative ileus, decreased pulmonary complications, decreased pain, and lower incidence of late complications including small bowel obstruction or aortoenteric fistulae.[1]
- Retroperitoneal aortic exposure can be converted, when necessary, to thoracoabdominal exposure with excellent visualization of the superior mesenteric artery (SMA), left renal artery, celiac axis, and descending thoracic aorta.[2]
- Examination of intraabdominal contents is possible through a retroperitoneal approach by simply opening a peritoneal window as necessary.

Preoperative Imaging

- Prior to aortic reconstruction, detailed anatomic imaging derived from modern, multirow detector computed tomographic arteriography (CTA) will greatly facilitate surgical planning. Image acquisition should extend from the normal proximal aorta to the common femoral artery bifurcations bilaterally. Runoff imaging may also aid decision making depending on clinical circumstances.
- Data derived from submillimeter imaging slices may be readily reformatted into multiplanar and 3-D reconstructions, with excellent resolution of the peripheral mesenteric and renal vasculature.
- Noncontrast images should also be obtained to help assess the degree of mural calcification present in diseased proximal aorta. Recognition of extensive mural calcification may modify the location chosen for clamp placement, or prohibit safe clamping entirely in diseased segments.
- CTA may require larger contrast dose than that required for catheter-based contrast aortography. Contrast volumes required for CTA may be reduced significantly by modifying the field of view or imaging parameters required for the procedure. Consultation with the responsible radiologist will ensure optimal imaging of the necessary arterial anatomy with minimal contrast and radiation exposure.
- Contrast-based aortography, either CT or catheter-based, may be contraindicated for patients with reduced creatinine clearance or an anaphylactic reaction to contrast. Milder allergic responses (hives, rash) may be successfully tempered by premedication with steroids and antihistamines, depending on the relative indication for contrast administration and the patient's overall medical condition. Adverse effects of intravenous or intraarterial contrast administration on creatinine clearance may be partially ameliorated by preprocedural oral or intravenous hydration and administration of N-acetylcysteine (Mucomyst). Although sometimes considered a reasonable alternative under these circumstances, gadolinium-based contrast administration for magnetic resonance arteriographic indications is also contraindicated in patients with a creatinine clearance less than 60 mL per minute. When contrast administration is absolutely out of the question, CT images acquired without contrast may provide adequate anatomic imaging to proceed with surgery, with the caveat that anomalies such as a retroaortic left renal vein may be present and unrecognized until exposed at surgery.

SURGICAL MANAGEMENT

Instrumentation

- In addition to standard vascular instrumentation, additional equipment may aid in exposure of the aorta and its visceral branches from the retroperitoneal approach:
  - Beanbag and airplane for positioning
  - A fully articulated operative table, capable of flex and reflex at the level of the umbilicus
  - Self-retaining, table-mounted retractor (e.g., Bookwalter, Omni, or other)
  - Finochietto chest retractor
  - Nos. 3, 4, and 5 Fogarty occlusion balloons
  - Cold renal perfusion
  - Arterial cannulas for renal perfusion

Positioning

- The patient is placed supine on a beanbag and all lines and tubes are placed. For exposure of the infrarenal aorta and iliac arteries, the left shoulder is lifted and protected with the beanbag and padding. The left arm can be abducted or rotated to the patient's right with a padded airplane retractor for support. The table break and the kidney bar are used to open up the retroperitoneal space between the 12th rib and the iliac crest as the incision is developed. For this reason, it is essential that the patient be positioned with the umbilicus on the table break. An oblique incision is made from below the umbilicus to the tip of the 11th rib. With this location, the incision can be extended into the 10th intercostal space and the chest entered if additional proximal exposure is required (**FIG 1**). When additional iliac artery or pelvic exposure is anticipated, the incision should be initiated distal to the umbilicus. Either way, in patients with considerable

abdominal girth and redundant pannus, landmarks should be confirmed to ensure that the incision is not placed too far distally on the abdomen, as juxtarenal aortic control can be extremely difficult when the incision is placed too far distally on the abdomen.

- For thoracoabdominal exposure, the patient is placed in the right lateral decubitus position using a beanbag and axillary role for support. The left arm is protected with adequate padding and an airplane-type retractor. It is important to secure the left arm such that the scapula rolls anteriorly, providing exposure of the posterior lateral chest. The incision will be made overlying the 8th intercostal space and extended toward the umbilicus.

FIG 1 • Patient position for thoracoabdominal exposure with incision in the 8th intercostal space (dotted line). Positioning is supported with a beanbag and right axillary roll.

- The incision is carried through the external oblique, internal oblique, and transversus abdominis muscles. The retroperitoneal space is then entered laterally near the tip of the 11th rib by identifying the characteristic yellow preperitoneal fat. The retroperitoneal space is then developed from lateral to medial using a sponge stick or hands for blunt dissection. Anteriorly, the peritoneum tends to be more adherent at the level of the rectus sheath; care should be taken to avoid entering the peritoneal cavity in this area. The psoas fascia is encountered as the dissection is developed posteriorly in the course of this dissection, which leads directly to the left iliac vessels and ureter. Dissection is continued proximally anterior to the ureter; the ureter is either left in situ to limit injury or gently retracted medially with silastic slings as the retroperitoneal space is developed.
- Superiorly, the kidney is identified as the dissection is continued anterior to Gerota's fascia—a potential space exists between descending colon and Gerota's fascia in the retroperitoneum, which is progressively developed in a cephalad direction from the psoas muscle, adjacent to the aorta. Once the renal vein is visualized in this space, the superior margin of the dissection is complete. If suprarenal aortic control and exposure is required, this same dissection plane should be developed posterior to the kidney, elevating the kidney and ureters along with the peritoneal contents and retracting all to the right to expose the subdiaphragmatic visceral aorta.
- Self-retaining retractor systems are best deployed either after the psoas muscle is identified or following exposure of the renal vein or elevation of the left kidney. Deploying the retractor system earlier will interfere with the dissection necessary to access the appropriate retrocolic space. Following placement of the initial padded retractor blade along the medial margin of the wound, circumferential retraction is secured by placement of additional blades, typically opposite each other to prevent undue tension on the retraction system, with sequential replacement with deeper blades and additional retraction until the entire periaortic retroperitoneum is exposed.
- The aorta and iliac arteries are then dissected free of surrounding tissue. Circumferential aortic control is an essential safety element of all aortic procedures, and care should be taken to gently and patiently create a space between the inferior vena cava (IVC), aorta, and vertebral bodies posteriorly to pass an umbilical tape around the aorta with a right-angle clamp. Circumferential control of the common iliac arteries, on the other hand, is not necessary in all circumstances. Sufficient medial and lateral dissection to allow for placement of a Wylie hypogastric clamp around the common iliac artery will usually suffice. Avoidance of attempts at circumferential iliac control will reduce the risk of right iliac vein injury. When circumferential control is required, patience is necessary to gradually separate the right common iliac artery from the distal IVC and left common iliac vein. When a venous injury is encountered during this maneuver, division of the common iliac artery may be necessary to gain adequate exposure for control. Alternatively, an occlusion balloon may be introduced from the right common femoral or external iliac veins will tamponade the venous

bleeding until sufficient exposure is gained to repair the wound. Finally, a covered self-expanding endograft may also be deployed over a wire to gain control. Again, readjustment of the retractor system with each consecutive stage of exposure will optimize operative efficiency. Frequently, to optimize distal exposure, the proximal retractor blades need to be temporarily relaxed and vice versa.

- This exposure provides adequate exposure to the infrarenal aorta (and inferior mesenteric artery if reimplantation is anticipated), right and left common and left external iliac arteries. The right external iliac artery is not well visualized from this approach, although tunneling to the right femoral artery is readily achieved for aortofemoral bypass grafting when necessary. Care should be taken to develop the tunnel immediately anterior to the iliac arteries to avoid injury to the right ureter or trapping the ureter between the graft limb and adjacent artery. When right external iliac artery exposure is required during a left retroperitoneal exposure, a counterincision may also be placed in the right lower quadrant, although patient positioning and retractor system placement may limit the potential use of this maneuver.
- For procedures requiring more proximal, visceral aortic exposure, the latissimus dorsi is identified and dissected from surrounding superficial and deep tissues and retracted laterally. The 8th intercostal space is opened posteriorly to the paraspinal muscles and anteriorly to the costal margin, which is divided. As the retroperitoneal space is developed, the peritoneum is bluntly separated from the inferior surface of the diaphragm. The diaphragm is divided in a circumferential manner 1 to 2 cm from its attachments to the chest wall to avoid injury to the phrenic nerve (**FIG 2**). The median arcuate ligament is identified and divided. Proximal aortic control can now be obtained under direct vision, again following strategic placement of self-retaining retractor blades, taking care to identify and avoid injury to the esophagus.

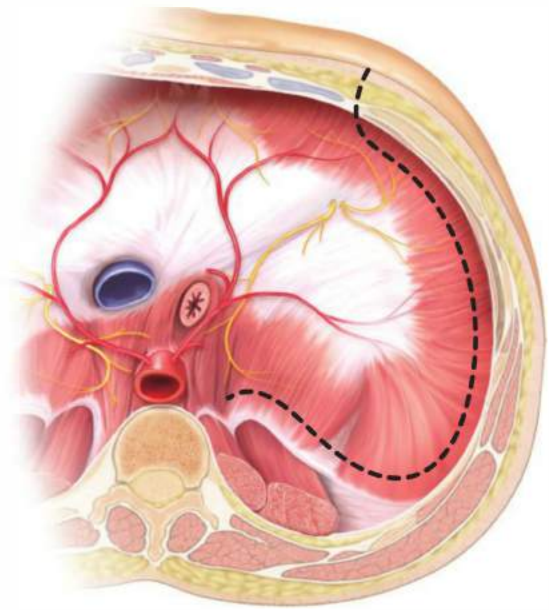

FIG 2 ● The diaphragm is incised circumferentially (dotted line) to protect the phrenic nerve and thereby preserve diaphragmatic function. A one-to two centimeter cuff of diaphragm is left attached to the chest was to aide in closure.

- Dissection of the plane posterior the Gerota's fascia allows for exposure of the left renal artery, which is an important landmark in further dissection of the visceral aorta. Once the origin of the left renal artery is identified and the median arcuate ligament has been divided, the visceral aorta and origins of the celiac axis and SMA can be isolated with sharp dissection. With the left kidney rotated anteriorly, the SMA can be exposed over a distance of approximately 5 cm (**FIG 3**).

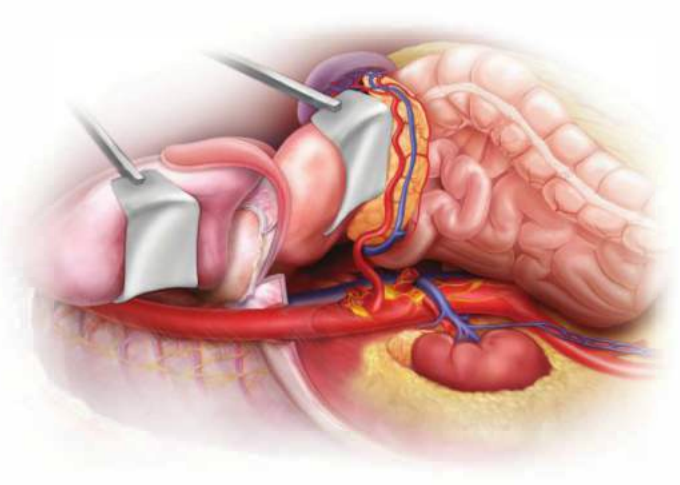

FIG 3 ● Exposure of the visceral aorta with the left kidney lifted to expose the left renal artery and the entire posterior-lateral aorta. Note that the left renal vein rolls off the aorta.

Additional exposure can be obtained by rotating the kidney posterior to expose the SMA as it courses behind the pancreas (**FIG 4**).

- Following vascular repair, the retroperitoneal space should be inspected for hemostasis. The ureter should be inspected, and any suspected injury or leak can be investigated with intravenous methylene blue. If needed, the peritoneum can be opened for inspection of abdominal contents.
- Removing the table break or lowering the kidney bar if used will aid in approximating tissue layers without tension.
- If divided, the diaphragm can be reapproximated with a continuous running absorbable suture. The suture can be secured at the anterior costal margin and will help approximate these structures as well.
- If the thorax was entered, a large-bore chest tube is placed dependently and secured with U stitches.
- A large Blake or Jackson-Pratt drain can be placed in the retroperitoneal space to avoid early postoperative fluid collections.
- The muscular layers are closed with continuous absorbable sutures and the subcutaneous tissue and skin closed with standard techniques.

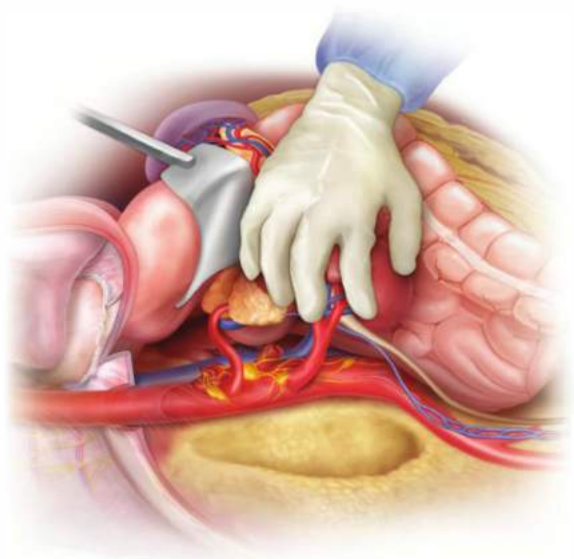

FIG 4 ● Exposure of the visceral aorta with the left kidney left *in situ*. This approach allows for additional exposure of the proximal superior mesenteric artery.

PEARLS AND PITFALLS

- Choosing the most appropriate procedure for any given patient with mesenteric or renal artery occlusive disease is dependent on a multitude of factors, especially with the widespread availability of percutaneous interventions. Open surgical procedures continue to remain an excellent alternative for patients with multivessel disease, with coexisting aortoiliac occlusive or aneurysmal disease, and with disease too extensive to be adequately treated with wire-based techniques. When selecting from the variety of open procedures, patient comorbidity, body habitus and its impact on adequate exposure, quality of the inflow and outflow vessels, and ability to safely clamp vessels should all be taken into consideration. Having a working knowledge of all alternatives is important, as occasionally, intraoperative findings dictate a deviation from the preoperative plan.
- Intraoperative management is similar to that for other abdominal vascular procedures. When the dissection is complete, patients are given heparin at a dose of 100 units/kg prior to clamping vessels, achieving a target activated clotting time (ACT) of 200 to 250 seconds. For cases where renal perfusion is interrupted, 0.25 to 0.5 g/kg of mannitol is given prior to cross-clamping. As soon as possible, the kidney is perfused with 300 to 400 mL of saline cooled to 4°C. This may be done at the renal artery ostium immediately after a renal endarterectomy, or directly into the renal artery at the level of the distal anastomosis. Renal artery cannulas, which come in a variety of sizes, are used for perfusion. Using a size that most closely matches the diameter of the renal vessel assures that the perfusate will go into the kidney and not spill onto the operative field.
- When revascularization is complete, heparin is reversed with protamine while checking for hemostasis. The patency of revascularization may be checked with intraoperative duplex imaging. Confirmation of an adequate endpoint is especially important when endarterectomy has been performed, as intimal flaps may present as a delayed vessel occlusion and end-organ loss.

POSTOPERATIVE CARE

- In addition to the standard postoperative strategies for patients undergoing aortic surgery, including serial hematocrit and hemoglobin, electrolytes, creatinine, and lactic acid, it is important to monitor renal and intestinal function. Patients undergoing renal revascularization commonly have an obligatory diuresis for the first 12 hours after surgery. This phenomenon may be due to residual effects of operative mannitol as well as a response to transient renal ischemia. During this time, urine output is not reflective of the patient's overall volume status, and crystalloid should be given at rates sufficient to maintain central filling pressures. Also, serum creatinine should be serially measured. It is common for the serum creatinine to increase slightly in the first 1 or 2 postoperative days, but increases of more than 20% or 30% warrant further investigation, especially if associated with oliguria. Sudden changes in renal function that are unexplained or unresponsive to corrective measures warrant duplex imaging to determine renal perfusion.

- Patients after mesenteric revascularization often develop hyperactive peristalsis, sometimes while the incision is still open. Under these circumstances, serial examination for bowel sounds in the first 24 hours can provide clues to the continued patency of the revascularization. Serial lactate levels are also checked. Although immediate postoperative lactate levels are elevated, they should return to normal as the patient is warmed and resuscitated. Coagulation parameters may also be elevated initially in response to blood loss and transient hepatic ischemia. These parameters should be monitored and corrected for active bleeding; normal values are usually present by the first postoperative day.

COMPLICATIONS

General Considerations

- As with all aortic surgery, potential complications after visceral artery revascularization include myocardial infarction, respiratory failure, and postoperative bleeding. Additionally, renal failure is always a potential complication during visceral revascularization, although its incidence is low.[3–5] Potential causes of renal failure include generalized hypoperfusion from cardiac dysfunction or hypovolemia, prolonged intraoperative ischemia, or thrombosis of the repair. Progressive or unexpected renal failure should initiate a prompt workup including duplex imaging of the kidneys to identify potentially treatable causes. Thrombosis with absence of flow to the kidney is generally irreversible unless identified immediately.
- Intestinal ischemia is the major concern after mesenteric revascularization. Signs and symptoms may include severe abdominal pain, continued acidosis, and hematochezia. Ischemia may be secondary to vessel or graft thrombosis or may result from distal embolization during or following the repair. Patients with evidence of peritonitis should be promptly reexplored, and those treated initially for acute mesenteric ischemia should have a planned second look at 12 to 24 hours if there was any question of intestinal viability at the time of the original operation. Arterial duplex may confirm the viability of the repair but cannot rule out embolization as a cause for postoperative intestinal ischemia. At exploration, nonviable intestine can be resected, and issues with the revascularization can be addressed.

Graft or Vessel Twisting or Kinking

- When performing a bypass to the SMA, it is important to retract the mesentery in a caudal direction to adequately assess graft length. Inadequate positioning will result in excessive graft length and potential kinking and thrombosis once the peritoneal contents are reduced to the abdomen and the incision is closed. Additionally, for retrograde bypass, the graft should be placed with enough slack to allow the distal endpoint to be in-line with the SMA with caudal retraction of the intestines. This positioning will prevent both kinking of the graft and tenting and narrowing of the anastomosis. Bypass to the renal arteries should similarly be constructed with appropriate graft length as it will lay in the retroperitoneum after retraction is released. For cases of arterial reimplantation, it is important to maintain orientation of the target vessel to prevent twisting during construction of the anastomosis. Additionally, the anastomotic site should be chosen in a similar coronal plane to prevent kinking once the end organs assume their natural position.

Injury during Endarterectomy

- Identifying the appropriate endarterectomy plane is usually straightforward in the aorta, renal arteries, and SMA. The celiac artery can be challenging, as it may be thin-walled, and plaque removal may injure the arterial wall. Limited injuries can be repaired with interrupted 4-0 or 5-0 Prolene sutures supported with Teflon pledgets, but larger injuries or those with severely attenuated vessel walls may not be successfully repaired with this technique. If the integrity of the artery is in doubt, it may be safer to transect it and perform a bypass from the aorta to the transected celiac artery using an 8-mm or 10-mm graft. The celiac artery stump can be oversewn with pledgeted 3-0 Prolene suture placed into healthy aorta. Unacceptable endpoints after renal endarterectomy are best treated with conversion to a bypass.

Inadequate Distal Endarterectomy Endpoint

- Plaque extending to the infrapancreatic SMA may be difficult to entirely remove with standard thoracoabdominal exposure. Intraoperative duplex can confirm an adequate endpoint, and if there is any uncertainty, the abdominal cavity can be entered and the SMA exposed by dividing the ligament of Treitz. This maneuver will provide exposure of the SMA as it emerges from behind the pancreas, usually at a place distal to the diseased segment. Inspection by palpation or with duplex ultrasound can evaluate the repair. Incomplete endarterectomy or intimal flaps can be managed through an arteriotomy at this location. A reasonably sized SMA can be transected and the retained plaque removed; reapproximation with interrupted sutures will secure the intima distal to the endarterectomy. Exposing the endpoint in a smaller vessel is most safely performed with a lateral arteriotomy and subsequent patch angioplasty closure to prevent narrowing.
- Problematic endarterectomy endpoints in the celiac artery or renal arteries may be best managed with placement of a bypass graft. Conversion to bypass will require enough exposure of the target vessel to allow for revascularization distal to the diseased segment. Either end-to-end or end-to-side reconstruction is acceptable and should be performed, making certain that the intima is secured with the suture line.

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Chapter 16

Hybrid Revascularization Strategies for Visceral/Renal Arteries

Benjamin W. Starnes

DEFINITION

- The term "hybrid" in vascular surgery traditionally refers to the use of *both* traditional open surgical and endovascular techniques for remedy of the vascular condition (**FIG 1**).
- Two hybrid approaches are described in this chapter.
  - Complete visceral debranching and endovascular tube graft repair
  - Partial visceral debranching and physician-modified fenestrated endovascular repair

DIFFERENTIAL DIAGNOSIS

- Paravisceral aortic aneurysms may develop due to the following conditions:
  - Degenerative aneurysm
  - Aortic dissection
  - Mycotic aneurysm
  - Paraanastomotic juxtarenal aneurysm
  - Connective tissue disorders (Marfan's syndrome)
  - Behçet syndrome

PATIENT HISTORY AND PHYSICAL FINDINGS

- The majority of patients are asymptomatic and the diagnosis is made with imaging done for other reasons. Some patients will complain of mild to moderate abdominal and low back pain. Severe and unrelenting pain should raise the index of suspicion for a mycotic process which, if confirmed, would make hybrid approaches prohibitive.

IMAGING AND OTHER DIAGNOSTIC STUDIES

- Contrast-enhanced, axial thin-slice computed tomography arteriography (CTA) is the current standard for imaging paravisceral aneurysms. Detailed information can be gathered regarding the precise origin of the celiac, superior mesenteric artery (SMA), and renal arteries (**FIG 2**).
- Other important findings on CTA should be as follows:
  - Size and quality of access vessels for delivery of endovascular devices (>7 mm)
  - Location of left renal vein
  - Aberrant anatomy (e.g., replaced right hepatic artery)
  - Quality of gastroduodenal artery for possible celiac artery ligation or sacrifice
  - Renal cortical thickness

SURGICAL MANAGEMENT

- Indications for repair include aortic aneurysms of more than 5.5 cm, symptoms, or evidence of rapid expansion (>0.5 cm per 6 months).

Preoperative Planning

- As formal open repair would often include a bicavitary incision (chest and abdomen, as in a formal thoracoabdominal repair), the standard preoperative assessment should focus on the patient's fitness to undergo major vascular surgery. This includes assessment of heart, lung, and kidney function and reserve.

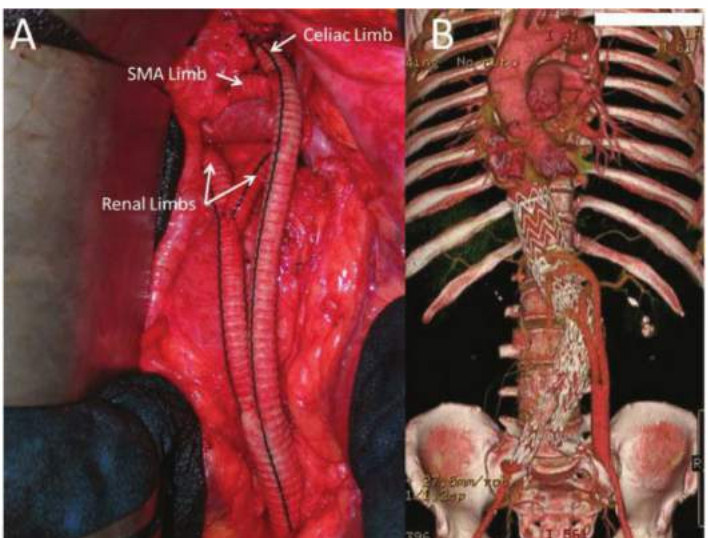

FIG 1 ● "Hybrid repair" refers to the use of both traditional open surgical and endovascular techniques to manage the same problem. SMA, superior mesenteric artery. **A.** Intraoperative photo. **B.** Post operative CTA after completed repair.

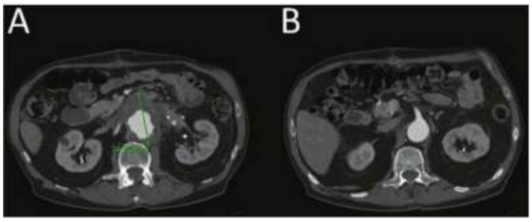

FIG 2 ● CTA axial images depicting **(A)** a 7.4-cm paraanastomotic juxtarenal aortic aneurysm and **(B)** a healthy aortic segment in the region of the SMA.

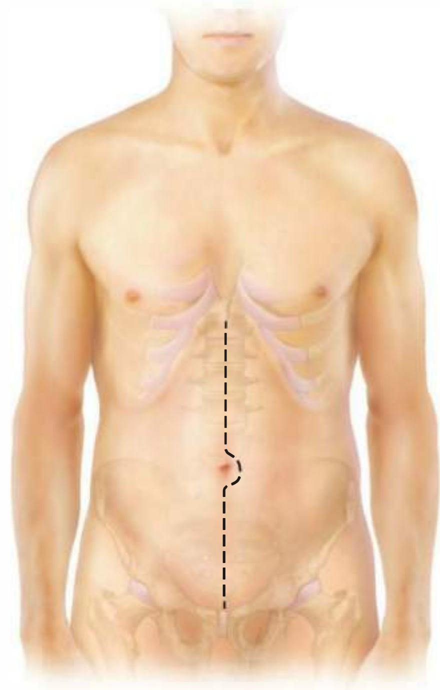

FIG 3 ● Depiction of positioning and intended incision in the midline.

Positioning

- Proper and precise positioning should be as follows (**FIG 3**):
  - Patient supine on standard operating room table or imaging table
  - Hair properly clipped over entire abdomen and both groins
  - Both arms tucked (option to have right arm at 90 degrees if planning brachial access)
  - Foley under one leg and padded

COMPLETE VISCERAL DEBRANCHING AND ENDOVASCULAR TUBE GRAFT REPAIR—STAGE 1

First Step—Exposure

- Standard midline laparotomy and positioning of retractor system
- Upon entry into the abdomen, the falciform ligament is divided between clamps and ligated. The triangular ligaments above the liver are divided to facilitate adequate exposure/retraction while minimizing risk of hepatic capsular injury, anticipating systemic anticoagulation later in the procedure.
- A nasogastric tube is positioned in the stomach to provide temporary decompression. The common hepatic artery is identified following division of the gastrohepatic ligament and traced back to origin of celiac artery. Once identified, the target artery is encircled with a silastic vessel loop. Space is created along the left side of the aorta with blunt/finger dissection, beginning at the level of the celiac artery, to create the retrograde bypass tunnel posterior to the pancreas (**FIG 4**).
- The colon and omentum are lifted in a cephalad direction, the small bowel swept to the patient's right and packed in moist towels. Self-retaining retractors (Omni or Bookwalter) should be positioned at this juncture to maintain exposure, with care taken to appropriately pad the retractor blades as necessary.
- The third and fourth portions of the duodenum are mobilized to the right following division of the ligament of Treitz, exposing the anterior surface of the aorta. The inferior mesenteric vein is ligated and divided as well and the dissection continued along the proximal aorta until the left renal vein is clearly identified (**FIG 5**).
- Widely mobilize the left renal vein sharply and encircle with a moist umbilical tape. The self-retaining renal vein retractor blade is used to retract the left renal vein cephalad as necessary to facilitate further exposure.
- The origin of the renal arteries is identified by careful posterolateral dissection around the aorta, just cephalad of the overlying renal vein. Exposure on the right is complicated somewhat by the overlying inferior vena cava/left renal vein confluence. At least 2 cm of renal artery should be exposed bilaterally. Encircle the renal arteries with silastic vessel loops. On the left, finger dissect bluntly along the aorta in a cephalad fashion to complete the retropancreatic tunnel for the celiac limb of the bypass graft.
- The SMA is identified next by palpation within the base of the small bowel mesentery, directly anterior to the pancreas. Doppler ultrasonography may assist identification when the pulse is faint. Once identified, a 3-cm segment of SMA is isolated as proximal as possible to the root of the mesentery. Beginning with the middle colic artery, multiple mesenteric arteries quickly branch from the SMA as it emerges from the pancreas, underscoring the need for proximal identification and isolation. The SMA is controlled with vessel loops.

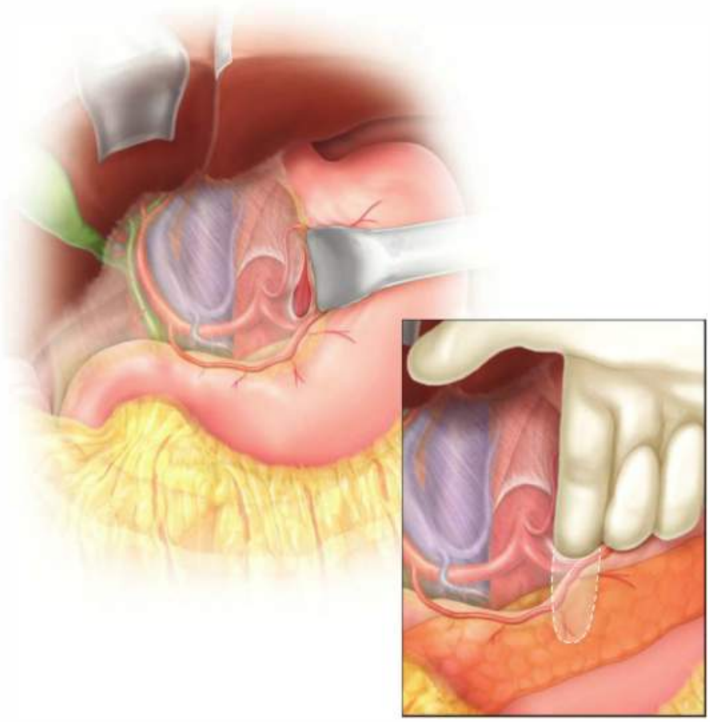

FIG 4 ● Drawing of exposure of the celiac artery through the lesser sac. Note the blunt finger dissection along the left side of the aorta and behind the pancreas.

- The next step is to prepare the donor artery for hybrid bypass. The specific artery—most commonly the common or external iliac arteries—should be selected from the preoperative imaging study. The retroperitoneum is opened directly over the selected donor artery, which is exposed while protecting the adjacent ureter. Alternatively, donor artery exposure may be achieved via medial-visceral rotation, developing the entire retroperitoneal plane on the left. The latter approach provides the added benefit of exclusion of the graft from the viscera and abdominal contents once the viscera are returned to their original position. This maneuver adds significantly more time to

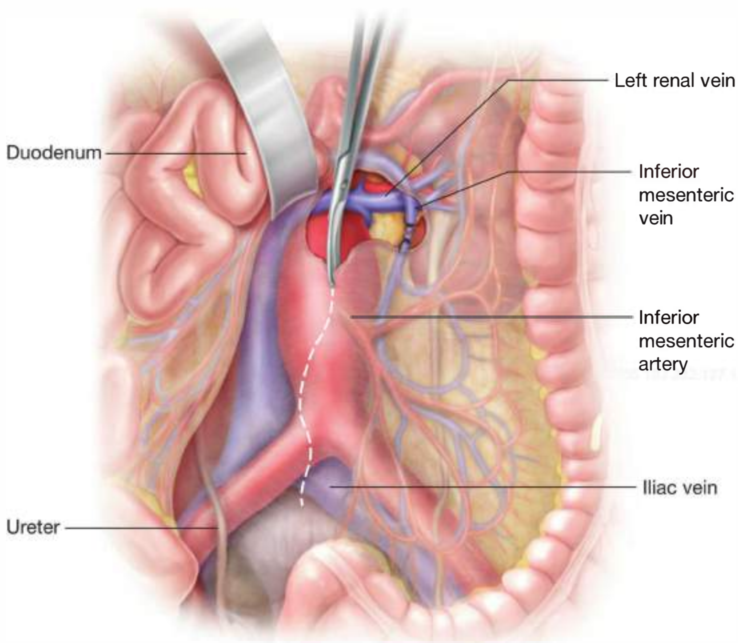

FIG 5 ● Drawing of exposure of the left renal vein and anterior surface of the aortic aneurysm. Dashed line depicts intended incision line to avoid nervi erigentes.

the case, however, and contributes to increased blood loss. Graft coverage can also be obtained without developing the entire retroperitoneal plane, either via direct tunneling along the preferred course of the graft or creation of an omental tongue affixed directly to the graft.

Second Step—Anticoagulation

- Systemic anticoagulation is achieved with a bolus injection of unfractionated heparin, 50 units/kg. Monitoring activated clotting time is a useful method of maintaining adequate anticoagulation during the procedure.

Third Step—Multivisceral Bypass

- Trifurcated grafts exist for the purpose of facilitating multivessel hybrid revascularization, but the use of these are limited by the tendency of the middle limb to occlude when "squeezed" between the outside limbs during graft routing and abdominal closure. In most circumstances, a standard 12 × 7 bifurcated, collagen-impregnated knitted polyester graft provides excellent conduits for bilateral renal revascularization, with a separate 8-mm limb connected to the celiac and SMA. Examples of bypass graft configurations are shown in **FIGS 6** and **7**.
- The proximal (iliac/inflow) anastomosis is completed first with running 4-0 or 5-0 polypropylene suture.
- The next anastomosis to be completed should be one anticipated to be the technically most difficult, given exposure and graft routing issues. Most commonly, this is the right renal artery. This is divided following placement of a large clip at the origin. The appropriate graft limb is pulled to length and anastomosed end-to-end with 5-0 polypropylene suture. The limb and artery are flushed just prior to completion of the graft, after which the clamps are released to reperfuse the kidney. Following this sequence, warm renal ischemia time is generally less than 12 minutes. The stump of the right renal artery is then suture ligated; avoid clip dislodgement. Note: Excessive traction on the confluence of the left renal vein and vena cava may cause caval injury and massive hemorrhage during preparation and completion of the right renal artery anastomosis. Retractor positioning needs to account for potential venous injury during exposure and significantly relaxed following completion of the anastomosis.

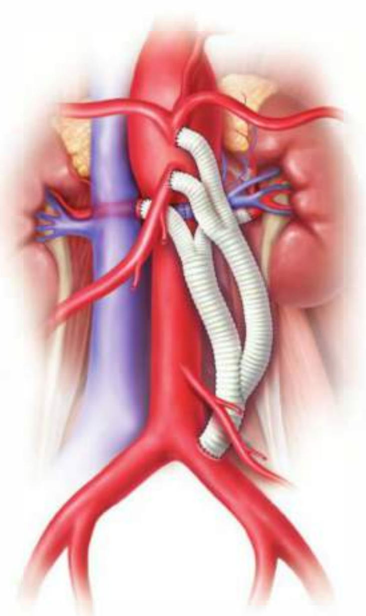

FIG 6 ● Drawing of a four-vessel debranching based off of the left common iliac artery. Note that the left renal vein was divided in this case, and subsequently repaired, for better exposure of the renal arteries.

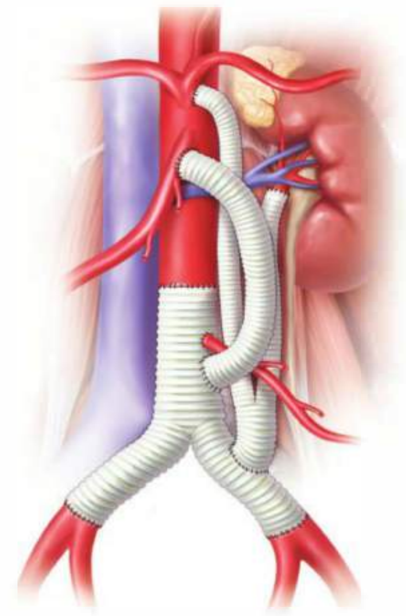

FIG 7 ● Aortobiiliac and subsequent debranching for a patient with a solitary left kidney and infrarenal aneurysm.

- The left renal anastomosis is completed in nearly identical fashion, minus many of the exposure limitations present on the right.
- The SMA graft is carefully sized to length so that it follows a "C"-shaped configuration without kinking. Inflow can be obtained either from the many bodies of the graft or either of the completed renal limbs. The SMA-graft anastomosis is completed end-to-side with interrupted or running 5-0 polypropylene suture. The end-to-side arteriotomy length is 1.5 to 2 times the width of the bypass graft (12 to 16 mm). Alternatively, end-to-end anastomotic configuration may reduce the likelihood of graft kinking depending on final configuration. Following completion of the anastomosis, the proximal SMA is ligated with a large clip or circumference suture. Again, ischemia time should be under 10 to 12 minutes.
- Typically, following SMA and renal graft completion, repositioning of the retraction system is necessary to reobtain and optimize celiac artery exposure. Prior to reexposing

the celiac, a vascular clamp is repassed through the retropancreatic tunnel left of the aorta. This position is then maintained until the transverse colon and mesocolon are reduced to their usual location. This reexposes the "looped" celiac and common hepatic arteries previously isolated in the lesser sac. The clamp tip exiting the retrohepatic tunnel is identified, and a moist umbilical tape is pulled through the tunnel. Following this, the celiac limb is tied to the umbilical tape, which is then pulled cephalad behind the pancreas and into position for either end-to-end or end-to-side anastomosis. Care again needs to be taken to optimize limb routing and length to minimize risk for kinking.

- After coverage of remaining exposed graft limbs with omentum or parietal peritoneum as appropriate, standard abdominal closure is performed.

COMPLETE VISCERAL DEBRANCHING AND ENDOVASCULAR TUBE GRAFT REPAIR—STAGE 2

First Step—Percutaneous Access

- Following the "debranching" procedure described in stage 1, endovascular aneurysm repair (EVAR) may be performed either at the same setting or within several weeks of the initial procedure. The risk of potential aneurysm rupture associated with a staged approach needs to be balanced with the additional operative risk inherent in the longer anesthetic time required to complete both stages in one sitting. For the EVAR procedure itself, standard percutaneous access to an appropriately sized access vessel is obtained using Seldinger technique and a wire advanced into the aorta under fluoroscopic guidance. In our practice, this is most commonly obtained percutaneously, using ultrasound guidance and preplacement of polypropylene suture prior to dilation of the access sites (also known as the "preclose" Perclose® technique (Abbott Vascular Inc, Redwood City, CA).[1] An 11-Fr standard sheath is placed into the common femoral artery and flushed with heparinized saline. Wire advancement from the femoral artery to the aortic arch must be visualized radiographically throughout its course, as the wire may preferentially enter the debranching graft and cause end-organ injury or hemorrhage without real-time position monitoring and guidance.

Second Step—Stiff Wire Exchange

- After wire advancement to the transverse aortic arch, standard wire exchange technique is used to position a 0.035-in stiff (e.g., Lunderquist®, Cook Medical, Bloomington, IN) wire through the abdominal and thoracic aorta. Optimal final wire positioning is at/just distal to the left subclavian artery orifice.

Third Step—Intravascular Ultrasound

- An 8.2-Fr Visions® catheter (Volcano Therapeutics, Irvine, CA) is used to confirm appropriate proximal and distal landing zones for endovascular graft placement. The optimal graft size and configuration is determined by analysis of CTA images reformatted and visualized on a dedicated 3-D image workstation (AquariusNet®, TeraRecon, Inc, San Mateo, CA). Graft diameter should be oversized by 10% to 15% for this application.
- During advancement of the device, the origin of the debranching graft can also be visualized either through fluoroscopic confirmation of a metallic clip placed during the debranching procedure or under intravascular ultrasound (IVUS) real-time guidance. Using IVUS, the position of the IVUS catheter is marked on the fluoroscopic monitor when the catheter itself recognizes the orifice of the debranched graft. Alternatively, a contrast power injection can be performed through an appropriately positioned arteriographic catheter with 30 mL of contrast injected at 15 mL per second to confirm the proximal and distal landing zones.

Fourth Step—Endograft Deployment

- The endovascular graft is deployed following device-specific instructions for use (IFU), covering the native origins of the visceral vessels and excluding the aortic aneurysm. The femoral arteriotomy is then closed.

PARTIAL VISCERAL DEBRANCHING AND PHYSICIAN-MODIFIED ENDOVASCULAR REPAIR—STAGE 1

First Step—Exposure

- Standard midline laparotomy and positioning of retractor system.
- Upon entry into the abdomen, the falciform ligament is divided between clamps and ligated. The triangular ligaments above the liver are divided to facilitate adequate exposure/retraction while minimizing risk of hepatic capsular injury, anticipating systemic anticoagulation later in the procedure.
- A nasogastric tube is positioned in the stomach to provide temporary decompression. The common hepatic artery is identified following division of the gastrohepatic ligament and traced back to origin of celiac artery. Once identified, the target artery is encircled with a silastic vessel loop. Space is created along the left side of the aorta with blunt/finger dissection, beginning at the level of the celiac artery, to create the retrograde bypass tunnel posterior to the pancreas.
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- The next anastomosis to be completed should be one anticipated to be the technically most difficult, given exposure and graft routing issues. Most commonly, this is the right renal artery. This is divided following placement of a large clip at the origin. The appropriate graft limb is pulled to length and anastomosed end-to-end with 5-0 polypropylene suture. The limb and artery are flushed just prior to completion of the graft, after which the clamps are released to reperfuse the kidney. Following this sequence, warm renal ischemia time is generally less than 12 minutes. The stump of the right renal artery is then suture ligated; avoid clip dislodgement. Note: Excessive traction on the confluence of the left renal vein and vena cava may cause caval injury and massive hemorrhage during preparation and completion of the right renal artery anastomosis. Retractor positioning needs to account for potential venous injury during exposure and significantly relaxed following completion of the anastomosis.
- The renal anastomosis is completed in nearly identical fashion, minus many of the exposure limitations present on the right.

PARTIAL VISCERAL DEBRANCHING AND PHYSICIAN-MODIFIED ENDOVASCULAR REPAIR—STAGE 2[2]

First Step—Creation of a Fenestrated Graft for the Celiac and Superior Mesenteric Artery

- The appropriate endovascular device is chosen according to standard IFU sizing guidelines, typically incorporating 10% to 15% oversizing. The sterile graft is unsheathed on a dedicated sterile table in the operating room and marked with the relative locations (length from proximal end and clockface measurements) of the celiac and SMA fenestrations as previously determined via TeraRecon® workstation analysis. Minor adjustments are allowed to minimize strut overlap of planned fenestration locations. Fenestrations in the polyester endograft fabric are created with a disposable ophthalmic cautery to minimize fraying. The fenestrations are outlined and reinforced with 15-mm gold Amplatz Gooseneck®

FIG 8 ● Photograph of a thoracic endograft with two fenestrations created for the celiac (struts present) and SMA (strut free), prior to resheathing and deployment.

snares (ev3 Endovascular, Inc, Plymouth, MN). These are hand sewn into place using 4-0 Prolene suture in a double row circumferentially (FIG 8). Diameter-reducing ties were then used to constrain the device along its posterior border (opposite the SMA and or celiac fenestration at 6 o'clock) by rerouting the existing proximal trigger wire through and through the graft material at the midportion of each of the top two Z stents. The constraining ties are then tied down into place over the trigger wire. The entire graft is then wetted with heparinized saline and then reloaded into the existing sheath.

Second Step—Percutaneous Access

- Standard percutaneous access to an appropriately sized access vessel is obtained using Seldinger technique. The initial guidewire is advanced into the aorta under fluoroscopic guidance. In our practice, this is most commonly obtained percutaneously, using ultrasound guidance and preplacement of polypropylene suture prior to dilation of the access sites (also known as the "preclose" Perclose® technique (Abbott Vascular Inc, Redwood City, CA).[1] An 11-Fr standard sheath is placed into the common femoral artery and flushed with heparinized saline. Wire advancement from the femoral artery to the aortic arch must be visualized radiographically throughout its course, as the wire may preferentially enter the debranching graft and cause end-organ renal injury, rupture of Gerota's fascia, and retroperitoneal hemorrhage without real-time position monitoring and guidance.

Third Step—Stiff Wire Exchange

- A standard 4- or 5-Fr catheter is used to perform a wire exchange to a stiff 0.035-in Lunderquist® wire (Cook Medical, Bloomington, IN). The wire is positioned so that its tip is just distal to the left subclavian artery.

Fourth Step—Marking of the Target Vessels and Graft Deployment

- A contrast power injection can be performed with 10 mL of contrast injected at 25 mL per second to mark the precise origins of the celiac and SMA (FIG 9). The modified graft is positioned over the target vessels, oriented, and deployed.

Fifth Step—Cannulation of the Target Vessels

- An 18-Fr sheath is advanced from the contralateral groin and into the distal graft over a stiff wire. Two

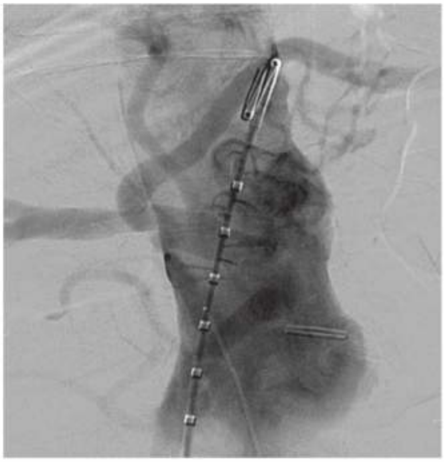

FIG 9 ● Note the double densities depicting the origins of the celiac and SMA on this flush aortogram.

7-Fr Raabe® sheaths (Cook Medical, Bloomington, IN) are advanced together through the 18-Fr sheath. Working through these sheaths, the SMA and celiac vessels are selected through the fenestrations using standard catheter and guidewire techniques, with the sheaths ultimately advanced into the target vessels over stiff wires.
- After sheath advancement and confirmation of target vessel acquisition, the main body is distended flush with the surrounding aorta with a moulding balloon (e.g., Coda®, Cook Medical, Bloomington, IN). This inflation represents the final opportunity to distend the endograft in the region of the visceral stents. Lateral positioning of the image intensifier guides stent placement into the SMA and celiac arteries (typically 8- to 9-mm stents; FIG 10). FIG 11 shows follow-up computed tomography (CT) imaging of a patient 1 year after successful treatment with this technique.

Sixth Step—Access Site Closure

- The access sites are closed with the previously placed sutures.

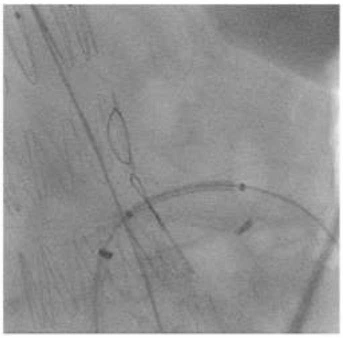

FIG 10 ● Lateral image depicting placement of a covered balloon-expandable stent into the SMA prior to deployment.

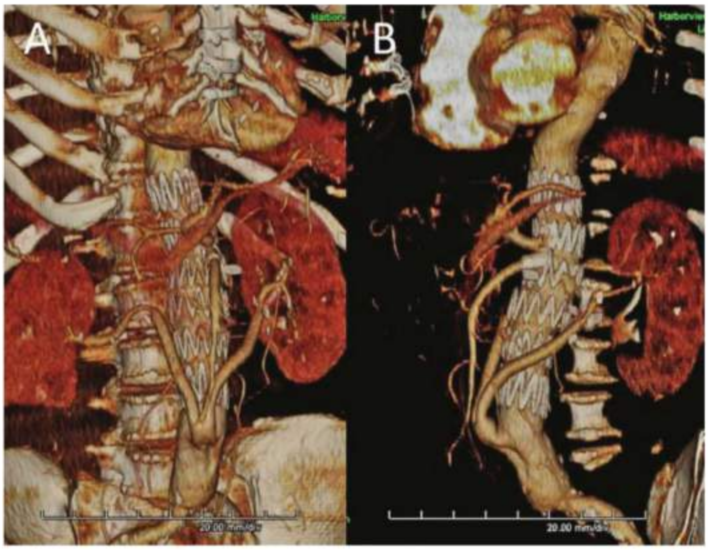

FIG 11 ● **A,B.** Follow-up CT images of a patient successfully treated with partial visceral debranching and physician-modified endovascular fenestrated repair.

PEARLS AND PITFALLS

Choice of operating room (OR) table	■ Use standard OR tables for open surgical procedures and imaging tables for image-guided or hybrid procedures. Advanced planning is essential to optimize outcome. Never sacrifice exposure!
Exposure of common iliac artery	■ Identify and protect the ureter.
Placement of wires after debranching procedure	■ Pass guidewires under continuous fluoroscopic guidance following debranching. An advancing aortic wire may preferentially enter and traverse the debranching graft, causing end-organ injury, disorientation, and possible endograft maldeployment if not recognized.
Timing of stent graft balloon moulding during fenestrated EVAR	■ Always seat the endograft with balloon inflation prior to placement of visceral bridging stents. Instrumentation or distention of the fenestrated endograft following branch vessel stenting may compromise stent positioning, integrity, and patency.

POSTOPERATIVE CARE

- Open aortic debranching procedures are not benign; almost all patients will require intensive care postprocedure. Spinal drainage is used selectively for aortic coverage extending more than 10 cm cephalad to the celiac artery. Postoperative anuria or persistent acidosis/rising lactate require immediate investigation to prove branch vessel patency.

OUTCOMES

- Contemporary hybrid debranching procedures for complex abdominal aortic aneurysmal disease are associated with a 13% operative mortality rate, 2% permanent paraplegia rate, and 1% stroke rate.[3]
- Hybrid approaches offer the advantage of versatility, avoidance of extensive operative exposures, and potentially offer a broader range of therapies to a patient population that would not otherwise be considered for aortic surgical repair.

COMPLICATIONS

- Access-related complications
- Hemorrhage requiring transfusion
- Paraplegia
- Stroke
- Renal failure
- Death

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Chapter 17

Snorkel/Chimney and Periscope Visceral Revascularization during Complex Endovascular Aneurysm Repair

Jason T. Lee   Ronald L. Dalman

DEFINITION

- Although routine endovascular aneurysm repair (EVAR) has gained widespread acceptance as the procedure of choice for patients with suitable aortic neck anatomy, the optimal approach to the juxtarenal aortic aneurysm (JAA), often with challenging anatomy at the visceral neck, remains controversial.[1] Although open repair is an effective and durable option for patients with JAA, particularly in centers of excellence for low physiologic risk patients,[2] endovascular techniques including fenestrated and branched EVAR (FBE) have emerged as effective, potentially less invasive alternatives.[3]
- In the United States, however, lack of widespread availability of FBE has allowed other techniques to emerge, and in this chapter, we describe the increasingly popular "snorkel" or "chimney" technique, defined as a parallel stent graft adjacent to the endograft main body to maintain perfusion to renal and visceral branches during EVAR and placed from a cranial direction, and the "periscope" technique, where the parallel stent graft is placed from the caudal direction.
- First described by Greenberg and associates,[4] the snorkel strategy can be employed either as a bailout from accidental coverage of vital side branches during deployments requiring close approximation of the main body to the branch artery in question, or the intentional cranial relocation of the EVAR seal zone for JAAs.[5–8]

DIFFERENTIAL DIAGNOSIS

- The challenge for the vascular specialist in treating JAAs revolves around an increasing number of choices for intervention, including traditional suprarenal repair, hybrid type debranching procedures, fenestrated and branched devices in clinical trials or certain centers, and snorkel/chimney/periscope techniques. The choice is most often based on patient physiologic parameters, physician experience with the multitude of techniques, and a very individualized approach to complex aortic anatomy.

PATIENT HISTORY AND PHYSICAL FINDINGS

- Most patients present electively and essentially without symptoms for consideration of repair of their JAA, as it is most often discovered during radiographic workup for vague abdominal discomfort, back pain, or as part of a screening program. A pulsatile, nontender abdominal mass can be elicited on careful abdominal exam. Any signs of persistent abdominal or back pain or hemodynamic instability or compromise should suggest the possibility of an acute aortic pathology and prompt more urgent workup and treatment. Careful attention during the history and physical examination to cardiac and renal comorbidities aids in risk-stratifying the patient for potential repair of their JAA. Because most patients are asymptomatic and aneurysms are repaired to prevent future rupture, some reasonable quality of life must be present for the patient to enjoy the survival advantage.

IMAGING AND OTHER DIAGNOSTIC STUDIES

- High-quality computed tomography angiography (CT-A) on a modern 64-slice scanner able to produce at least 2-mm–thin cuts is a requirement for treatment with snorkel techniques. These imaging algorithms allow the creation of virtual models of the aneurysm for the surgeon to better appreciate the relationship of branches and potential areas of technical challenge (**FIG 1**). Patients with compromised kidney function who cannot undertake iodinated contrast are poor candidates for snorkel procedures, as noncontrast scans fail to elucidate thrombus volume, branch artery patency, and luminal diameter in the preoperative planning that is paramount to success.
- Access to a three-dimensional (3-D) workstation/program and familiarity with reconstruction software by the implanting surgeon for manipulation of the images and creating centerline pathways should be mandatory to most accurately plan device orientation, selection, and sizing (**FIG 2**).
- Because the snorkel technique usually involves access of the brachial artery for delivery of the parallel visceral stent grafts, visualization of the arch and proximal subclavian is

FIG 1 ● 3-D reconstruction of juxtarenal aneurysm with infrarenal neck length of 5 mm.

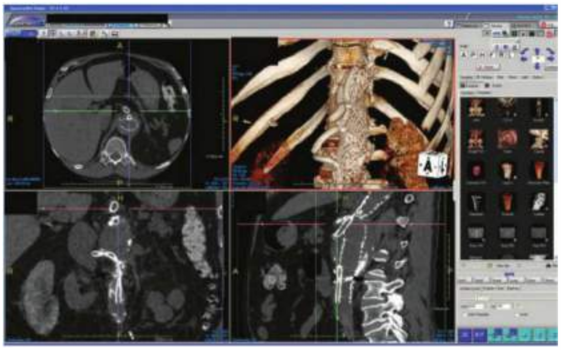

FIG 2 ● TeraRecon workstation view highlighting ability to manipulate images in multiple user-defined planes.

most conveniently obtained by including the chest in the standard CT-A of the abdomen and pelvis. The presence of a challenging type III arch, where the subclavian inserts below the inner curve of the aortic arch, makes the procedure more challenging and many times prohibitive due to concerns about arch manipulation, cerebral emboli, and deliverability of stent grafts (**FIG 3**). If the patient has already undergone an adequate CT-A abdomen and pelvis and one wishes to avoid the additional contrast load of repeating the study, a noncontrast chest computed tomography (CT) can be performed to visualize the arch but then should be combined with arterial duplex and waveforms of the upper extremities to ensure patency of the axillosubclavian arterial system.

- For patients with chronic kidney disease, high-grade renal stenosis, atretic kidneys, or multiple visceral and renal vessels involved in the endovascular plan for snorkeling, nuclear medicine split renal function tests can help determine if it is reasonable to sacrifice one of the renal arteries. This can be done in order to simplify the snorkel strategy and keep the number of cranially oriented stent grafts to two, which may have an influence on overall morbidity and mortality from the procedure.[1,7,8]

FIG 3 ● Type III aortic arch with origin of subclavian artery being lower than inner curve of aortic arch. The ability to advance a snorkel sheath from the left arm is severely compromised in this configuration and generally not recommended if alternative repair methods are available.

SURGICAL MANAGEMENT

Preoperative Planning

- All patients considered for snorkel/chimney or periscope techniques should have undergone an extensive informed consent discussion related to off-label use of endograft components for treatment of their complex aneurysm. Alternatives often discussed include open surgery with suprarenal clamping, hybrid debranching, referral to a center with access to fenestrated or branched devices, or no surgery at all. Once the decision is made to proceed with the snorkel strategy, we prefer a two-surgeon approach with one performing the femoral access portion and one the brachial access portion. Both surgeons should have reviewed on the 3-D workstation the anatomy, the endovascular plan, and the sequence for deployment.
- Access to a hybrid endovascular suite is highly recommended, although not mandatory, for successful completion of these procedures. Fixed imaging provides improved accuracy, reliability, and reproducibility of the anatomy throughout the sequence of the snorkel procedure. Knowledgeable operating room and cath-angio staff should be assigned to these cases and available endografts and wires/catheters as well as backups should all be arranged ahead of time to provide the safest working environment for the patient as well as the operative team.
- Choosing the main body endograft, its configuration, and size has been described by numerous authors who all report excellent results overall with a wide variety of devices and formulas.[9] In general, we often "oversized" to about 25% to 30% instead of the typical 15% to 20% for standard EVAR to account for the additional fabric infolding to accommodate the snorkel stent(s).
- Given the amount of dye often used as well as renal artery manipulation during the most complex of snorkel cases, we prefer to admit the patient the evening before or several hours prior to surgery for additional intravenous hydration when possible.
- General anesthesia is preferred, with consideration for preoperative lumbar drainage based on risk of spinal cord ischemia. Arterial monitoring, when necessary, is achieved via the right arm. Adequate venous access can consist of either large-bore peripheral intravenous lines (IVs) or a central line. There is usually not a need for autotransfusion or cell saver setups unless an iliac or axillary conduit is planned where there is more potential for early blood loss during the procedure.

Positioning

- The hybrid room can be set up as either "head" position (**FIG 4**) or "right side, table rotated" depending on the type of imaging equipment. With the right arm tucked, the left arm is prepped circumferentially and placed on an armboard at about 75 to 90 degrees while the chest and abdomen down to the groins are prepped. Surgeon A, who will stand at the patient's right hip, has control of the C-arm and imaging functions and is in charge of obtaining femoral access and delivery of devices from the groins. Surgeon B stands above the outstretched left arm, with an additional sterile table extending off the left hand to allow for wires and catheters to remain sterile and available for arm access during the procedure. The monitor is placed at a slight angle toward the foot of the bed to allow both surgeons to visualize, or a slave monitor can be employed.

FIG 4 ● Endovascular suite setup for snorkel/chimney EVAR with left arm prepped and outstretched, C-arm at right-sided/table rotated position to allow for lateral imaging, and monitors at foot of bed. Surgeon A stands at patient's right hip and controls C-arm. Surgeon B stands above patient's left arm to deliver wires and catheters from side table.

SNORKEL/CHIMNEY ENDOVASCULAR ANEURYSM REPAIR

Arm Access

- A 5-cm transverse incision slightly below the left axilla over the palpable brachial pulse affords several centimeters of longitudinal exposure of the high brachial artery (FIG 5A). Staying proximal to the deep brachial artery takeoff allows a large enough caliber of brachial artery for typical delivery of two 7-Fr sheaths for a double renal snorkel procedure. At least 7 to 8 cm of healthy brachial artery should be dissected free and slung with vessel loops to allow accurate puncture of the vessel. The two punctures should be placed at least 2 cm apart, and not next to each other, to facilitate later simpler, individual primary closure.
- For cases when larger delivery sheaths may need to be inserted or in cases where potentially up to three or four snorkel stents need delivery, then an infraclavicular incision and exposure of the axillary artery for possible 10-mm Dacron conduit placement is recommended (FIG 5B). When this is planned, a 20-Fr or 22-Fr sheath can be inserted to get around the arch and then three 6-Fr or 7-Fr sheaths can be used to cannulate the visceral vessels.
- For the simplest of all snorkel cases, when just one renal artery needs stenting, a lower brachial incision can be made to allow insertion of a single 7-Fr sheath (FIG 5C).

Renal/Visceral Cannulation and Sheath Advancement

- A 5-Fr micropuncture access is obtained under direct visualization into the brachial artery. A Bentson wire is advanced, under fluoroscopic guidance, most often into the ascending aorta. The use of an Omniflush catheter and glidewire (either a 260-cm Rosen or Amplatz [Cook Medical, Bloomington, IN]) combination, to direct the wire toward the visceral aorta, allows a wire exchange for a stiffer platform. Over this stiffer platform, two 7-Fr 90-cm Pinnacle Destination sheaths (Terumo Medical, Somerset, NJ) are positioned near the visceral target branches to facilitate cannulation attempts (FIG 6A).
- Through the 7-Fr sheaths, the targeted renal and visceral branches are cannulated using 260-cm–length hydrophilic guidewires and a 125-cm JB1 catheter (Cook Medical, Bloomington, IN). An angiographic run can be performed from a flush catheter advanced from femoral access to aid in renal cannulation (FIG 6B). Thorough knowledge of the preoperative anatomy, derived from reformatting from the 3-D workstation facilitates

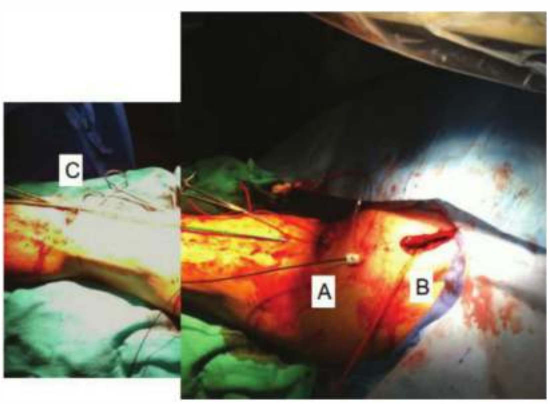

FIG 5 ● **A.** Skin incision via a high brachial incision near the axilla exposes the proximal brachial artery, often giving adequate size for double puncture. **B.** Infraclavicular incision to expose the axillary artery necessary when three or four snorkel/chimney sheaths needed. A 10-mm or 12-mm Dacron conduit can be sewn into the axillary artery in this position. **C.** Small incision over palpable brachial artery near antecubital crease can be used when only single snorkel/chimney sheath necessary.

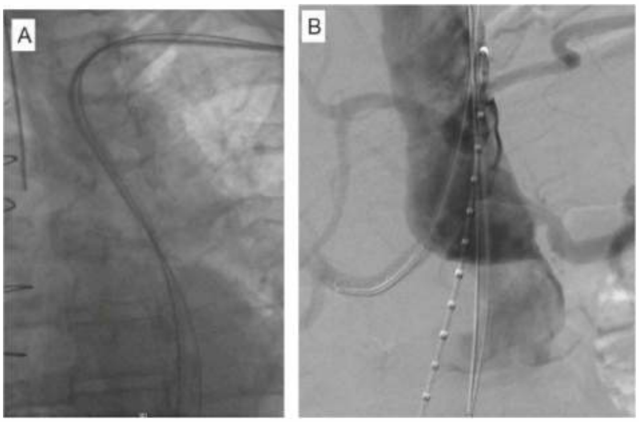

FIG 6 ● **A.** Two 7-Fr Terumo sheaths placed from arm access down descending thoracic aorta ready to be positioned near visceral aortic region. **B.** Right renal artery cannulated with glidewire and JB1 catheter. Omniflush catheter from below reveals in an angiogram the position of the left renal artery to be cannulated next.

this portion of the procedure, guiding optimal angulation of the C-arm.

- Once cannulated, the sheaths are advanced coaxially into the target artery orifice. When necessary, or in cases where there is a slight turn to the horizontal rather than downward angled, the soft hydrophilic guidewire needs to be exchanged for a 260-cm J-tip Rosen wire (Cook Medical, Bloomington, IN) or Amplatz Superstiff (1-cm tip) to facilitate sheath advancement into the target renal artery. Confirmation angiography, through the sheath, is performed to ensure patency of the renal arteries, cannulation of the main renal artery, and avoidance of accidental side branch cannulation.

Positioning of Main Body Endograft and Snorkel Stent Grafts

- Standard femoral access for EVAR is employed for snorkel technique. This is well described in other chapters. Briefly, a small transverse incision, below the inguinal ligament, can be used to expose the common femoral artery to the bifurcation for delivery of endograft components. The percutaneous approach involves the "preclose" technique and employs two Perclose ProGlide devices (Abbott Vascular, Santa Clara, CA) oriented at 10 o'clock and 2 o'clock positions.[10]
- The main body endograft can then be delivered up the chosen femoral side to the paravisceral aorta at the same time as the iCAST (Atrium Medical, Hudson, NJ) or Viabahn (Gore Medical, Flagstaff, AZ) stents are advanced through the snorkel sheaths out to the target renal arteries (**FIG 7A**). The typical length of the iCAST is 59 mm, with the diameter sized appropriately to seal in the target renal artery, most often 5, 6, or 7 mm. For Viabahn stents, similar diameters are used in 50- or 100-mm lengths as appropriate. To prevent theoretical compression of the Viabahn stent by the main body of the endograft, the Viabahn can be reinforced from the inside with a bare-metal, balloon-expandable stent along the areas of overlap with the main body. The positioning of the snorkel stent requires that at least 10 mm of fixation into the renal artery be present and that the proximal extent of the graft is above the fabric of the main body endograft.
- In a lateral projection angiography, the superior mesenteric artery (SMA) is visualized (when performing the typical double renal snorkel) and the main body fabric edge placed immediately below the origin of the SMA (**FIG 7B**).

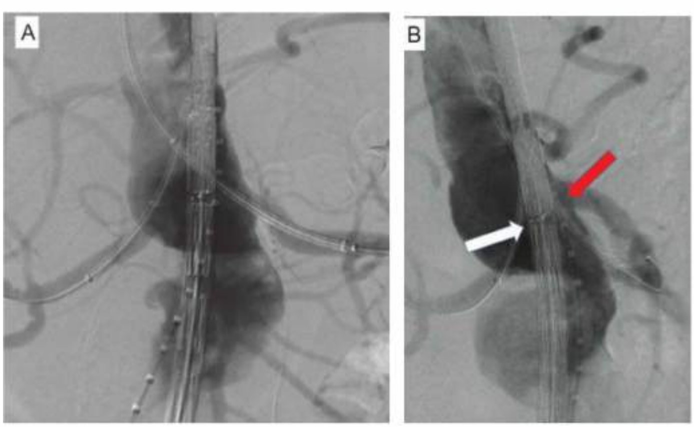

FIG 7 ● **A.** In the anterior-posterior view, both snorkel iCAST stents in position from arm approach along with main body endograft being put into position. **B.** Lateral view angiogram shows takeoff of SMA *(red arrow)* and positioning of the main body endograft fabric edge *(white arrow)* immediately below SMA.

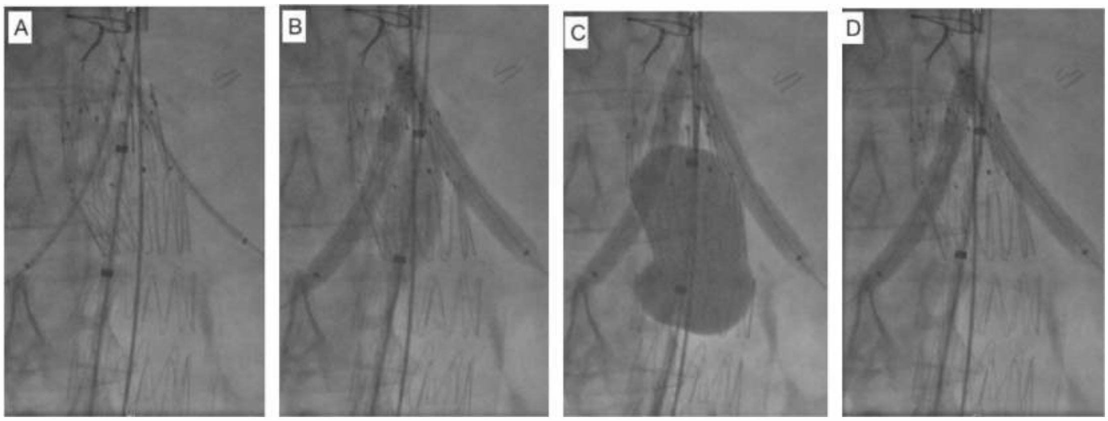

FIG 8 ● **A.** Main body endograft deployed in anteroposterior (AP) view with snorkel stents in position. **B.** After cannulation of contralateral gate and advancement of proximal molding balloon into aortic stent, the two snorkel stents are fully inflated. **C.** The molding balloon is then maximally inflated to profile and to minimize gutters. **D.** The molding balloon is completely deflated prior to snorkel stent balloon deflation.

- At this point, final small adjustments can be made as well as further angiography to ensure that the snorkel stents are in good position. To avoid the issue of the iCAST stent being unstable off its balloon, we often leave the 7-Fr sheaths in place to protect them until final deployment.

Sequence of Stent Graft Deployment and Balloon Molding

- The main body endograft is deployed at the target location with its fabric edge being immediately below the SMA edge (**FIG 8A**). Depending on the endograft system used, deployment proceeds down to the contralateral gate opening. From the contralateral femoral access, cannulation of the gate is confirmed and a noncompliant molding balloon (32- or 40-mm Coda balloon; Cook Medical, Bloomington, IN) is placed up to the level of the renal vessels.
- The 7-Fr sheaths are slowly withdrawn from the brachial approach so the tip is just proximal to the edge of the renal snorkel stents and deployment of the iCAST occurs, most often simultaneously and to a nominal pressure of eight atmospheres (**FIG 8B**). At the same time that the iCAST stents are being deployed by balloon inflation, slower inflation of the Coda occurs to slowly mold the main body fabric around the snorkel stents to minimize gutter formation.
- Only when the renal snorkel stents are maximally inflated can the Coda balloon go up to full main body endograft diameter (**FIG 8C**). This step cannot be overemphasized, as deflation of the snorkel stents while the Coda is inflated is likely to crush the balloon-expandable covered stents.
- With the renal snorkel stents still maximally inflated, the Coda balloon can finally be let down after a few seconds of balloon molding to complete the sequence (**FIG 8D**). After the proximal molding balloon is completely deflated, the renal snorkel balloons are deflated to allow perfusion of the kidneys.

Completion of Distal Components

- Prior to losing wire access to the renal vessels, a proximal aortogram is performed to look for a large type I endoleak or poor perfusion of either targeted kidney. If this is satisfactory, the distal components of the endograft can be advanced and deployed in the usual fashion.
- Repair of the access sites, particularly the brachial site, requires careful interrupted 6-0 or 7-0 Prolene sutures, and adequate hand and foot perfusion is verified prior to completion of the case.
- Postoperative CTA demonstrates the typical appearance of the snorkel stents adjacent to the main body endograft with minimal gutters (**FIG 9A**), and the 3-D reconstruction shows excellent alignment and configuration of the snorkel EVAR components (**FIG 9B**).

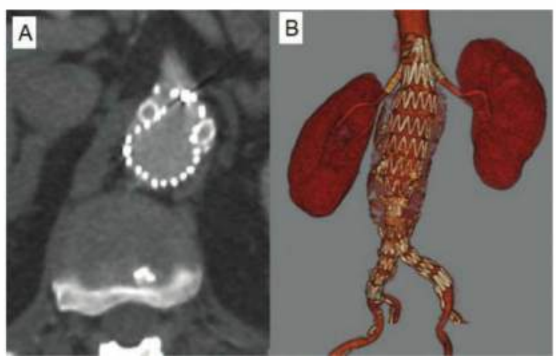

FIG 9 ● **A.** Postoperative CTA axial view showing molding of main body endograft around two widely patent snorkel stents. **B.** 3-D reconstruction demonstrating excellent perfusion of both kidneys and no evidence of endoleak.

PERISCOPE ENDOVASCULAR ANEURYSM REPAIR/THORACIC ENDOVASCULAR AORTIC REPAIR

Femoral Access for Introduction of Main Body Endograft

- Periscope EVAR/thoracic endovascular aortic repair (TEVAR) builds on the concept above of parallel endografts but places the visceral stents from a femoral approach, requiring blood flow to go through the main body stent graft, then turn around and return cranially to the visceral or renal vessel.[11]
- The femoral access for periscope, in contradistinction to snorkel/chimney strategies, often involves the use of larger caliber thoracic or fenestrated main body components (often 22 Fr to 26 Fr), leading to a slightly higher usage of open or endovascular iliac conduits.
- One useful modification to an iliac conduit that can be helpful in delivering and torquing large-caliber main body components or sheaths during periscope EVAR/TEVAR involves creating a patch at the distal end (**FIG 10**). This patch region is created by cutting a 10- or 12-mm Dacron graft along its long access, creating a sewing patch that enlarges the transition from graft to vessel, and not limiting the flexibility of the branch to the initial angle it is sewn into.

Contralateral Access and Cannulation of Target Visceral Branch(es)

- After the femoral access side has been chosen and prepared for main body endograft delivery, the contralateral femoral site is used to cannulate the planned visceral or renal branches from the bottom. In the periscope configuration, the parallel stent graft is often required to make a U-turn, so the more flexible covered stent, the self-expanding Viabahn (Gore Medical, Flagstaff, AZ), is preferred. This requires larger sheath access (up to 12 Fr) than the iCAST described earlier; however, for a double periscope configuration, a larger 20-Fr or 22-Fr sheath is usually necessary to perform multiple punctures into (**FIG 11**).
- The typical periscope EVAR/TEVAR involves the need for a distal landing zone (**FIG 12**). In this particular case, the celiac and one renal artery were already occluded, so the periscope technique was used to revascularize the SMA and remaining renal artery, with an 11-mm Viabahn in the SMA requiring a 12-Fr sheath *(blue arrow)* and an 8-mm Viabahn as the renal periscope requiring an 8-Fr sheath *(orange arrow)* (**FIG 13**).

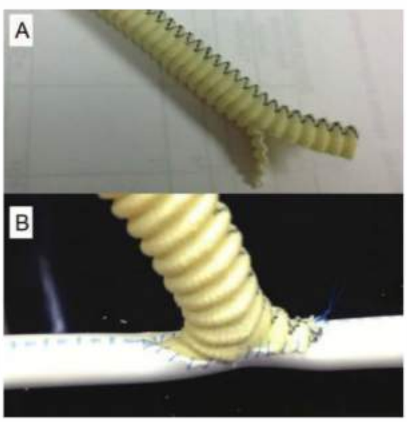

FIG 10 ● **A.** 10-mm Dacron conduit bisected longitudinally to create a sewing patch. **B.** Dacron iliac conduit sewn to native iliac artery allows easy mobility of the conduit at multiple angles of entry for large-caliber device or sheath. (From Lee JT, Lee GK, Chandra V, et al. Comparison of fenestrated endografts and the snorkel/chimney technique [published online ahead of print April 27, 2014]. *J Vasc Surg.* doi:10.1016/j.jvs.2014.03.255.)

FIG 11 ● 22-Fr sheath with multiple punctures allows three separate 6-Fr sheaths to be inserted without leakage.

Sheath Advancement and Periscope Stent Graft Positioning

- Similar to the snorkel/chimney EVAR procedure earlier, the general principles of advancing the sheath into the target visceral vessel are repeated, but in periscope EVAR/TEVAR, all is performed from the femoral approach. The SMA and renal periscopes are positioned several centimeters into the target vessel origin, with the distal end *(blue arrow)* below the bottom end of the main body stent graft *(white arrow)* (**FIG 14**).

Sequence of Deployment and Balloon Molding

- The main body endograft is deployed with the periscope sheaths still in position (**FIG 15A**). The sheaths are then slowly withdrawn to allow the periscope stent grafts (Viabahns) to deploy against the main body endograft (**FIG 15B**). Because there is often some compression of the self-expanding periscope stents, an additional balloon-expandable bare stent is placed along where there is contact with the main body endograft and a similar sequence as earlier of balloon molding is performed to minimize gutter formation (**FIG 16**).
- The remainder of the proximal aspect of the aneurysm is visualized and appropriately stent grafted with proximal extensions and ballooned (**FIG 17**), and postoperative CT-A confirms aneurysm exclusion with wide patency of the periscope stent grafts and normal target vessel perfusion (**FIG 18**).

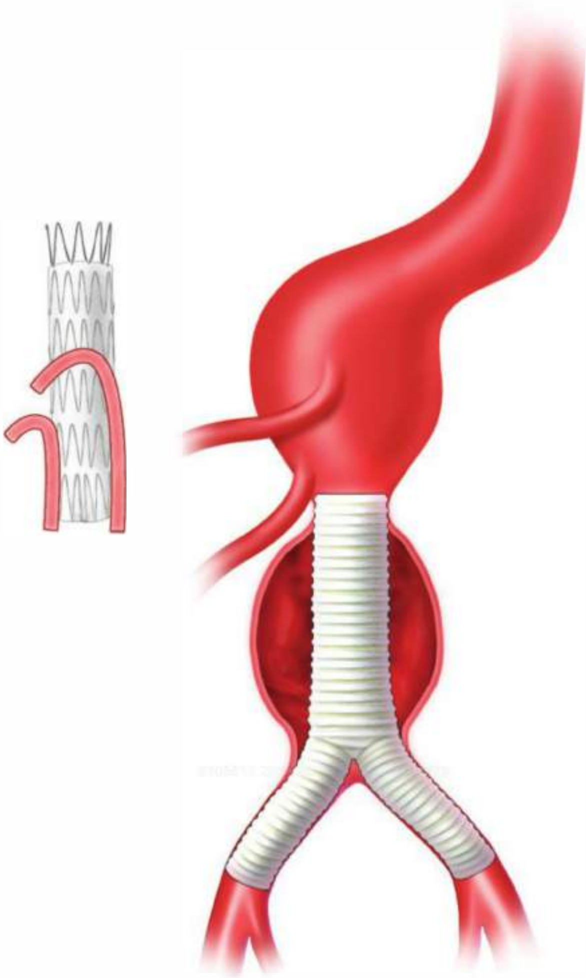

FIG 12 ● Thoracoabdominal aneurysm formed above prior open repair with occluded right renal and celiac arteries. Periscope configuration to keep SMA and right renal artery perfused.

FIG 13 ● 22-Fr sheath *(white arrow)* houses 12-Fr periscope sheath *(blue arrow)* into SMA as well as 8-Fr sheath *(orange arrow)* positioned to try to cannulate renal artery.

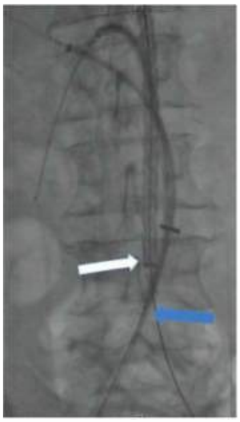

FIG 14 ● Bottom of both periscope stents (SMA and right renal) are at *blue arrow* position and therefore lower than bottom of planned distal component of main body endograft *(white arrow)*.

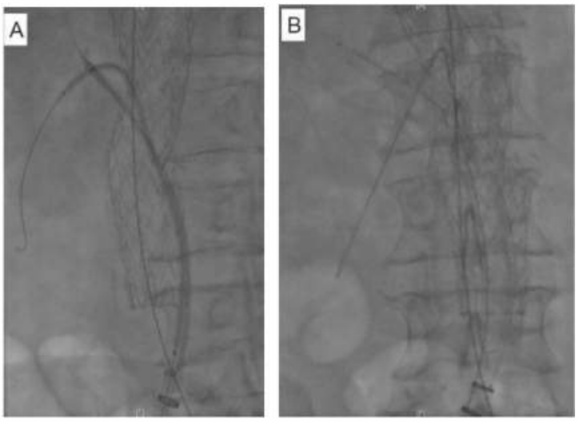

FIG 15 ● **A.** Main body endograft deployed while periscope sheaths still in place. **B.** After withdrawal of sheaths, periscope stents (Viabahns) are deployed.

FIG 16 ● Balloon molding of main body endograft with compliant aortic balloon against balloon-expandable bare stents placed within periscope stents at level of contact and distal seal.

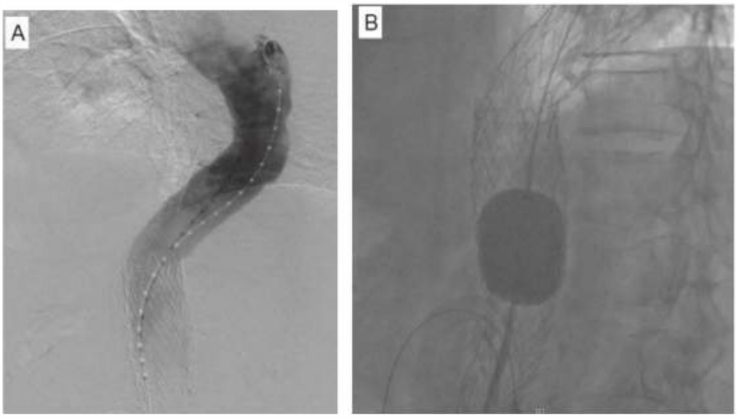

FIG 17 ● **A.** Proximal angiography shows region of proximal aneurysm to treat. **B.** Proximal main body endograft is delivered and overlap is molded with compliant aortic balloon.

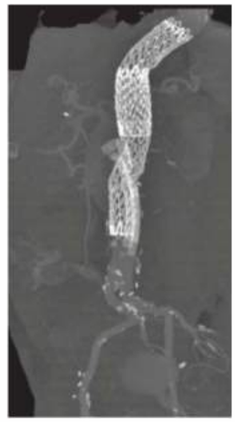

FIG 18 ● Completion CTA showing exclusion of aneurysm and periscope stents in excellent position, perfusing SMA and right renal artery.

PEARLS AND PITFALLS

Indications	■ Follow general recommendations for elective repair of abdominal aortic aneurysms (AAAs) and consider raising criteria when applying complex snorkel/chimney/periscope procedures to these often compromised patients. ■ Most of these procedures use approved devices in an off-label manner so informed consent to discuss all available options is important.
Preoperative workup	■ High-quality imaging and the ability to manipulate images on a 3-D workstation are mandatory for successful preoperative planning and device choices. ■ Adequate preoperative and perioperative hydration is important, given the amount of renal artery manipulation that occurs during these cases.
Patient setup	■ The advanced imaging afforded by a dedicated hybrid endovascular suite allows improved visualization during these very technically demanding procedures. ■ A well-trained staff and two-surgeon approach are important to ensure safe delivery of endograft components from both the femoral and brachial positions.
Arm access	■ Two 7-Fr sheaths can be placed in the high brachial position from a transverse incision, and the puncture sites need to be at least 2 to 3 cm away from each other to allow safe and independent arteriotomy closure.
Renal cannulations	■ A coaxial system with sheath and covered stent into the target renal or visceral vessel from the brachial approach optimizes safe and accurate deployment of snorkel stents. ■ Careful wire manipulation in distal renal and using less stiff wires with J-tips, if possible, minimizes likelihood of renal parenchymal injury and theoretical possibility of renal microemboli.
Balloon molding sequence	■ Careful attention to sequence of snorkel/chimney/periscope balloon sequence minimizes gutter formation, promotes good neck apposition, and prevents compression of vital visceral and renal branches.

POSTOPERATIVE CARE

- At the conclusion of the procedure, patients are usually extubated, observed for 2 to 3 days in a monitored setting (in the intensive care unit overnight if lumbar drain present), and discharged home when ambulating, tolerating a normal diet, and with stable renal function. Clopidogrel and aspirin are given if the patients are not already taking these medications for at least 6 weeks postoperatively.

OUTCOMES

- Multiple reviews of the worldwide experience with snorkel/chimney and periscope techniques continue to find it to be technically successful with target revascularization rates in the 95% to 100%, mortality in the 2% to 5% range, morbidity up to 10%, and midterm renal and branch patency rates of 92% to 96%.[12,13]
- Rupture-free survival after snorkel/chimney or periscope EVAR is excellent in the small amount of literature published

on this new approach but will be important to observe in the mid- and long-term to ensure that this technique is durable as a strategy for endovascular repair of complex aneurysms.

COMPLICATIONS

- Perioperative complications related to complex EVAR in general include cardiac ischemia, arrhythmias or exacerbation of heart failure, groin wound seroma and infection, early thrombosis of endograft components, and bleeding issues related to access site. Reported rates of these issues are not particularly different than the wealth of literature for routine EVAR.
- Particular to snorkel/chimney techniques involve the use of the arm access, which has the potential of leading to arm ischemia, nerve injury/irritation of the brachial plexus, and axillary seromas.
- Wire and catheter manipulation and poor wire hygiene can lead to inadvertent renal parenchymal injury that can lead to hematomas and excessive bleeding requiring transfusion. The rate of renal function decline is certainly more than in standard EVAR, although we do not believe it to be worse than open suprarenal surgery, fenestrated, or branched devices.
- Right arm access for multiple snorkel/chimney stents has been reported to lead to higher rates of cerebrovascular complications.[1,8] This is likely due to moderate amounts of time that sheaths are across the aortic arch and the possibility of thrombus formation that can lead to cerebral emboli.
- Gutter leaks are a unique consequence of the parallel stent graft strategy and are poorly understood. Some general guidelines involve placing as long of stents as possible in parallel configuration to force gutter leaks to thrombose, and careful long-term imaging follow-up to ensure that the aneurysm is excluded.

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Chapter **18**

Branched and Fenestrated Endovascular Stent Graft Techniques

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- Anatomic constraints for endovascular management of abdominal aortic aneurysms include the presence of short or angulated surgical necks and aneurysmal degeneration of the origins of the visceral arteries. Fenestrated and branched endografts were introduced to enable minimally invasive repair of complex juxta- and suprarenal aortic aneurysms.[1] These devices incorporate reinforced fenestrations or directional branches, permitting incorporation of visceral artery origins into the proximal endograft seal zone without compromising end-organ perfusion or aneurysm exclusion.[2] This chapter summarizes the technical features of endovascular aneurysm repair using fenestrated and branched stent grafts for pararenal and thoracoabdominal aortic aneurysms.

DEFINITION

- The term *fenestrated repair* refers to deployment of an endograft featuring custom orifices created and reinforced at precise locations around the aortic perimeter to enable branch artery access, cannulation, and placement of a bridging stent graft in the course of aneurysm exclusion. Fenestration sites are created from patient-specific cross-sectional image data to enable exclusion of aneurysms with short or angled infrarenal necks. In most circumstances, the target arteries (e.g., renal or mesenteric) must arise from normal aorta to enable fenestrated repair. As a rule, fenestrations must be able to deploy flush with the aortic wall to ensure adequate aneurysm exclusion. "Alignment" stents (covered or uncovered, depending on individual patient circumstance) are deployed as needed to prevent target artery malperfusion as a consequence of misalignment between the fenestration and target artery orifice.
- *Branched repair* refers to endovascular aneurysm exclusion employing covered stents to directly connect the main lumen of the endograft to the target visceral artery. These devices enable repair of aneurysms involving or extending proximal to the origins of the renal or visceral vessels (e.g., type IV thoracoabdominal aortic aneurysms [TAAAs]). Of necessity, some distance must be present between the main body of the endograft at full deployment and the aortic wall at the target visceral artery orifice. Branched stent grafts are currently available in two distinct configurations:
  - *Fenestrated branches* arise from reinforced fenestrations bridged by balloon-expandable covered stents.
  - *Directional or cuffed branch* devices feature appended fabric cuffs, precisely located to enable straight, helical, down- or up-going guidewire egress, target vessel cannulation, and deployment of bridging covered stents. Self-expanding flexible nitinol stents are usually employed for this purpose.

DIFFERENTIAL DIAGNOSIS

- Most aneurysms are degenerative (previously characterized as "atherosclerotic," based on a similar, although not identical, causal risk factor profile).
- Other relevant etiologies include infection (e.g., mycotic aneurysms), inflammation (e.g., inflammatory aneurysm or aortitis), development of penetrating ulcers or asymmetric saccular enlargement, and related aortic pathologies (dissection or intramural hematoma).

PATIENT HISTORY AND PHYSICAL FINDINGS

- Most patients' aneurysms do not prompt symptoms prior to catastrophic rupture and are diagnosed incidentally or during screening. Indications for repair are size greater than 5.5 cm for males and greater than 5 cm for females or enlargement greater than 5 mm in 6 months.[3]
- In approximately 5% to 10% of patients, aneurysms induce periaortic inflammation and resultant retroperitoneal fibrosis involving adjacent structures, including the duodenal and ureters.[4] These patients may present with abdominal or back pain, fatigue, malaise, or low-grade fever even at relatively small diameters. Commonly, these aneurysms also enlarge at accelerated and unpredictable rates. Other uncommon presentations of abdominal aortic aneurysm disease include the presence of distal embolization with "blue toe syndrome," congestive heart failure from aortocaval fistulae, or gastrointestinal bleeding from primary aortoenteric fistulae.
- A comprehensive history should be obtained to fully appreciate the potential natural history of each patient's disease, including a comprehensive assessment of cardiovascular risk factors, current smoking habits, and a family history of aneurysmal disease or connective tissue disorders.
- Evaluation of perioperative clinical risk emphasizes cardiac, pulmonary, and renal functional status and reserve, including baseline laboratory testing, noninvasive cardiac stress testing, pulmonary function assessment, and carotid duplex ultrasonography when indicated.

DIAGNOSTIC IMAGING

- Preprocedural aortic imaging studies provide fundamental and necessary guidance for endovascular repair strategies of all types. Aneurysm morphology is best analyzed through acquisition of high-resolution computed tomography angiography (CTA) datasets.[5] CTA with submillimeter slice acquisition is recommended for optimal acquisition, allowing three-dimensional reformatting techniques, maximum intensity projections, and volume rendering.

- Stent grafts are currently custom-made to conform to patient anatomy, based on estimates of longitudinal distance, axial clock position, arc lengths, and angles derived from centerline of flow measurements.
- Anatomic limitations to be considered include difficult iliac access, excessive aortic tortuosity, visceral artery occlusive disease, and anatomic variants including multiple accessory renal arteries or early renal branch bifurcation.

STENT GRAFT DESIGN

- Device planning starts with selection of the proximal landing zone based on "healthy" aorta. The proximal landing zone should include at least a 2-cm length of "normal," noncalcified, parallel aortic wall. The outer-to-outer aortic diameter should be more than 18 mm and less than 32 mm for pararenal aneurysms and more than 18 mm and less than 38 mm for TAAAs.[6] Landing zone diameter should be no larger than the diameter of the next most proximal aortic segment.
- Fenestrated stent grafts are currently manufactured with three fenestration options: small and large circles and more proximal scallops (**FIG 1A**). *Small fenestrations* are 6 × 6 mm or 6 × 8 mm, created without crossing struts and reinforced by circumferential nitinol rings. *Large fenestrations*' diameters are 8, 10, or 12 mm and may incorporate stent struts crossing the edge or middle of the circular defect, limiting space available for alignment stents. *Scallops* are contoured indentations along the upper edge of the main body endograft fabric, 10 mm wide and ranging in height from 6 to 12 mm, depending on individual patient anatomy.[5]
- Device designs vary with aneurysm extent. For pararenal aneurysms, 70% of patients are adequately treated with two small fenestrations for the renal arteries and a scallop for the superior mesenteric artery (SMA).[5] Suprarenal and type IV TAAAs typically require four fenestrations (no scallops). Extensive TAAAs (types I to III) need directional branches, particularly if the aortic diameter is relatively large or aneurysmal at the level of the visceral arteries. The combination of directional branches for celiac and SMA management with fenestrations for the renal arteries is increasingly popular.

SURGICAL MANAGEMENT

Ancillary Tools

- These procedures require advanced endovascular skills and a comprehensive inventory of applicable catheters, balloons, and stents (Table 1). Dedicated training in fenestrated and branched techniques is highly recommended for physicians already experienced in endovascular disease management and ancillary procedures including renal and visceral artery disease management.

Perioperative Measures

- Patients with difficult aneurysm anatomy, chronic kidney disease, or advanced age are preadmitted for bowel preparation and intravenous hydration with bicarbonate infusion. Oral acetylcysteine is administered to minimize risk of periprocedural renal dysfunction following administration of iodinated contrast.
- Hybrid, fixed imaging platforms are essential for optimal results of these complex procedures. Most are performed using general endotracheal anesthesia; local or regional anesthesia may be sufficient in select cases.
- Intraoperative blood salvage systems ("cell saver") are recommended for difficult cases and all TAAAs. The creation of large, impermeable pockets within dependent portions of the surgical drapes will facilitate pooling and collection via the cell saver.

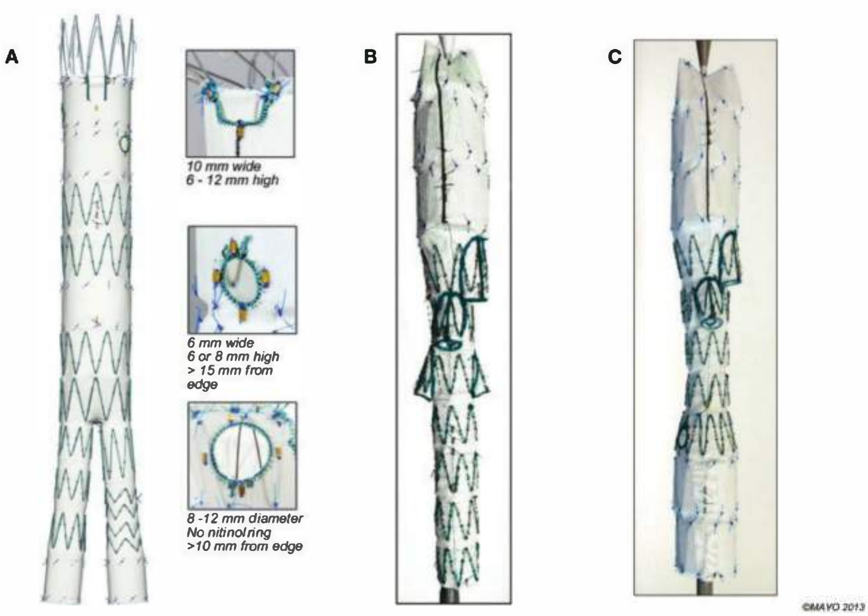

FIG 1 ● **A.** There are three types of fenestrations that can be manufactured: small, large, and scallop fenestrations. The fenestrated stent graft consists of a proximal fenestrated tubular component, a distal bifurcated universal component, and a contralateral iliac limb extension. **B.** The Cook Zenith® stent graft lineage. **C.** Newer design with two straight down-going branches and two fenestrations.

Table 1: List of Ancillary Tools Recommended for Physicians Performing Fenestrated Stent Graft Procedures

Category	Manufacturer	Application
Sheaths		
20- to 24-Fr Check-Flo sheath (30 cm)	Cook Medical, Bloomington, IN	Femoral access for multivessel catheterization
7-Fr Ansel sheath (55 cm, flexible dilator)	Cook Medical, Bloomington, IN	Femoral access for branch artery stenting
7- or 8-Fr Raabe sheath (90 cm long)	Cook Medical, Bloomington, IN	Brachial access for branch artery stenting
12-Fr Ansel sheath (55 cm, flexible dilator)	Cook Medical, Bloomington, IN	Brachial access for tortuous aortic arch to facilitate branch artery stenting
5-Fr Shuttle sheath (90 cm)	Cook Medical, Bloomington, IN	Branch artery access during difficult arch
Catheters		
Kumpe catheter 5 Fr (65 cm)	Multiple	Selective vessel catheterization
Kumpe catheter 5 Fr (100 cm)	Multiple	Selective vessel catheterization
C1 catheter 5 Fr (100 cm)	Multiple	Selective vessel catheterization
MPA catheter 5 Fr (125 cm)	Multiple	Selective vessel catheterization
MPB catheter 5 Fr (100 cm)	Multiple	Selective vessel catheterization
Van Schie 3 catheter 5 Fr (65 cm)	Cook Medical, Bloomington, IN	Selective vessel catheterization
Vertebral catheter 4 Fr (125 cm)	Multiple	Selective vessel catheterization
VS1 catheter 5 Fr (80 cm)	Multiple	Selective vessel catheterization
Simmons I catheter 5 Fr (100 cm)	Multiple	Selective vessel catheterization
Diagnostic flush catheter 5 Fr (100 cm)	Multiple	Diagnostic angiography
Diagnostic pigtail catheter 5 Fr (100 cm)	Multiple	Diagnostic angiography, selective vessel catheterization
Quick-cross catheter 0.014 in to 0.035 in (150 cm)	Spectra-Medics	Selective vessel catheterization
Renegade catheter (150 cm)	Boston Scientific, Minneapolis, MN	Selective vessel catheterization
Guide catheters		
LIMA guide 7 Fr (55 cm)	Cordis Corporation, Bridgewater, NJ	Precatheterization
Internal mammary (IM) guide 7 Fr (100 cm)	Multiple	Selective vessel catheterization
MPA guide 7 Fr (100 cm)	Multiple	Selective vessel catheterization
Balloons		
10-mm × 2-cm angioplasty balloon	Multiple	Proximal stent flare
12-mm × 2-cm angioplasty balloon	Multiple	Proximal stent flare
5-mm × 2-cm angioplasty balloon	Multiple	Advance sheath over balloon
Wires		
Bentson wire 0.035 in (150 cm)	Multiple	Initial access
Soft glidewire 0.035 in (260 cm)	Multiple	Target vessel catheterization
Stiff glidewire 0.035 in (260 cm)	Multiple	Target vessel catheterization
Rosen wire 0.035 in (260 cm)	Multiple	Branch artery stenting
1-cm tip Amplatzer wire 0.035 in (260 cm)	Multiple	Branch artery stenting
Lunderquist wire 0.035 in (260 cm)	Multiple	Aortic stent graft
Glidegold wire 0.018 in (180 cm)	Multiple	Target vessel catherization
Stents		
iCAST stent grafts 5 to 10 mm	Atrium, Hudson, NH	Branch artery stenting
Balloon-expandable stents 0.035 in	Multiple	Branch artery stenting or reinforcement
Self-expandable stents 0.035 in	Multiple	Distal branch artery stenting
Self-expandable stents 0.014 in	Multiple	Distal branch artery stenting

MPA, main pulmonary catheter; VS1, Van Schie 1; LIMA, left internal mammary artery.

- The use of iodinated contrast is minimized by avoidance of power injector digital substraction angiography (DSA) runs during device implantation and side stent placement. Whenever possible, hand injections of dilute contrast (70% saline) are used to locate the side branches. Completion aortography is obtained only after all stents are positioned and postdilated, again using diluted contrast (50%).
- To minimize contrast, precatheterization of targeted visceral arteries or use of onlay computed tomography (CT) images, when available, is recommended. In experienced hands, precatheterization adds little to the overall procedure time.

Positioning

- Patients are positioned supine with the imaging unit oriented from the head of the table. Both arms are tucked for repair of pararenal aneurysms requiring up to three fenestrations.
- Brachial artery access is used in patients treated by directional branches or those who need four fenestrations. The left arm is abducted and prepped in the surgical field up to the axilla. A working sterile side table is oriented in the same axis of the abducted arm for optimal support of necessary wires and catheters.
- Electrocardiogram (EKG) leads, urinary catheter, and other monitoring cables and lines should be taped or secured so that they are not in the path of the x-ray beam of the fluoroscopic unit and do not impede movement of the C-arm gantry.

Arterial Access

- Access is established in the femoral arteries. Patients with small, calcified, or stenotic iliac arteries may require creation of an iliac conduit for safe device delivery.
- Total percutaneous femoral access is the preferred approach in patients with noncalcified arteries or mild posterior plaque. The standard "preclose" technique enables complete hemostasis in more than 95% of patients irrespective of sheath diameter.[7] When femoral arteries are small, calcified,

or bifurcate close to the inguinal ligament, standard surgical exposure and access is obtained. Proximal and distal control is obtained using vessel loops.

- The left brachial artery is surgically exposed via small longitudinal incision in the upper arm, just proximal to the origin of the deep brachial artery.
- Intravenous heparin (80 to 100 units/kg) is administered immediately after femoral and brachial access is established. An activated clotting time longer than 250 seconds is maintained throughout the procedure with frequent rechecks every 30 minutes. Prior to deployment of the stent graft, diuresis is induced with intravenous mannitol and/or furosemide.

ENDOVASCULAR REPAIR USING FENESTRATED STENT GRAFTS

- Fenestrated–branched repair is currently performed using the Cook Zenith® stent graft lineage. Newer designs by Endologix (Ventana), Terumo (Anaconda), and Cook Medical (p-Branch) are under clinical investigation.
- The Cook Zenith® fenestrated stent graft consists of a proximal fenestrated tubular component, a distal bifurcated universal component, and a contralateral iliac limb extension (**FIG 1A**). The fenestrated tubular component is custom-made to fit the patient's anatomy. Four to 6 weeks are required for manufacturing and delivery in the United States.
- Bilateral percutaneous femoral access is established under ultrasound guidance; each femoral puncture is preclosed using two Perclose devices. Bilateral 8-Fr sheaths are introduced to the external iliac arteries over Benson guidewires (Cook Medical, Bloomington, IN). The guidewires are exchanged to 0.035-in soft glidewires and Kumpe catheters, which are advanced to the ascending aorta and exchanged for stiff 0.035-in Lunderquist guidewires (Cook Medical, Bloomington, IN).
- Choice of access site is dependent on tortuosity and vessel diameter. Provided there are no issues with both iliac arteries, the branches are performed via the right femoral approach, whereas the fenestrated and bifurcated devices are introduced via the left femoral approach. A 20-Fr (two fenestrations) or 22-Fr (three fenestrations) Check-Flo sheath (Cook Medical, Bloomington, IN) is introduced via the right femoral approach (**FIG 2A**). The valve of the

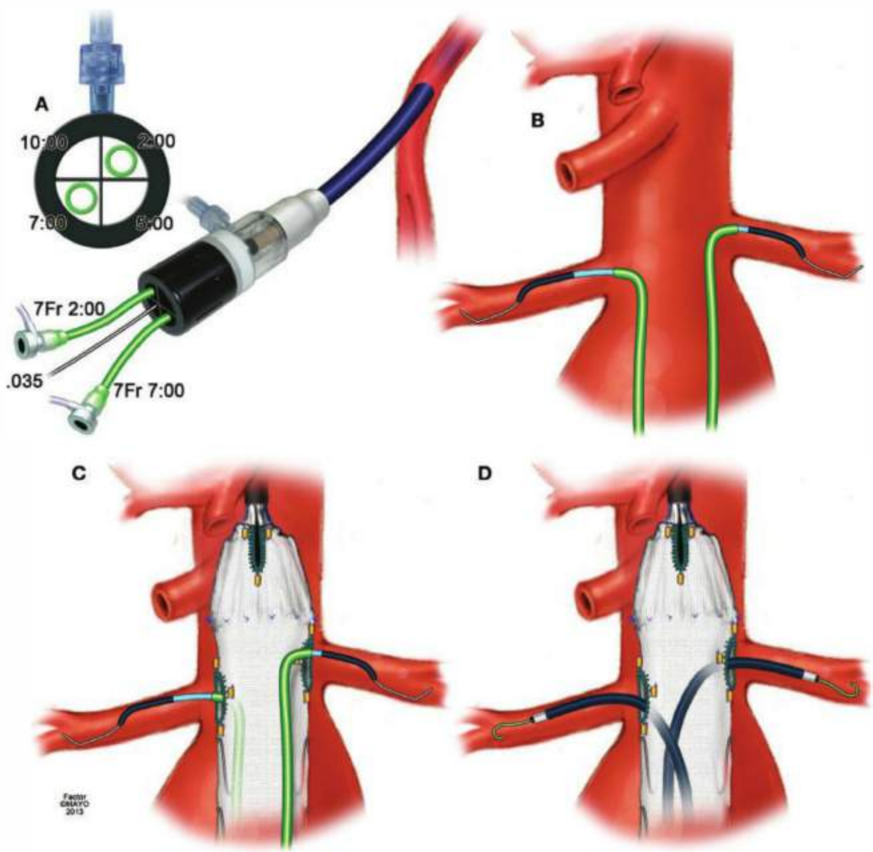

FIG 2 ● **A.** A 20-Fr (two fenestrations) or 22-Fr (three fenestrations) Check-Flo sheath (Cook Medical, Bloomington, IN) is introduced via the right femoral approach. **B.** Precatheterization of the renal arteries. **C.** Sequentially regain access into the fenestrated component, fenestration, and target vessel. **D.** An alignment stent is advanced under protection of the sheath.

Check-Flo sheath has four leaflets, which are accessed by two short 7-Fr sheaths at 2 o'clock and 7 o'clock positions.

- Precatheterization of the renal arteries is performed using 0.035-in soft glidewires and 5-Fr Kumpe or C1 catheters (Cook Medical, Bloomington, IN), which are supported by 7-Fr left internal mammary artery (LIMA) guide catheters (**FIG 2B**). Alternatively, onlay fusion CTA is recommended to minimize contrast use.
- Once the target vessels are catheterized, the fenestrated stent graft is oriented extracorporeally, introduced via the left femoral approach, and deployed with optimal apposition between the fenestrations and the target catheters.
- Proper device orientation, using the anterior and posterior markers, is essential. It is useful to deploy the first two or three stents and then rotate the imaging unit laterally, confirming alignment between the catheter and its respective fenestration. The device should be deployed slightly higher than what is anticipated, with the catheter matching the lowest of the four radiopaque markers in the fenestration. The diameter-reducing wire on the fenestrated component allows for some rotational and cranial–caudal movement to optimize alignment following initial deployment.
- After deployment of the fenestrated component, each catheter is removed from its target artery and used to sequentially regain target vessel access through the respective fenestration. (**FIG 2C**). In most cases, when alignment is carefully confirmed prior to attempted cannulation, the target vessel is accessed without difficulty.
- After the target vessel is catheterized, soft glidewire is removed and hand injection is used to confirm location. The glidewire is exchanged for a 0.035-in Rosen guidewire (Cook Medical, Bloomington, IN). The Rosen guidewire has a floppy J tip, reducing the risk of branch renal artery perforations. When additional support is required, the Amplatz guidewire (Cook Medical, Bloomington, IN) with 1-cm soft tip can be used.
- After the Rosen or stiff guidewire of choice is positioned, a 7-Fr Ansel sheath with flexible dilator is advanced. If there is difficulty to advance the sheath, an undersized balloon may be used as a dilator to facilitate advancement.
- Once the sheath is in position, an alignment stent is positioned under protection of the sheath with the tip of the stent just beyond the tip of the sheath (**FIG 2D**).
- For repairs requiring two or three vessel fenestrations, the target vessels are accessed sequentially using femoral approach. For those requiring four fenestrations, the celiac axis is accessed via brachial approach using a preloaded catheter, which is placed through the celiac fenestration and exits the stent graft via an access scallop at the top of the device.
- The diameter-reducing tie on the fenestrated segment is removed after all the target arteries are accessed and secured by 7-Fr hydrophilic sheaths.
- The top cap of the device is advanced forward to deploy the uncovered fixation stent (**FIG 3A**). The top cap is retrieved prior to deployment of the alignment stents.
- After the top cap and dilator are removed, the proximal landing zone is gently dilated using a compliable balloon such as the Coda balloon (Cook Medical, Bloomington IN, **FIG 3B**). It is critical that the balloon dilatation is performed prior to placement of alignment stents, or alternatively, each stent has to be protected by separate balloons.
- The alignment stents are sequentially deployed following removal of the diameter-reducing tie, retrieval of the top cap, and balloon dilatation of the neck. **The sequence of stent deployment is renal arteries followed by SMA and celiac axis.** Prior to each stent deployment, the position of the stent is confirmed by hand injection. The stent is deployed 3 to 5 mm into the aorta (**FIG 3C**) and flared

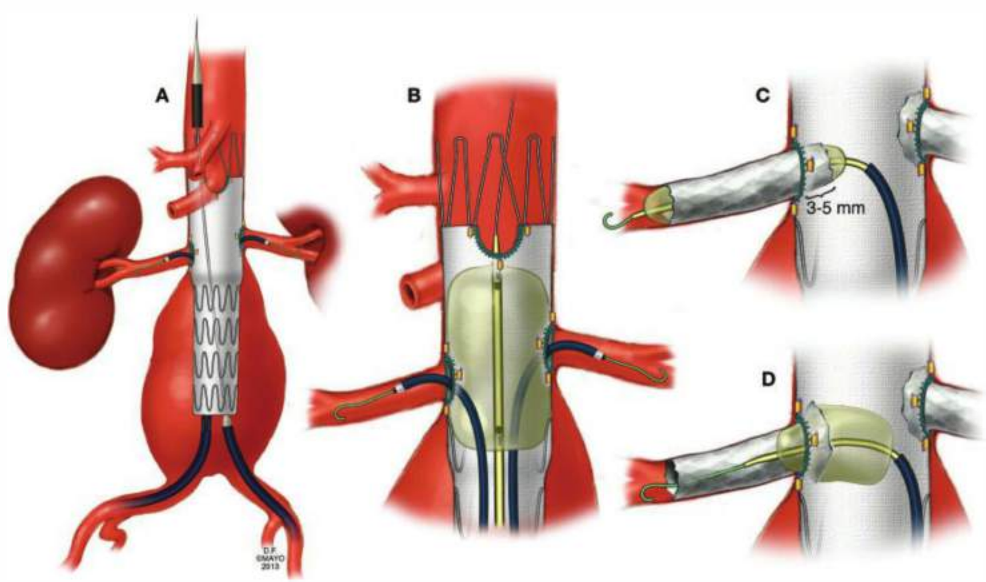

FIG 3 ● **A.** The top cap of the device is advancing forward allowing deployment of the uncovered fixation stent. **B.** The proximal landing zone is gently dilated using a compliable balloon. Stent deployed 3 to 5 mm into the aorta **(C)** and flared using a 10-mm × 2-cm balloon **(D)**.

using a 10-mm × 2-cm balloon (**FIG 3D**). A completion angiography of each branch is performed using hand injection after direct injection of 100 to 200 μg of nitroglycerin to minimize spasm.

- Following placement of the alignment stents, a distal bifurcated stent graft is oriented, advanced, and deployed with preservation of the ipsilateral internal iliac artery. The dilator of the bifurcated device may encroach the contralateral renal stent or the SMA stent. In these cases, it is useful to leave a 10-mm balloon ready to be inflated in the renal stent to prevent damage (**FIG 4A**, *inset*). The minimum overlap between the bifurcated and the fenestrated component is two full-length stents (17 mm each), but ideally, more than three full stents is recommended to minimize risk of component separation (**FIG 4B**).[8] After deployment of the bifurcated device, the dilator is removed with care to avoid damage or dislodgement of the renal stents.
- The contralateral gate is catheterized using a soft glidewire and 5-Fr catheter (**FIG 4B**). Access is confirmed by 360-degree catheter rotation. The glidewire is exchanged for a 0.035-in Lunderquist guidewire. Limited iliac angiography using contralateral oblique views with hand injection. The contralateral limb extension is deployed with preservation of the internal iliac artery (**FIG 4C**).
- A completion angiography of the aorta and iliac arteries is obtained using power injection to demonstrate patency of the visceral arteries, main body, iliac limbs, and iliac arteries.

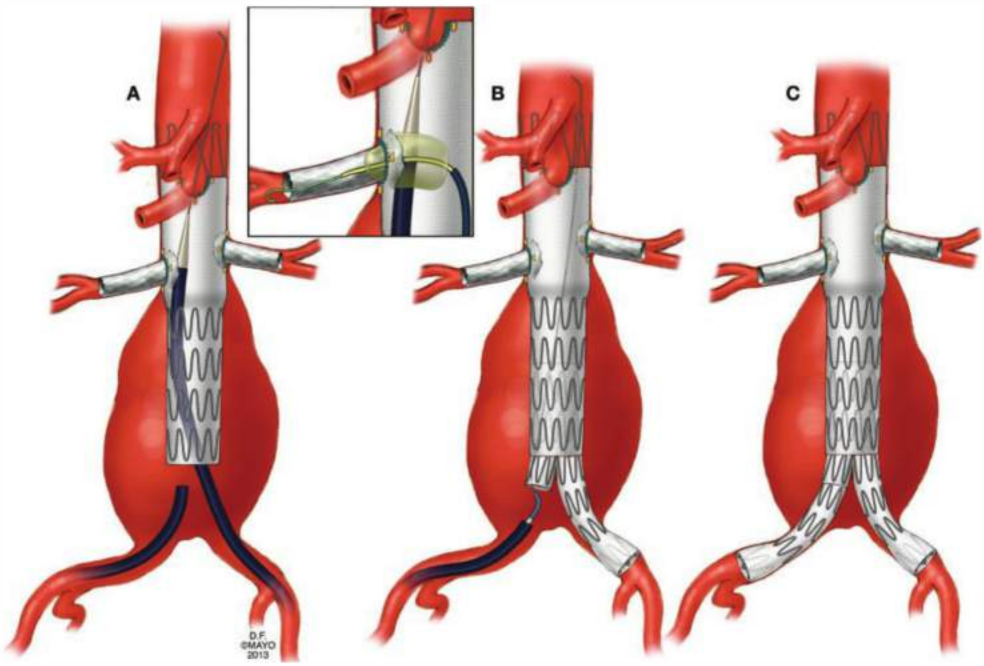

FIG 4 ● To avoid the dilator of the bifurcated device encroaching the contralateral renal stent or the SMA stent, leave a 10-mm balloon ready to be inflated in the renal stent (**A**, *inset*). **B.** The minimum overlap between the bifurcated and the fenestrated component is more than two full-length stents. **C.** The contralateral limb extension is deployed with preservation of the internal iliac artery.

ENDOVASCULAR REPAIR USING MULTIPLE DIRECTIONAL BRANCHES (MULTIBRANCH T-BRANCH STENT GRAFT)

- Directional branches created with presewn cuffs are currently available from Cook Zenith® stent graft lineage on an investigational-use basis (**FIG 1B**). A four-vessel multibranch stent graft design (T branch) is also being investigated for treatment of TAAAs.[9]
- The extent of repair varies depending on the proximal extension of aneurysm within the thoracic aorta. The procedure is performed using bilateral femoral and left brachial approach. In general, the repair starts with deployment of a proximal thoracic TX2 stent graft (Cook Medical, Bloomington, IN) followed by deployment of the T-branch stent graft (Cook Medical, Brisbane, Australia) and distal bifurcated component and contralateral limb extension. The self-expandable stents are placed into the four branches following deployment of all aortic components. The critical steps are reviewed as follows:
    - Bilateral femoral and left brachial arterial access is obtained (**FIG 5A**). A proximal thoracic stent graft is deployed if needed depending on aneurysm extent.

- Precatheterization of the renal arteries is not required, but it is critical that the distal edge of the directional branch is deployed above its intended target vessel. To guide deployment of the T-branch component, the SMA is precatheterized via the brachial approach (**FIG 5B**).
- The T-branch stent graft is oriented extracorporeally, introduced via the femoral approach, and deployed with the directional branches located proximal to its intended target vessel (**FIG 5C**).
- Deployment of the distal universal bifurcated stent graft and contralateral iliac extension are identical

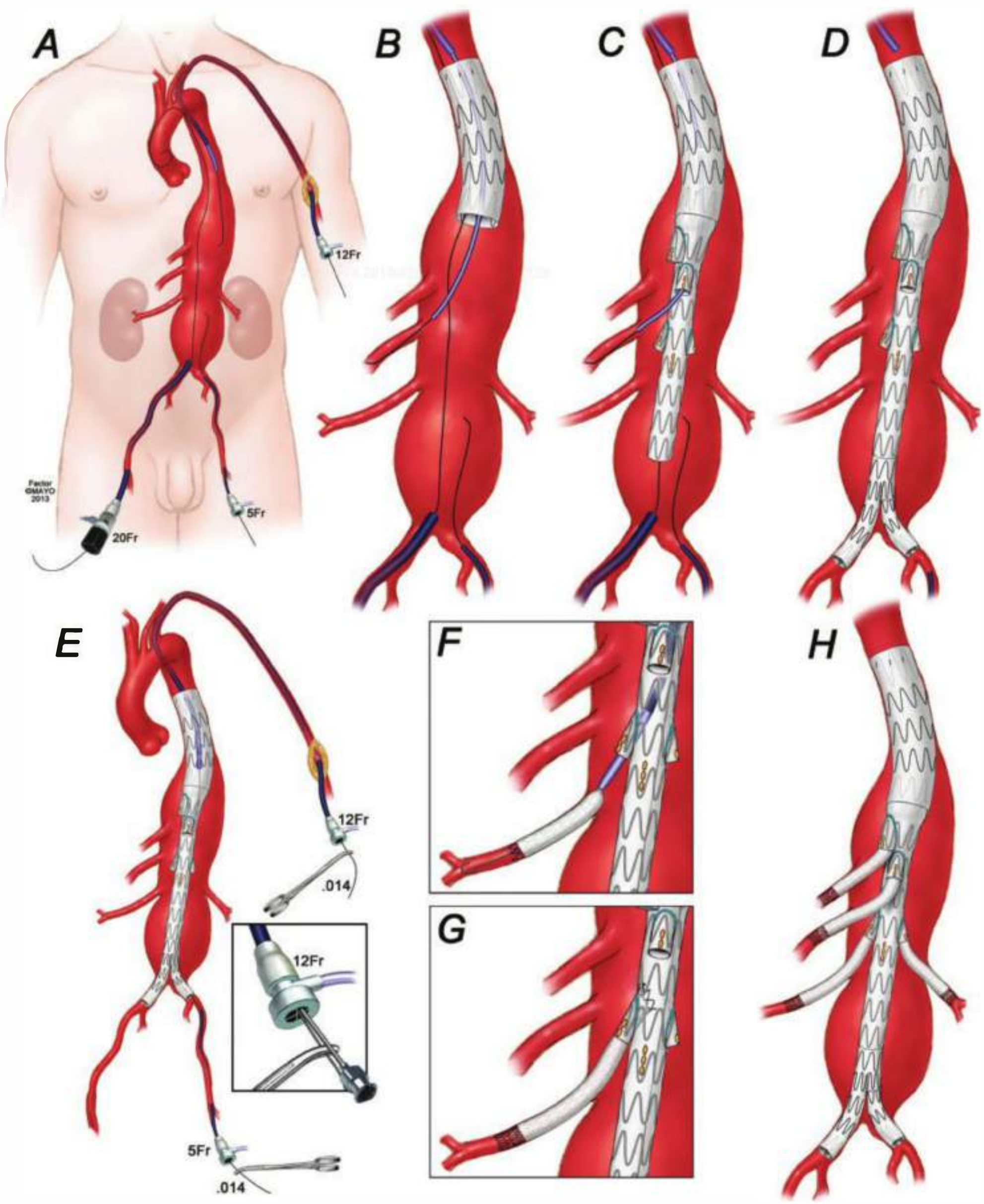

FIG 5 ● **A.** Endovascular repair using multiple directional branches is performed using bilateral femoral and left brachial approach. Deployment of proximal thoracic TX2 stent graft (Cook Medical, Bloomington, IN) **(B)**, followed by deployment of the T-branch stent graft (Cook Medical, Brisbane, Australia) **(C)**, and distal bifurcated component and contralateral limb extension **(D)**. The femoral arteries may be closed, restoring flow into the lower extremities; maintain access into one of the femoral arteries using a 5-Fr sheath (**E**, *inset*). **F,G.** 9-Fr 80-cm flexor sheath (Cook Medical, Bloomington, IN) is advanced into the target vessel, followed by placement of a self-expandable stent graft. **H.** Complete procedure.

to what was described in the fenestrated technique (FIG 5D).

- The femoral arteries are closed at this point, restoring flow into the lower extremities. It is useful to maintain access into one of the femoral arteries with a 5-Fr sheath (FIG 5E, *inset*). This maneuver allows passage of a 0.014-in guidewire from the left brachial artery to femoral artery. The guidewire is clamped in both ends, which locks the 12-Fr sheath in place and provides support for deployment of the side branches.
- The 12-Fr Ansel I sheath (Cook Medical, Bloomington, IN) is advanced via the left brachial approach and positioned inside the T-branch component in the descending thoracic aorta (FIG 5E). At this point, a 0.014-in guidewire is advanced through and through from the left brachial to femoral artery, preventing movement of the 12-Fr sheath in the aortic arch.
- Each side branch is individually catheterized in a sequential fashion, starting with the renal arteries (FIG 5F) followed by the SMA and celiac axis. A 5-Fr main pulmonary artery (MPA) or Kumpe catheter (Cook Medical, Bloomington, IN) is used to access the directional branch and target vessel. Once the vessel is catheterized, the soft glidewire is exchanged for a stiff guidewire (Rosen or short-tip Amplatzer, Cook Medical, Bloomington, IN), which is positioned in the target vessel.
- A 9-Fr 80-cm flexor sheath (Cook Medical, Bloomington, IN) is advanced coaxially within the 12-Fr sheath into the target vessel.
- Each target vessel is stented with a self-expandable stent graft (FIG 5F). The stent graft should be oversized by 1 to 2 mm and should provide at least 2 cm of distal landing zone in the target vessel, extending 3 to 5 mm into the aortic lumen of the T-branch device.
- To prevent kinks in the transition of the stent graft to the target artery, each self-expandable stent graft is reinforced by a second self-expandable uncovered stent, which is deployed 1 cm beyond the distal edge of the stent graft (FIG 5G). Selective completion angiography is obtained for each sequential branch.
- A completion angiography of the arch and thoracoabdominal aorta is obtained after all matting stent grafts are deployed (FIG 5H).

ENDOVASCULAR REPAIR USING TWO DIRECTIONAL BRANCHES AND TWO FENESTRATIONS (TWO BRANCH–TWO FENESTRATED STENT GRAFT)

- A design with directional branches for the celiac and SMA and fenestrations for the renal arteries has been widely used at the Cleveland Clinic.[10] More recently, a newer design with two straight down-going branches and two fenestrations has been used (FIG 1C). The advantage of the latter is the ability to provide short, transversely oriented branches for the renal arteries.
- The same principles already described for fenestrated stent grafts are applied with respect to device design, planning, and arterial access.
- Bilateral femoral access and left brachial artery access is needed (FIG 6A). The right femoral access is used for precatheterization of the renal arteries. The left brachial access is used for the celiac axis and SMA (FIG 6B).
- A proximal thoracic TX2 stent graft (Cook Medical, Bloomington, IN) is deployed first, depending on proximal extension of the aneurysm (FIG 6A).
- After the renal arteries and SMA are precatheterized, the fenestrated–branched stent graft is oriented extracorporeally, introduced via the femoral approach and deployed with perfect apposition between the renal fenestrations and the target renal arteries (FIG 6B).
- The celiac and SMA branch are accessed using preloaded catheters and glidewires, which are snared via the left brachial approach (FIG 6B).
- Each catheter is sequentially removed from the renal arteries and used to regain access into the fenestrated component, renal fenestration, and target renal artery (FIG 6C). Hydrophilic sheaths and alignment renal stents are advanced as previously described.
- The preloaded catheters in the SMA and celiac branch allow advancement of a 0.035-in soft glidewire, which is snared via the left brachial approach (FIG 6B). A sheath and catheter are advanced into the celiac branch. Following access into the celiac axis, a 0.035-in Amplatz guidewire is placed.
- The SMA is accessed using similar steps, and after access is established with Amplatz guidewire, a 9-Fr sheath is advanced to allow positioning of a self-expandable stent graft.
- Once all four vessels are catheterized and sheaths are positioned into the renal arteries and SMA, the diameter-reducing tie is removed, allowing complete expansion of the fenestrated–branched component (FIG 6D).
- Sequential target artery stenting is performed using balloon-expandable covered stents for the renal fenestrated branches (FIG 6E, *inset*) and self-expandable stent grafts for the SMA and celiac axis (FIG 6E, *inset*). Selective branch angiography is performed after each branch stent is placed.
- Deployment of distal bifurcated component and contralateral iliac limb extension is identical to what has been described for fenestrated stent grafts (FIG 6F).

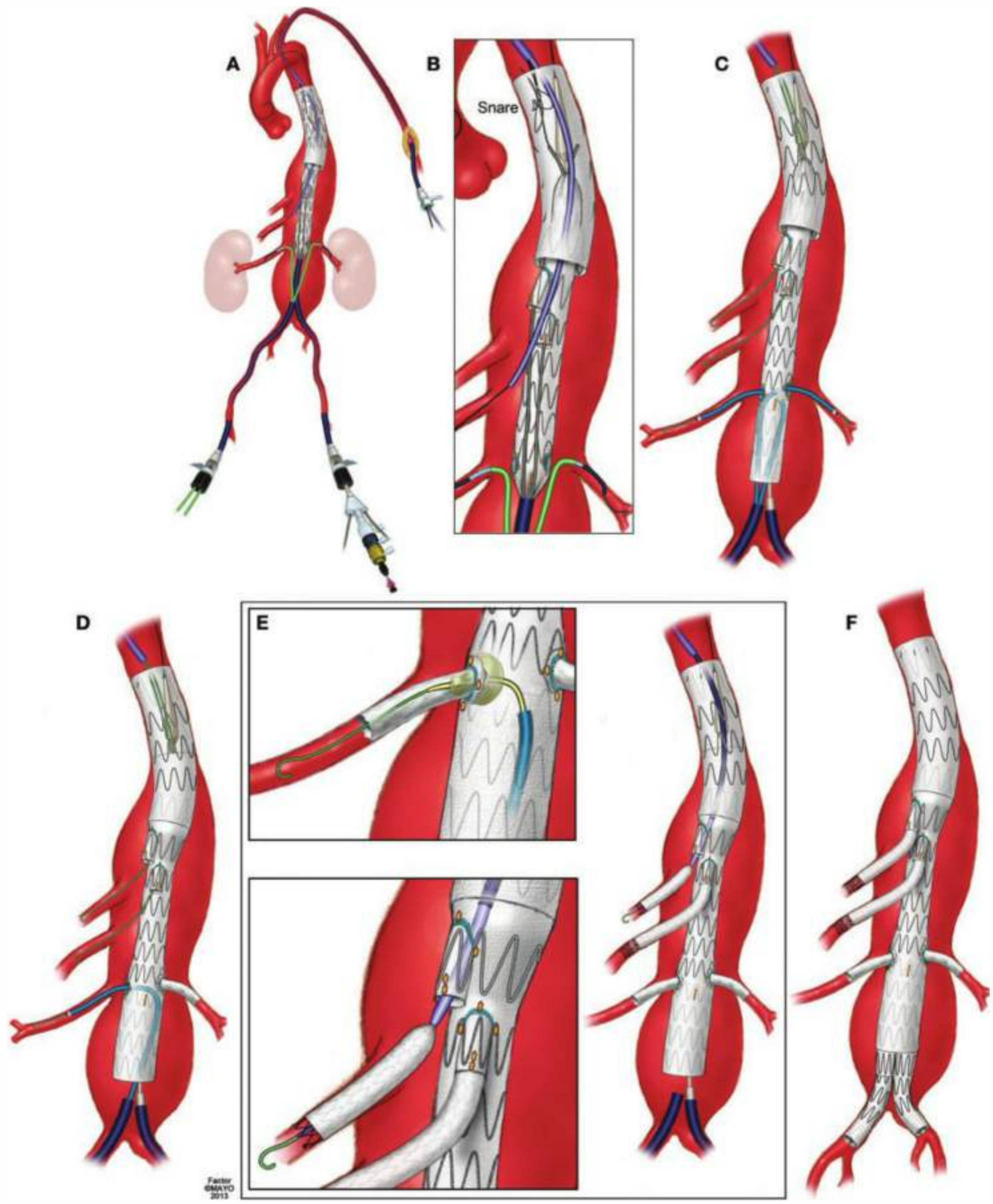

FIG 6 • **A.** Bilateral femoral access and left brachial artery access is needed. **B.** After the renal arteries and SMA are precatheterized, the fenestrated–branched stent graft is oriented extracorporeally, introduced via the femoral approach. The celiac and SMA branch are accessed using preloaded catheters and glidewires, which are snared via the left brachial approach. **C.** Regain access into the fenestrated component, renal fenestration, and target renal artery. **D.** Complete expansion of the fenestrated–branched component. Sequential target artery stenting is performed using balloon-expandable covered stents for the renal fenestrated branches and self-expandable stent grafts for the SMA and celiac axis (**E**, *inset*). **F.** Deployment of distal bifurcated component and contralateral iliac limb extension.

PEARLS AND PITFALLS

Preoperative evaluation	■ Complete history and physical examination with emphasis on cardiovascular risk factors, family history of aneurysm disease, and connective tissue disorders ■ Preoperative medical evaluation focused on cardiac, pulmonary, and renal performance ■ Aortic imaging with computed tomography angiography allows detailed analysis of aneurysm morphology for stent graft design and procedure planning.
Arterial access	■ Iliac conduits are recommended in patients with small, diseased, or excessively tortuous iliac arteries. ■ Pelvic perfusion with maintenance of internal iliac artery flow decreases risk of spinal cord injury.
Stent graft implantation	■ Precise stent graft design and implantation are critical aspects of the procedure. ■ Minimize use of iodinated contrast by avoiding contrast aortography during device implantation. ■ Precatheterization and/or onlay CT allows precise device implantation with minimal need of angiography. ■ Fenestrations are typically accessed via the femoral approach and stented using balloon-expandable covered stents. ■ Directional branches are accessed via the brachial approach and stented using self-expandable stent grafts.
Misaligned fenestrations	■ Excessive tortuosity in the iliac or visceral segment may cause misalignment of fenestrations and difficult target vessel catheterization. ■ Rotation of the device, which is constrained by a diameter-reducing tie, and use of balloon displacement or curved catheters allow successful catheterization in most cases.
Branch perforation or dissection	■ Small, diseased, and tortuous visceral arteries are prone to perforation or dissection, particularly if an Amplatz guidewire is needed to provide more support. ■ Careful attention to detail and minimizing guidewire manipulation with close attention to the tip of the guidewire help prevent this complication.
Stent kinks	■ Branch tortuosity may lead to kinks within the side stents. ■ This should be immediately recognized and treated by placement of a second self-expandable stent to prevent branch occlusion.

POSTOPERATIVE CARE

- Length of stay averages 2 to 3 days for endovascular repair of pararenal aneurysms and 4 to 5 days for TAAAs.
- Cerebrospinal fluid drainage is discontinued on postoperative day 2, after a 6-hour clamp trial and documentation of normal coagulation profile.
- Oral diet is resumed the day after the operation for uncomplicated cases requiring two to three fenestrations, but it is typically withheld for 1 or 2 days for difficult cases or those requiring four fenestrations or branches.
- A CTA and baseline duplex ultrasound of the visceral branches is obtained prior to dismissal. Follow-up includes clinical examination and imaging (CTA and ultrasound) in 6 to 8 weeks, every 6 months during the first year, and yearly 1 year, and early thereafter.
- Patients are started on aspirin indefinitely. Clopidogrel is not recommended unless there is a specific concern with one of the side branches because of small size (<4 mm), occlusive disease, or dissection. Clopidogrel should be avoided early after extensive TAAA repair because of risk of delayed spinal cord injury and paraplegia, which may necessitate replacement of the spinal drain.

OUTCOMES

- Fenestrated and branched stent grafts have been widely applied to treat pararenal and TAAAs. Early mortality rate is dependent on the extent of repair. For pararenal aneurysms, mortality ranges from 0% to 3% in single-center reports[11,12] and averages 1.8% in a systematic review.[13] TAAAs are associated with early mortality of 0% to 9% in single-center reports.[14,15]
- Technical success is high for endovascular repair using fenestrated stent grafts (91% to 100%)[16,17] and branched stent grafts (93% to 100%).[11,18]
- Endoleaks from the attachment sites (type I and type III) are uncommon with fenestrated and branched stent grafts. Type II endoleak is the most common type of endoleak and occurs in 0% to 20% of the patients.[19,20]
- Branch vessel patency is excellent with fenestrated branches, averaging 90% to 100%.[15,21] In a recent report by Mastracci and associates,[22] freedom from any branch-related complication (occlusion, kink, reintervention) was 84% at 5 years.

COMPLICATIONS

Intraprocedural Complications

- ***Fenestration misalignment***
  Neck angulation, tortuosity, and errors of design or implantation can lead to misalignment between the fenestration and the target vessel. Several maneuvers can be used to overcome misalignment between the fenestration and the vessel. Initially, the catheter and guidewire are rotated to "probe" the aortic wall in search for the vessel. To maintain access into the fenestration, a 7-Fr Ansel sheath is advanced into the fenestration and secured by a 0.018-in guidewire, whereas a 5-Fr "buddy" catheter (e.g., Van Schie [VS] 3) is used to locate the renal artery. In patients with down-going or stenosed renal arteries, it may be difficult to advance the

catheter over a soft glidewire. The catheter and glidewire may bounce up into the top cap, providing support for the catheter to be advanced deep into the renal artery.

- Diameter-reducing ties are located posteriorly, which may result in the fenestrations being pulled slightly more posterior than its intended location. A useful maneuver is to gently rotate each fenestration, usually anteriorly. Other maneuvers are rarely needed but included use of curved catheters (e.g., VS1 or SOS) for down-going vessels or vessels that are originating from the lower part of the fenestration, microcatheters, and balloon displacement of the main stent graft. The latter is rarely needed but may provide more room for catheter manipulations.
- ***Branch perforation or dissection***
  Branch vessel perforation and/or dissection can be prevented by meticulous technique, visualization of the tip of the wire, and avoiding wire manipulations. The guidewire should not be positioned in small terminal branches, which are prone to perforate or dissect. It should be visualized and stabilized during exchanges manipulations, avoiding forward or retrograde movement. If perforation occurs, it should be immediately recognized and treated using a microcatheter and coil embolization. Dissections within the main renal artery can be treated by placement of a self-expandable stent.
- ***Endoleaks***
  Type II and type IV endoleaks may occur and should be left untreated. Type I and type III endoleaks (<3%) are infrequent with proper selection of a healthy landing zone and adequate planning.[23] In the U.S. fenestrated trial, there were no type I or III endoleaks.[5] In the event of a type Ia endoleak, the proximal neck may be redilated, but all the alignment stents need to be protected by separate balloons. Type III endoleaks may result from inadequate flare, lack of apposition, use of bare metal stent, or inadequate length into the aorta.
- ***Stent kinks or narrowing***
  Kinks are highly preventable and can be anticipated from careful review of vessel anatomy by CTA. These remain a cause of reintervention or branch vessel loss if not recognized. Short stents (<2 cm) tend to avoid bends and the mid- or distal portion of the renal artery, which has greater respiratory motion. The right renal may have a posterior orientation from its course behind the inferior vena cava. If a kink is anticipated by CTA or is evident by completion angiography, a self-expandable stent should be placed. Kinks or narrowing may also result from inadequate flare, strut compression, and ostial disease. In these cases, angioplasty or stenting with a second balloon-expandable stent may be recommended.

Postoperative Complications

- Spinal cord injury
- Stroke
- Cardiac events (myocardial infarction, arrhythmias, congestive heart failure)
- Pulmonary complications (pneumonia, prolonged ventilation, tracheostomy)
- Gastrointestinal complications (ileus, pancreatitis, cholecystitis)
- Systemic inflammatory response (fever, leukocytosis, thrombocytopenia)
- Renal function deterioration
- Access-related problems (bleeding, thrombosis, pseudoaneurysm)

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Chapter 19

Stenting, Endografting, and Embolization Techniques: Celiac, Mesenteric, Splenic, Hepatic, and Renal Artery Disease Management

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DEFINITION

- The content discussed in the following text presupposes familiarity with basic wire and catheter-based endovascular techniques. For a summary of such techniques, the reader may refer to excellent existing references.[1]
- Various occlusive and/or aneurysmal disease processes in renal and visceral arteries may necessitate endovascular interventions (Table 1).
- Progressive renal artery stenosis (RAS) or occlusion may predispose to renovascular hypertension (RVH; most common form of secondary hypertension) and ischemic nephropathy.[2] Aortic atherosclerosis at the ostia or proximal renal artery accounts for two-thirds of cases.[3] Fibromuscular dysplasia (FMD) also causes progressive serial stenoses throughout the renal arteries and may also predispose to RVH. FMD occurs most commonly in younger female patients.[4]
- Acute mesenteric ischemia (AMI) and chronic mesenteric ischemia (CMI) are life threatening but fortunately rare (1 in 1,000 and 1 in 100,000 hospital admissions, respectively) conditions.[5,6] The infrequent nature of symptomatic mesenteric ischemia may be due to the rich collateral supply derived from the celiac, superior, and inferior mesenteric arteries. CMI most commonly develops following progressive atherosclerotic occlusion of two or more mesenteric arteries, with the superior mesenteric artery (SMA) being the most critical of the three. Arterial embolization, leading to acute occlusion of the celiac artery or SMA, more commonly is associated with AMI.[6] In rare circumstances, in critically ill patients, impaired intestinal perfusion due to arterial vasospasm may occur in the absence of thromboembolic occlusion.
- Extra- and intraparenchymal renal artery branch aneurysms occur with a reported autopsy incidence between 0.01% and 0.7% and may arise from various disease etiologies.[7] Overall, the risk of acute clinical evolution (rupture or thrombosis) is low but may be increased during pregnancy, with high resultant maternal and fetal mortality. The risk of progression/rupture, as is the case in most visceral artery aneurysms, is presumed to decline significantly following menopause.
- Aneurysms of the celiac artery, SMA, and their branches are also infrequent and associated with varying etiologic entities. Splenic artery aneurysms are the most common (60%), followed by aneurysms in the hepatic (20%), superior mesenteric, and celiac arteries, in that order.[8,9] Syndromes such as polyarteritis nodosa or Kawasaki's disease may be associated with aneurysms in various segments of the mesenteric arterial circulation. Guidelines for intervention vary, depending on aneurysm location, rate of enlargement, symptom status, and demographic considerations: age, gender, and menstruation status.

Table 1: Renal/Visceral Arterial Disease

Causes of renal/visceral artery stenosis or occlusion	• Atherosclerosis • Fibromuscular dysplasia • Dissection • Coarctation syndromes • Extrinsic compression • Vasculitis • Hypercoagulable state
Causes of renal/visceral artery aneurysm	• Extension of aortic aneurysmal disease • Atherosclerotic degeneration • Blunt or penetrating trauma • Fibromuscular dysplasia • Connective tissue disorder • Iatrogenic injury

PATIENT HISTORY AND PHYSICAL FINDINGS

- RVH, with or without concurrent evidence of ischemic nephropathy, is seen in less than 50% of individuals manifesting severe RAS.[2,3] Hypertension in children, new onset hypertension in individuals younger than 30 or older than 55 years old, or accelerated hypertension should prompt suspicion for the presence of RAS. Older patients with RVH/RAS typically manifest other stigmata of systemic vascular disease, including coronary and cerebrovascular disease, in addition to peripheral vascular disease. In patients with severe bilateral RAS, renal failure may be exacerbated with recent initiation of an angiotensin-converting enzyme (ACE) inhibitor.[10] Acute exacerbations of poorly controlled RVH may manifest with "hypertensive crisis," flash pulmonary edema, or neurologic symptoms ranging from headache to seizure and stroke. Physical examination may reveal severe elevation of both systolic and diastolic blood pressures, abdominal bruits, and other manifestations of peripheral arterial occlusive disease.
- Patients with CMI are typically elderly and have a prior history of symptomatic vascular disease. Like RAS/RVH patients, CMI rarely is present without other signs and symptoms of advanced vascular disease, including aortic and mesenteric branch arterial calcification on plain x-ray films of the abdomen. Symptoms produced by CMI are frequently nonspecific and intermittent, leading to delayed diagnosis and disease progression. Classical symptoms usually include postprandial dull/crampy midepigastric abdominal pain, progressive weight loss, and "food fear" with decreased caloric intake.[11] Findings on physical examination are usually noncontributory, save those related to advanced peripheral

vascular disease (e.g., absent pedal pulses); patients frequently are malnourished and cachectic. Abdominal auscultation frequently reveals hyperactive bowel sounds, and a bruit may sometimes be auscultated.

- AMI presents more dramatically, with sudden onset of abdominal pain, often in patients suffering acute embolic occlusion of the SMA. Although pain may seem out of proportion to objective physical examination findings initially, progressive tenderness to palpation and ultimately peritoneal signs develop in parallel with diminishing bowel viability. Clinical status also rapidly deteriorates, with progressive metabolic acidosis, shock, and multisystem organ failure.[6]
- Patients with renal artery aneurysms (RAAs) may provide a history of trauma, arterial dissection, syndromic vascular conditions, connective tissue disorders, or RAS. The majority of RAAs are asymptomatic at the time of diagnosis, identified as incidental findings on cross-sectional imaging studies ordered for unrelated indications. Specific associated historical and physical findings are rare but may include acute onset hypertension, abdominal distension, flank pain, hematuria, syncope, and shock. Occasionally, an abdominal pulsatile mass is present on physical examination.[7] Although not always fatal, RAA rupture, particularly those in segmental branches, frequently predisposes to renal infarction and resultant decrease in glomerular filtration capacity.
- Patients with aneurysms of the celiac and SMAs and derived branches may manifest with a history of arterial dissection, trauma, pancreatitis, or other local inflammatory processes or infections. One-third of patients may also have aneurysmal disease in other segments of their arterial anatomy.[8] As is the case with RAAs, patients rarely present with symptoms other than rupture, which itself is also rare. Free rupture may result in hemoperitoneum, hematobilia, or life-threatening gastrointestinal hemorrhage. The risk of rupture is highest with hepatic (20% to 44% of mesenteric arterial aneurysm ruptures) and splenic artery aneurysms, the latter notoriously at risk during the third trimester of pregnancy.[12,13] Presence of a splenic artery aneurysm recognized during pregnancy should prompt consideration of immediate repair, regardless of the status of the pregnancy.[14]

IMAGING AND OTHER DIAGNOSTIC STUDIES

- Renal artery disease assessment usually begins with duplex ultrasonography, which has a reported sensitivity of 86% to 93%, specificity of 98%, and overall accuracy of 96%.[15] Duplex criteria used to diagnose more than 60% RAS include an arterial peak systolic velocity of more than 180 to 200 cm per second, a ratio of renal artery to aortic peak systolic velocity of more than 3.5, or acceleration time between onset and peak of systole of more than 100 m per second. Kidney length and resistive indexes derived from parenchymal insonation may also provide important insight into the presence, nature, and severity of end-organ disease.
- Similarly, duplex ultrasound provides a useful, noninvasive method of assessing for the presence of chronic mesenteric occlusive disease.[16] In the celiac artery, peak systolic velocities of more than 200 cm per second provides a sensitivity and accuracy for detecting a greater than 70% stenosis of 87% and 82%, respectively. In the SMA, peak systolic velocities of more than 275 cm per second provides a sensitivity and accuracy for detecting a greater than 70% stenosis of 92% and 96%, respectively.
- Computed tomography angiography (CTA) is the current gold standard for confirming the presence, severity, and extent of occlusive mesenteric vascular disease. CTA-derived images also provide insights into the potential underlying mechanism of occlusion, including FMD, associated dissection, evidence of inflammation/infection, or thromboembolic occlusion. Moreover, three-dimensional reconstructions generated from CTA datasets also provide valuable guidance for preprocedural planning. In emergent circumstances, such as those associated with suspected AMI, CTA usually represents the "go-to" diagnostic test.
- For patients with contrast allergies or other contraindications to computed tomography (CT) scanning, magnetic resonance angiography (MRA) may provide a suitable alternative, particularly for initial diagnosis and screening purposes. Overall resolution of MRA is not equal to that of CTA and in some circumstances may not provide sufficient detail for the precise surgical or interventional planning.

SURGICAL MANAGEMENT

Patient Selection

- Appropriate patient selection for endovascular intervention is paramount and dependent on therapeutic indication, anatomy, patient comorbidities, and acuity of the disease process. In the following text, we discuss considerations for patients with renal/mesenteric arterial occlusive disease, followed by considerations for patients with renal/mesenteric arterial aneurysmal disease.
- For RAS, the indication for endovascular intervention is contingent on severity of stenosis, the presence and severity of presumed resulting hypertension, and extent of residual glomerular filtration capacity. For RAS, there is no accepted indication currently for "prophylactic" intervention. Endovascular intervention is considered only in patients with severe hypertension, who have failed medical management with at least three concurrent antihypertensive medications or have demonstrated progressive loss of renal function due to ischemic nephropathy in the setting of more than 60% RAS. The future role for endovascular intervention in treating RVH has been called into question by level I data demonstrating only modest reductions in blood pressure following renal artery stenting.[17]
- Patients with critical stenosis or occlusion of at least two mesenteric arteries, in the setting of signs and symptoms consistent with CMI, are also potential candidates for endovascular management. Patients with atypical symptoms who may meet anatomic criteria for mesenteric occlusive disease often experience disappointing results following endovascular intervention.
- Given the compromises inherent in management of AMI, often in the setting of uncertain bowel viability, hybrid open and endovascular approaches may represent the safest and most expeditious option. Particularly in regard to "acute-on-chronic" occlusion of the proximal SMA, with a patent distal segment preserved by collateral flow, surgical exposure at celiotomy enables distal SMA cannulation and sheath placement. Standard angiographic techniques are

then employed to cross the occlusive proximal lesion in a retrograde fashion, with subsequent angioplasty and stenting performed to restore pulsatile antegrade flow.[18] We have employed this technique reliably under a variety of challenging clinical conditions with consistently good results.

- In patients with disease in multiple mesenteric arterial segments and symptoms concerning for mesenteric ischemia, SMA revascularization, either via endovascular or open surgical approaches, represents the most reliable and effective method for resolving critical mid- and distal gut ischemia. Decompressive laparotomy should always be considered as an essential adjunct in these circumstances, regardless of revascularization method used, to facilitate selective resection of nonviable bowel if needed and limit the noxious effects of abdominal compartment syndrome in these already compromised patients.
- In comparison, the safety and use of primary inferior mesenteric artery (IMA) endovascular intervention remains controversial in patients with disease in multiple mesenteric arteries. Recent series report relatively frequent procedure-related complications and poor outcomes following attempted IMA intervention.[19] These results may in part be due to the progressive nature of occlusive vascular disease in the most distal aortic segment at the level of the IMA and resulting difficulty in resolving significant ostial stenoses with even high-pressure angioplasty techniques.
- The criteria for elective repair of asymptomatic RAAs is controversial. Recommendations vary for intervention based on aneurysm diameter, also taking into account the size of the parent artery, extent of mural calcification, and rate of enlargement, if available. Consensus exists regarding treatment for all aneurysms larger than 3 cm in diameter.[20,21] Similarly, patients with intact but symptomatic true aneurysms, recent-onset false (pseudo-) aneurysms, and aneurysms resulting from associated FMD are also typically repaired promptly, given their presumed higher risk of rupture. RAAs in women of childbearing age with plans for future pregnancies are usually repaired, when recognized, at almost any size. Less agreement is present for RAAs larger than 2 cm but smaller than 3 cm in diameter, with treatment recommendations often customized based on individual circumstances.
- There are no set size criteria for visceral artery aneurysm repair. Although larger aneurysms are thought to have an increased potential risk of rupture, small visceral artery aneurysms are also known to rupture and manifest with life-threatening hemorrhage. Therefore, most visceral aneurysms larger than 2 cm should be repaired when identified. This recommendation does not necessarily apply to poststenotic arterial dilations (not true aneurysms) and distal SMA aneurysms. The latter are generally best managed by embolization and/or resection of the dependent loops of adjacent small intestine. In most circumstances, ruptured visceral artery aneurysms are best managed by open or hybrid approaches, allowing for assessment of bowel or end-organ ischemia in conjunction with restoration of arterial flow.

Preoperative Planning

- Prior to attempted repair or exclusion, aneurysm location and access issues should be precisely determined via cross-sectional imaging studies. Luminal plaque, thrombus burden, associated aneurysms, and preexisting dissections should also be noted. Finally, target vessel diameter should be determined at several intervals before, within, and after the lesion of interest to optimize coil, stent, and graft selection.
- The preferred method of critical renal artery ostial lesion management is by balloon-expandable stent placement. In rare circumstance, angioplasty predilation may be required to advance the appropriate stent through the renal ostia and across the stenotic lesion. Renal artery stents range from 10 to 30 mm in length and 4 to 7 mm in diameter. Transfemoral approaches to the renal artery are generally preferred due to the shorter distance to target, smaller imaging fields, and abundant availability of purpose-specific instrumentation. However, cephalad angulation of the renal artery origins relative to the aorta, the presence of extensive infrarenal aortoiliofemoral arterial occlusive disease, or significant iliac artery tortuosity may favor consideration of the left brachial artery and descending thoracic aorta as the preferred route of access.
- For the treatment of mid- to distal RAS in the setting of FMD, angioplasty alone is generally the preferred treatment modality. Either transfemoral or transbrachial approaches may be considered, depending on the considerations noted earlier. Care must be taken to minimize procedural trauma with precise determination of target artery diameter and selection of appropriately sized instruments (sheaths, balloons, and stents). Poor planning or ill-considered procedural technique may precipitate arterial dissection, thrombosis, and renal infarction.
- Depending on the degree of lesional calcification, the extent of associated juxtaostial aortic occlusive disease, lesion length and associated target vessel tortuosity, balloon- or self-expanding stent grafts may be chosen for luminal reconstitution and may provide improved long-term patency in the proximal SMA.[22] Cannulation of either the celiac or SMA may be achieved from both femoral and brachial approaches. However, in emergent or extenuating circumstances, left brachial access often proves more expeditious and effective. This is particularly true in the setting of high-grade ostial stenosis or occlusion, where brachial access and antegrade aortic sheath placement may provide improved guidewire, sheath, and crossing catheter pushability and trackability.
- Successful wire cannulation of ostial SMA and celiac lesions may require “telescoping” techniques with different sheath and wire combinations (see in the following text). This is also true of attempts to deploy devices in the mid- and distal splenic artery, where a triaxial catheter and sheath combination extending into the target lesion is frequently most effective. Given the short and often tortuous nature of the celiac artery, stable sheath placement is challenging, often representing the most difficult aspect of the procedure.
- Similar principles are used when treating aneurysms of renal and visceral arteries, including precise catheter positioning and stable sheath support. Aneurysm size, location, neck anatomy, and extent of tortuosity of feeding target vessels impact the strategy of repair. For example, for large retropancreatic splenic artery aneurysms, coil embolization of the aneurysm sac (preferably with large-end-first or nesting coils) prior to covered stent placement across the ostium of the aneurysm is necessary to ensure long-term procedural

success. For precise embolization of shallow or wide-necked aneurysms, adjuncts such as distal balloon occlusion with deployment of detachable coils may be necessary. For more accessible aneurysms with a wide-based aneurysm neck, bare metal stenting may be performed across the ostium of the aneurysm first, followed by placement of coils through the open interstices of the stent to keep the coils localized to the area of interest. Branch artery aneurysms usually occur at bifurcation points and are accompanied by small, well-defined necks and are ideally suited for embolization with microcoils (0.018-in catheter compatible) delivered through a triaxial delivery system.

- The preferred size/shape of embolization devices or covered stents may be either accurately estimated from a preprocedural CT arteriogram or determined at the time of angiographic imaging and sheath placement. Based on these measurements, coil and plug diameters may be oversized by 20% of the target vessel diameter. The length of coils selected is derived from the anticipated arterial lumen surface area that requires embolization. Similarly, the length of vascular plugs selected depends on the target artery to be embolized and the estimated luminal flow. For example, higher flow arteries, such as those proximal to arteriovenous fistulae, usually need more extensive coverage to ensure definitive occlusion. Both self-expanding and balloon-expandable stent grafts are available. The former are also typically oversized by 20%, and the latter are usually sized 1 mm greater than the target artery diameter. Attention should be given to the sheath selection to ensure adequate diameter and length. The device-specific instructions for use (IFU) should be consulted in all circumstances prior to use of occlusion devices, or more generally, any endovascular device with the potential risk for significant vascular injury.
- Depending on their specific location, some visceral artery aneurysms may be embolized without specific end-organ ischemic injury. However, embolization of distal aneurysms, such as those located within the splenic hilum, may result in splenic infarction, further bleeding, or abscess formation. Therefore, splenectomy remains a viable alternative method of splenic artery aneurysm management for many patients. Appropriate vaccinations should be administered with sufficient lead time to allow for an appropriate immunization response prior to elective splenic artery embolization procedures or planned splenectomy.

Operating Room Setup

- Procedures may be performed in an angiography suite, or in an operating room, equipped with a floating-point carbon fiber, radiolucent operating table; fluoroscopy platform; and monitor-viewing bank. However, for precise visceral artery interventions requiring steep oblique/lateral imaging and higher fluoroscopic kilovolt (kV), portable systems in the operating room setting may not provide sufficient image clarity and resolution. Under these circumstances, use of a fixed-imaging system, either in an angiography suite or hybrid operating room, will maximize the likelihood of success.
- For the majority of elective renal and visceral artery interventions, conscious sedation with a combination of short-acting analgesic and sedative agents will provide adequate patient comfort, immobility, and optimal imaging parameters. Standard patient safety measures for conscious sedation, including supplemental oxygen, standard monitoring, and availability of resuscitation equipment should be employed in compliance with local hospital policy. However, general anesthesia is clearly indicated to facilitate treatment of AMI, urgent/emergent management of aneurysm rupture, and/or hemorrhage potentially requiring bowel resection or open conversion.
- For the most part, all renal and visceral artery endovascular interventions can be performed with the patient in the supine position. The left arm may be positioned out at 90 degrees to allow for transbrachial interventions. If a transfemoral intervention is planned, the patient's arms may be extended over the head to aid with image clarity; however, most patients can only tolerate this for certain time periods prior to fatigue. Placing the patient in a 30-degree rotation to the right, on bolsters placed behind the left flank, at the time of the procedure, will facilitate "true lateral" position to localize and cannulate the origin of the SMA without requiring the image intensifier and radiation source to be in full horizontal position and limiting operator access to the patient as a result.
- In addition to a full array of complementary wires, catheters, and sheaths, premounted balloon-expandable stents and stent grafts should be available, including in low-profile platforms (0.014 in or 0.018 in). Appropriate sizes of coils and plugs should also be identified and readily available.

RENAL ARTERY ANGIOPLASTY AND STENTING

First Step

- For arterial access, a retrograde transfemoral approach is usually selected; however, antegrade transbrachial access may improve accessibility and sheath stability in the presence of significant abdominal/pelvic girth, significantly down-sloping renal arteries, or tortuosity/obstruction of the distal aorta or iliac arteries.
- Arterial access is usually obtained percutaneously using standard Seldinger technique. Bedside ultrasound may facilitate precise placement. Once an interventional sheath access is placed, intravenous unfractionated heparin is administered to maintain an activated clotting time (ACT) of more than 200 seconds.

Second Step

- Wire access to the pararenal aorta may be achieved with 0.035-in guidewire. A 4- or 5-French (Fr) flush catheter is advanced over the guidewire to approximately the level of the 1st lumbar vertebral body.
- If renal function permits, a complete aortoiliac arteriogram in anterior–posterior image intensifier orientation

should be performed to assess both the renal arteries and renal accessory arteries. A power injector should be used for the road map aortogram, using a high injection rate (e.g., 15 to 20 mL per second) and low volume (e.g., 10 to 15 mL). Breath-holding instructions should be given to the patient or the assisting anesthesiologist to allow for aortogram acquisition during end expiration. Glucagon (0.25 to 2 mg intravenous; approximately 10 minutes pre-procedure) can also be administered to diminish intestinal motility and enhance arterial visualization.

- A magnified angiogram can be repeated of areas of interest and intended treatment. For better visualization of the renal artery, the image intensifier should be oriented with a few degrees in cranial and lateral obliquity ipsilateral to the renal artery of interest.
- Intraoperative angiographic measurements are obtained to confirm device selection. A marked flush catheter or radiopaque ruler may facilitate accurate angiographic measurements.

Third Step

- A stiff 0.035-in guidewire (i.e., Amplatz, Rosen) is placed in the pararenal aorta to facilitate advancement of a 45-cm 8-Fr renal dilation guide catheter (RDC), or 6-Fr RDC sheath (i.e., Terumo Pinnacle™ destination or Cook Ansel™ Flexor™). The sheath dilator tip should not be advanced into the target vessel to avoid compromise of the residual vessel lumen.
- Wire cannulation of the renal artery is the essential first step. Depending on the angle of entry at the orifice, a number of different catheter tip shapes may facilitate successful renal cannulation (Sos 1 or 2, Cobra, Vanchi, etc.). Once cannulated, the sheath tip is advanced immediately adjacent to, but not across, the renal artery orifice (FIG 1). A 0.014-in or 0.018-in stiff guidewire with a floppy or hydrophilic tip is then employed to probe across areas of severe stenosis, through a reverse curve or angled catheter, depending on the optimal angle for access. Alternatively, a 0.035-in guidewire, with improved handling and radiopacity, may provide suitable trackability for less critical stenoses.
- Once access is achieved, the wire should be advanced to a secondary branch to optimize positional stability. Care should be taken to maintain wire tip visualization in the field of view, particularly when using hydrophilic guidewires, as they can easily perforate parenchymal arterioles when advanced too far into the segmental renal circulation. Parenchymal perforation may precipitate intra- or extracapsular hematoma formation, renal hemorrhage, and circulatory collapse unless immediately recognized and corrected.

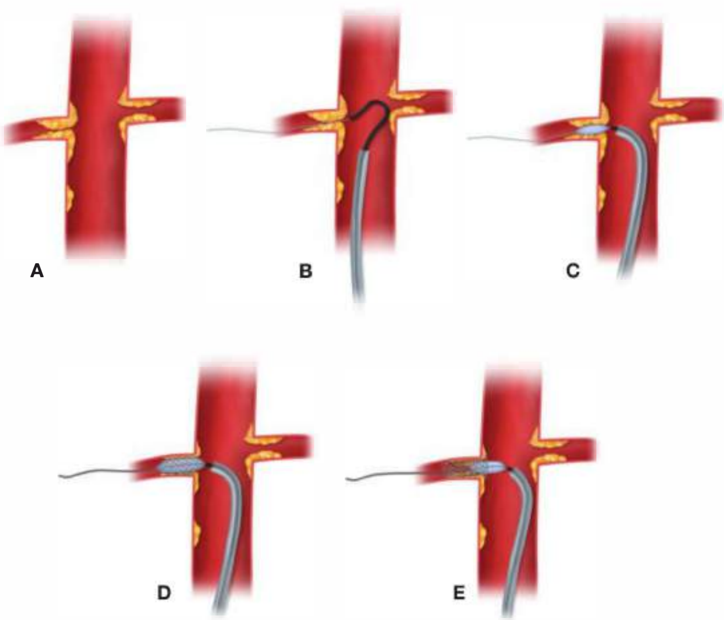

FIG 1 ● **A.** Pararenal aorta demonstrating high-grade stenosis at the right renal artery orifice. **B.** Cannulation of the right renal artery with a 0.014-in or 0.018-in glidewire guided by a curved-tip catheter. Wire and catheter cannulation system are stabilized by a 6-Fr sheath. The cannulating wire is advanced into the distal right renal artery to provide additional stability to the system. **C.** The right renal artery orifice stenosis is predilated with a low-profile, small-diameter balloon. **D.** Using sheath support for stability, an appropriately sized balloon-expandable stent is deployed across the stenosis and is protruding 1 mm into the aortic lumen. **E.** While maintaining cannulation system, protruding edge of the stent is flared into the aortic lumen with an appropriate compliant angioplasty balloon.

Fourth Step

- Prior to renal artery stenting, predilation may be necessary to provide sufficient luminal space for delivery of the crimped stent/delivery catheter (**FIG 1**). A 2- to 4-mm low-profile, semicompliant, or coronary balloon compatible with a 0.014-in or 0.018-in system can be used for this purpose. Care needs to be taken to maintain wire position during subsequent stent exchange; loss of wire position here can preclude stent delivery or precipitate luminal thrombosis if aortic and/or orificial atheroma is displaced by predilation.
- Using a low-profile 0.014-in or 0.018-in system (rapid exchange or over-the-wire [OTW]), a balloon-expandable stent (e.g., Cordis Palmaz Blue, Boston Scientific Express SD, Cook Formula) is delivered across the lesion (**FIG 1**). The low-profile nature of these devices enables facile placement, as well as contrast delivery across the lesion to confirm appropriate position. Rapid exchange or monorail systems allow for shorter wire length, aiding procedural efficiency vis-à-vis catheter/wire/device exchanges. In contrast, OTW devices provide improved pushability and trackability across constricting lesions.
- For mid- or distal RAS, the shortest balloon-expandable stent length providing complete coverage should be selected. For mid- or distal RAAs, appropriate length self-expanding or balloon-expandable stent grafts should be selected to provide adequate pre- and postaneurysm renal artery sealing zones (**FIG 2**).
- Following stent placement under fluoroscopic guidance, the balloon should be deflated fully prior to its withdrawal to avoid movement or dislodging of the stent. Areas with substantial tortuosity may precipitate arterial kinking at the transition point between stented and nonstented segments. Excessive oversizing, or overinflation of stents mounted on semicompliant balloons, may promote renal artery injury, dissection, or thrombosis. Temptation to optimize the postprocedural angiographic image, potentially at the expense of vessel integrity or anticipated long-term patency, should also be avoided.
- For ostial renal artery lesions, the balloon-expandable stent should be positioned so that the aortic end is deployed approximately 1 mm into the aortic flow stream. The aortic edge of the stent can be “flared” outward with a repeat angioplasty using the distal edge of the same balloon (**FIG 1**).

Fifth Step

- After successful deployment, the sheath should only be withdrawn after the completion imaging encompassing the entire ipsilateral kidney is performed to confirm uniform perfusion and absence of parenchymal and/or capsular injury.
- Following withdrawal of the sheath from the renal orifice, while maintaining wire access, completion paraorificial aortography is performed to confirm stent positioning and target lumen diameter. Residual stenosis, kinking, or dissection should be confirmed to be absent prior to withdrawal of the wire.

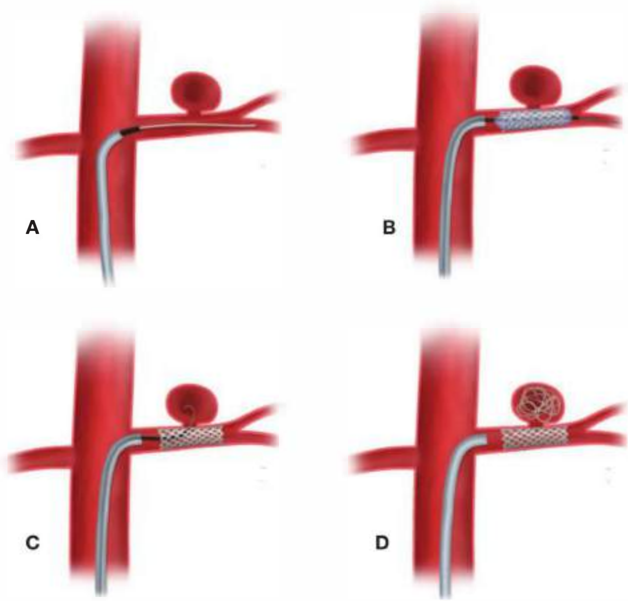

FIG 2 ● **A.** Left renal artery has an associated saccular aneurysm. Cannulation of the left renal artery is facilitated with an angled guidewire and curved-tip catheter. The cannulation system is stabilized by an appropriately sized sheath. **B.** A bare metal stent is deployed across the origin of the left RAA. **C.** A telescoping technique is used to cannulate the aneurysm sac through an interstice of the bare metal stent. Sheath tip is advanced to the renal artery orifice and catheter is advanced up to the inner luminal wall of the bare metal stent to stabilize and facilitate cannulation of the aneurysm sac. **D.** Appropriately sized coils are deployed into the aneurysm sac through the stent interstices.

VISCERAL ARTERY ANGIOPLASTY AND STENTING

First Step

- As previously noted, access considerations need to account for individual patient anatomy, operator experience and skill, available devices, potential complications, goals of treatment, and anticipated time of the procedure. Most internationalists prefer the transfemoral approach for visceral vascular access. However, proximal left brachial artery exposure and puncture often facilitates access to significantly down-sloping or tortuous mesenteric arteries.
- A 4- or 5-Fr sheath is placed in the arterial access site to facilitate advancement of a 4- or 5-Fr marked flush catheter to the paravisceral aorta.
- Intravenous unfractionated heparin is administered after sheath placement to achieve an ACT of more than 200 seconds.

Second Step

- After a standard aortogram, a magnified paravisceral aortogram can be performed with the image intensifier placed in a steep oblique or true lateral position to optimize localization and cannulation of the celiac artery and SMA origins.
- Care should also be taken here to visualize the major branches of the celiac artery and/or SMA. Attempts should be made to visualize the first significant branch of the SMA, usually the middle colic artery, to avoid inadvertent coverage and/or compromise of colonic arterial perfusion as a consequence of planned procedures.
- Visceral lesions of interest can be further characterized at this time by optimizing image intensifier obliquity. Accurate measurements are facilitated by marked flush catheter or radiopaque ruler placement.

Third Step

- After withdrawal of the flush catheter, a stiff guidewire and a long (90 cm), braided 6-Fr sheath (i.e., Terumo Pinnacle™ destination, Cook Ansel™ Flexor™) is advanced to the paravisceral aorta. Various angled sheath tips (i.e., straight, angled hockey tip, curved) can be used depending on the degree of visceral artery angulation, aortic diameter, and access approach (femoral or brachial).
- Along with selected sheath, various guide catheter types (i.e., angled, vertebral, cobra, RDC, or reverse curved SIM or Sos catheters) can be used to facilitate visceral artery cannulation.

Fourth Step

- An exchange-length, stiff 0.014-in or 0.018-in guidewire, with a floppy tip, is advanced through the preselected catheter and sheath combination. However, wire cannulation of a diseased visceral arteries orifice may be challenging. From the brachial approach, successful cannulation may be facilitated with sheath placement distal to the artery of interest, followed by gradual withdrawal of the sheath with the selected angled catheter inside the sheath protruding slightly outward. When the catheter "clicks" into place, an exploratory hydrophilic guidewire is then gently advanced to obtain luminal access. Once the lumen is cannulated, the guidewire is then advanced to a secondary visceral branch to facilitate catheter and sheath advancement, as indicated (FIG 3). Another cannulation strategy is to withdraw wire and catheter combinations from a stable sheath position

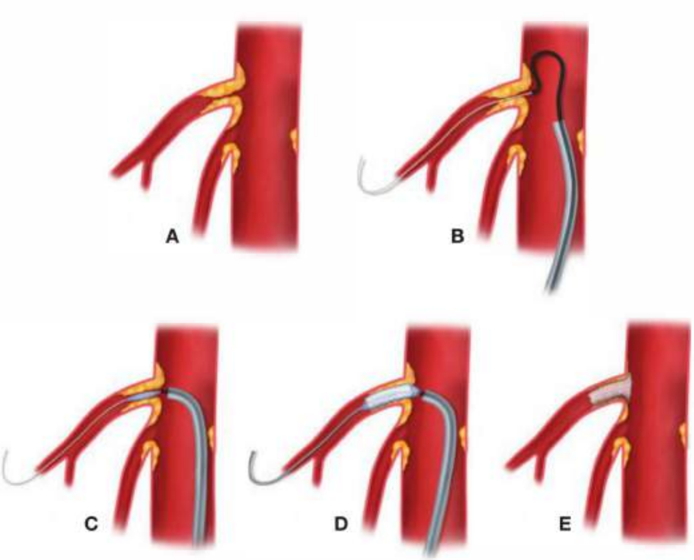

FIG 3 ● **A.** High-grade stenosis of the proximal celiac artery origin. **B.** A curved-tip guide catheter is used to facilitate celiac artery cannulated with a 0.014-in or 0.018-in guidewire. The cannulation system is stabilized with distal advancement of the guidewire into a celiac artery branch, as well as maintaining a sheath in the aortic lumen. **C.** A low-profile, compliant predilation balloon may be advanced over the guidewire to dilate the stenosis and provide a tract for future stenting. **D.** An appropriately sized balloon-expandable covered stent graft is deployed across the stenosis while slightly protruding into the aortic lumen. **E.** Full stent apposition following deployment and proximal flaring of the stent graft at the prior stenosis site.

across the anticipated vessel orifice area at various "clock" positions.

- For a "no-touch" technique, a shaped catheter or sheath tip is positioned luminally in direct proximity to the orifice of interest. A 0.014-in or 0.018-in hydrophilic guidewire is then used to localize and facilitate cannulation. To improve trackability and pushability of the system, a stabilizing "buddy" stiff guidewire may also be advanced, when necessary, to "pin" the cannulation sheath to the opposite wall.
- When single-wire cannulation proves inadequate to support catheter and sheath advancement in to the target vessel, placement of a second, or even third 0.014-in or 0.018-in wire, across the area of stenosis may facilitate successful catheter/sheath advancement.

Fifth Step

- An appropriately sized self-expanding or balloon-expandable stent graft is preferred for the treatment of visceral artery stenoses. Predilation of the tract may be necessary with a small, low-profile balloon to facilitate advancement of the balloon-expandable stent (**FIG 3**).
- The aortic end of a balloon-expandable stent used for the treatment of ostial or proximal visceral artery lesions should be positioned 1 mm into aortic flow lumen, and the stent edge should be flared out with the edge of an angioplasty balloon.
- Accuracy of deployment of self-expanding stent grafts can be improved with partial deployment of the stent while maintaining the cannulation sheath in the orifice of the visceral artery. Once the distal portion of the stent graft is accurately deployed, the remainder of the proximal stent graft can be unsheathed to allow for full deployment. An appropriately sized compliant balloon may then be subsequently used to fully mold the self-expanding stent graft to profile and/or slightly flare the aortic edge.
- For friable lesions, or lesions that may include fresh thrombus, consideration should be given to advancing and deploying balloons and stents over a filter wire (0.014-in eV3 SpiderFX embolic protection system). Although placement of a distal filter may not preclude all embolic sequelae, it may reduce the severity or significance of associated potential complications. This option may be particularly valuable in SMA interventions.

HYBRID REPAIR OF PROXIMAL MESENTERIC ARTERY STENOSIS/ OCCLUSION

First Step

- In the setting of acute or acute-on-chronic mesenteric ischemia, where exploratory laparotomy is otherwise indicated to assess bowel viability, a hybrid retrograde catheterization approach is generally preferred. At laparotomy, surgical exposure of the superior mesenteric or celiac artery is obtained. To expose the celiac artery, the left triangular ligament is incised, the left hepatic lobe is retracted to the right, and the gastroesophageal junction is retracted to the left. Further caudal dissection along the surface of the aorta may be used to expose the SMA origin.
- For purposes of both embolectomy and hybrid retrograde catheterization, exposure of the proximal section/midsection of the SMA is preferentially obtained at the superior root of the small bowel mesentery (**FIG 4**). This location generally provides access 4 or more centimeters distal to the SMA orifice, which allows stable sheath positioning to facilitate retrograde cannulation and stenting. Distal to the lower margin of the pancreas, the length of the SMA is limited by early branching of the ileocolic artery and intestinal cascade, so relatively proximal positioning should be achieved to minimize excessive dilation/trauma to the vessel by the sheath.[18]

Second Step

- When embolic occlusion is present, embolectomy is performed gently through an anterior arteriotomy. The tapering nature of the SMA in this area requires gentle catheter withdrawal with gradual balloon deflation in order to avoid iatrogenic arterial damage, dissection, or thrombosis.
- Retrograde cannulation of an exposed distal segment of the target vessel provides optimal access for definitive endovascular intervention. In emergent conditions with compromised intestine, this approach is preferential to open revascularization strategies, which may require prosthetic graft placement following prolonged, extensive dissection of the mesentery and aortic root.
- Retrograde mesenteric cannulation is facilitated by placement of a longitudinal arteriotomy in the exposed distal segment of the target vessel. To reduce the risk of injury to the exposed artery during cannulation, the arteriotomy site is closed with a prosthetic or autogenous patch. The patch itself is then cannulated to facilitate sheath placement, angiogram, stent placement as well as expedited puncture site closure at the end of the procedure (**FIG 4**).
- Relatively long sheaths (20 cm or more) should be used during retrograde cannulation to ensure that the operator's hands are clear from the fluoroscopy field and minimize operator radiation exposure during catheterization maneuvers.[18]

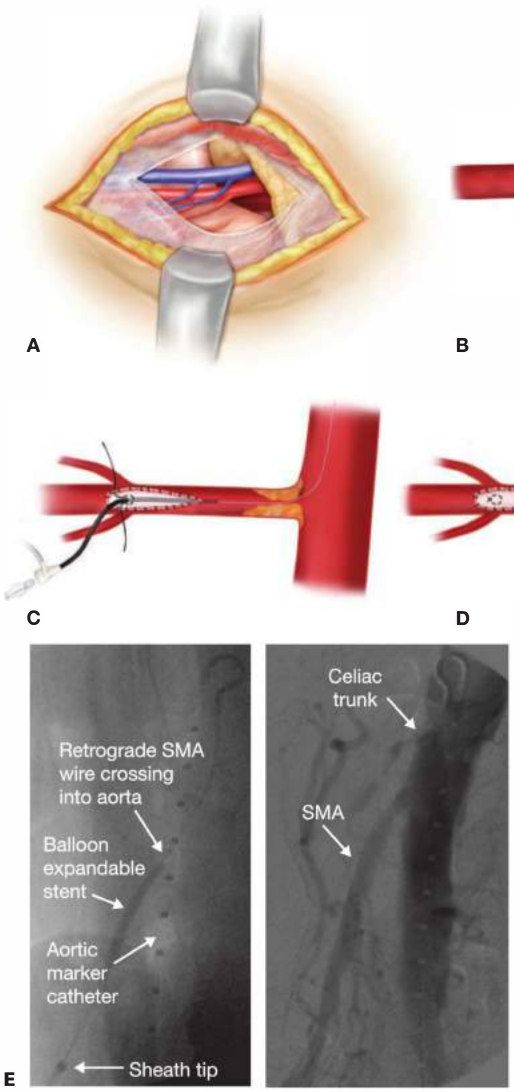

FIG 4 ● **A.** Open exposure of the proximal SMA at the caudal portion of the mesenteric root. **B.** The proximal SMA, ~3 to 4 cm from its aortic origin, is circumferentially exposed while preserving its side branches. A longitudinal arteriotomy is created and thrombectomy is performed with patch angioplasty. **C.** Sheath is placed through a puncture in the angioplasty patch and arteriogram is performed to evaluate stenosis in the proximal SMA origin. **D.** A stent is deployed using fluoroscopic guidance at the SMA origin across the identified hemodynamic stenosis. The patch puncture site is repaired to maintain hemostasis. **Ei.** Retrograde access to SMA, with inflation of balloon expandable stent extending into aorta proximally, spanning length of proximal occlusive lesion. **Eii.** Completion mesenteric arteriogram from aortic injection, showing complete restoration of mesenteric arterial lumen and normal distal arterial perfusion. Retrograde mesenteric wire has been removed, and arteriotomy closed at the patch site in distal SMA.

RENAL OR VISCERAL ARTERY EMBOLIZATION

First Step

- Arterial access can be secured via either a left brachial artery or transfemoral approach, depending on the intended target vessel and its angulation relative to the aorta.
- For standard coil embolization, a 5- or 6-Fr sheath access will be adequate. However, if an occlusion device will be used, a larger sheath size may be required depending on device specifications.
- Systemic anticoagulation with intravenous unfractionated heparin is also commonly used during these procedures.

Second Step

- Angiographic characterization may require angiograms in multiple different obliquities to fully appreciate size, extent, and angulation of the lesion of interest, particularly those affecting secondary visceral branches. In the angiographic parlance, regarding the extent, severity, and profile of a luminal obstruction, "one view is no view."
- One should note the extent of vascular collateralization associated with the vascular segment that will be embolized.

Third Step

- A telescoping cannulation technique is usually used to enhance the positioning and stability of the embolization

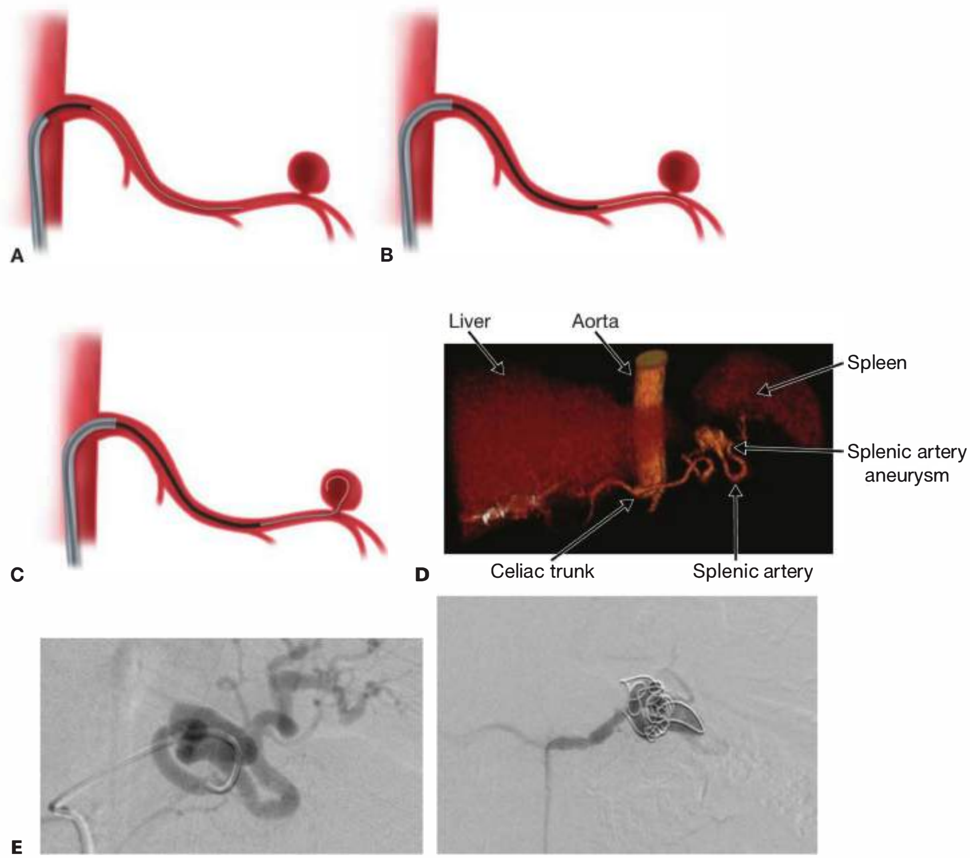

FIG 5 ● **A.** Cannulation is attempted of a saccular visceral artery aneurysm. A sheath and angled catheter facilitate cannulation of the visceral artery origin with a guidewire. **B.** A 0.035-In catheter and guidewire negotiate proximal arterial tortuosity. **C.** A microcatheter is telescoped through the 0.035-in catheter to facilitate wire cannulation of the aneurysm. **D.** Three-dimensional abdominal CTA of a female with a mid–splenic artery saccular aneurysm. **E.** Selective splenic artery aneurysm pre- and postselective coiling.

system. To perform this, a sheath is advanced as close to the target lesion as possible. A catheter is then extended from beyond the tip of the sheath and used to protrude into target lesion (FIG 5).

- Embolization of remote target lesions may require higher orders of telescoping. Placing a sheath into another larger sheath, or a 0.018-in microcatheter (i.e., Codman Prowler™, Cook CXI™, BSCI Renegade™) into a standard 0.035-in guide catheter, can help access more challenging lesions (FIG 5). Alternating wire and microcatheter advancements may facilitate cannulation of smaller and more tortuous arteries (such as the superior and inferior gastroduodenal arteries [FIG 6]) and distal/hilar splenic artery.
- If possible, the cannulation catheter/microcatheter should be advanced into the lesion slightly further than the intended embolization site, because the system can draw back during deployment of coils or plugs.

Fourth Step

- Once the cannulation catheter is positioned in the target lesion, 0.018-in or 0.035-in coils are delivered sequentially into the target area through their respective catheters. For detached coils, the metal tube housing the coil is attached to the back end of the cannulation catheter, and the stiff end of a guidewire is used to push the coil out of its housing unit and into the catheter shaft. The floppy tip of the guidewire is then replaced into the catheter to push the coil along the entire shaft of the catheter and into the lesion (FIG 5). The stiff end of the guidewire should not be used to push the coil into the lesion because it can change the cannulating catheter tip shape and lead to instability in the cannulation system and maldeployment.
- Alternatively, small aneurysm may be occluded with detachable or nondetachable microcoils or ethylene vinyl alcohol copolymer. IFU are variable and should be referred to for recommended deployment techniques.
- When coil deployment can be accurately localized, and precise coil positioning is critical to the success of the procedure, large-to-small tapered coils should be used. When arterial blood flow is needed/required to carry part of the coil into the preferred deployment location, small-to-large tapered coils are preferred in this situation. Newer "nesting" coils will reform immediately into larger, obstructing profiles. Older tubular coils need

to be advanced as they are being deployed to avoid simply lining the target artery without sufficient luminal obstruction. Attention to understanding what coils are in inventory, and how respective coil choices are optimally deployed, is essential for procedural success.

- For larger aneurysms or planned occlusion of an entire vessel lumen, a vascular plug (i.e., AGA Medical Amplatzer™ I or II vascular plug) may be preferable and a more effective means for target embolization. However, plug placement usually requires stable sheath target artery cannulation. Amplatzer™ I and II vascular plugs are produced in diameters ranging between 4 and 22 mm and lengths ranging between 6 and 18 mm. Recommended device IFU should be consulted to ensure proper device selection and deployment. When sheath access cannot be withdrawn to enable plug deployment, catheter-delivered coils should be deployed instead.
- Once a coil or plug is delivered into a lesion, its position may be modified slightly by catheter tip advancement. This maneuver, when performed properly, maximizes the obstructive surface area and resulting coil thrombogenicity.
- When multiple coils or plugs are used, deployment should also be strategized and deliberate. For example, the first coil should be placed in the deepest part of the lesion (base of an aneurysm), whereas the last coil should be placed in the entry point of the lesion (neck of an aneurysm).
- For acutely bleeding vessels (such as the gastroduodenal arteries in the setting of duodenal ulcerations), a "back-door"–"front-door" approach ensures hemostasis. This involves occluding the culprit vessel pre and post the area of bleeding (FIG 6). Coiling only one side of the bleeding artery may prevent further access attempts while not providing sufficient vessel occlusion and hemostasis. Small bleeding pelvic arteries may similarly be embolized using a Gelfoam slurry slush preparation.[23] Recommended IFU should be consulted to ensure proper preparation and administration of these slurries.

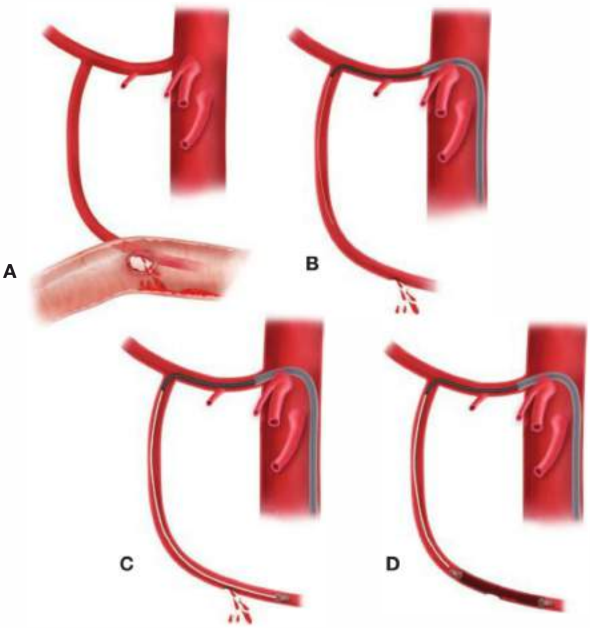

FIG 6 ● **A.** Bleeding gastroduodenal artery with an associated duodenal ulceration. **B.** Sheath cannulation of the common hepatic artery branch of the celiac artery, followed by catheter cannulation of the gastroduodenal artery. **C.** Back-door deployment of an embolization coil distal to the angiographically identified bleeding point in the gastroduodenal artery. **D.** Subsequent "front-door" embolization of the feeding segment of the gastroduodenal artery.

Fifth Step

- It is customary to perform postembolization arteriography to confirm final coil/plug positioning. Residual flow will still be evident in the recently embolized vessel segment, because the patient generally remains heparinized during this period of the procedure. If uncertainty persists as to the adequacy of embolization, arteriography may be repeated following reversal of anticoagulation, taking into account increased risks of thrombosis/embolization around the delivery sheaths and catheters proximal to the targeted lesion.

PEARLS AND PITFALLS

Indications	■ Preoperative imaging (duplex and CTA) should be reviewed in detail to ensure patient suitability and help plan out appropriate intervention. ■ Combining information gathered from duplex and CTA is beneficial, especially in situations when the stenosis is overestimated due to heavy luminal calcification.
Vessel cannulation	■ One should note the angulation of the target vessel relative to the aorta. Because this angle may vary with respiration, angiograms should be obtained while the patient is apneic (if intubated) or at end expiration. ■ Generally, renal arteries and up-sloping visceral vessels may be easier to cannulate from a transfemoral artery approach. Down-sloping renal and visceral vessels may be easier to cannulate from a proximal left brachial artery puncture. ■ Using an angulated, flexible, low-profile sheath system also aids in the cannulation process.

Angioplasty balloon selection	▪ Care should be taken in selecting appropriate size and types of balloons. ▪ Generally, only low-profile compliant balloons should be used for angioplasty interventions in the renal and visceral arteries. In rare circumstances, a noncompliant balloon may be used to help mold a stent graft to full profile. ▪ Diameter of angioplasty balloon should be estimated relative to adjacent normal vessel lumen. Oversizing is generally not necessary, and a smaller diameter balloon may be preferred when performing angioplasty across highly calcified lesions.
Stent selection	▪ Care should also be taken in selecting appropriately sized stents for desired interventions. ▪ Stent diameter should be estimated relative to normal vessel lumen diameter adjacent to target lesion to be treated and is generally oversized by approximately 1 mm. ▪ Stent length should be estimated relative to the length of the target lesion while providing enough coverage into the adjacent normal vessel lumen (area of needed coverage is variable depending on type of lesion and intervention). ▪ Oversized stents are prone to kinking and may risk damaging the target vessel. Undersized stents may lead to maldeployment, migration, and ineffective seal with adjacent vessel lumen. ▪ Sometimes, the angioplasty balloon of a balloon-expandable stent gets stuck in the stent during its removal. In this situation, pulling the balloon risks misplacing or dislodging the stent from its desired location. Instead, the operator should ensure complete deflation of the balloon and attempt slowly advancing the balloon while rotating its catheter.
Coil/plug selection	▪ Size of coils and plugs should be selected relative to lesion dimensions. Undersized coils and plugs risk migration to unintended vascular beds. ▪ Stability of the embolization delivery system should be selected relative to the size of the embolization device. Larger embolization devices may cause instability in low-profile delivery systems.
Renal/visceral artery dissection	▪ Sheath and large catheter cannulation of renal and visceral arteries should be avoided to prevent damage or dissection. ▪ If a dissection occurs, angiographic evaluation is required to determine whether it is flow limiting. All flow-limiting dissections should be stented with an appropriately sized balloon-expandable stent.
Renal/visceral arterial spasm	▪ Arterial spasms may be induced with vessel cannulation, angioplasty, or stenting. Younger patients are typically more prone for this. Arterial vasodilators, such as nitroglycerin or papaverine, may be infused into the vessel lumen by way of cannulation sheath or catheter to help relieve this. ▪ The operator should be aware that papaverine may precipitate out of solution if mixed with heparin.
Renal capsular perforation or hematoma	▪ This may be caused by inadvertent advancement of cannulating wire into the renal parenchyma. To avoid this complication, always keep the end of the wire in sight during sheath and device advancements over the wire. Also, avoiding the use of straight or angled-tip stiff glidewires in this circumstance can decrease the risk of this complication. ▪ Symptoms of renal capsular hematoma or perforation include abdominal pain and nausea, accompanied by a vasovagal response, which frequently requires aggressive resuscitation and stabilization maneuvers by the interventional team. ▪ If this complication is encountered, maintain wire access (do not remove the offending wire) to facilitate a catheter exchange to provide access to coil placement and occlusion of the perforation site. Loss of wire access can further complicate this situation; however, as long as sheath access remains in the renal artery, the relevant segmental branches can be reaccessed for coil delivery.
Removal of malpositioned/misplaced devices	▪ All attempts should be made to safely reposition malpositioned/misplaced stents, endografts, coils, or plugs. This may involve secondary cannulations, larger sheath placement, and balloon angioplasty with gentle directional force. ▪ If endovascular retrieval or repositioning is unsuccessful, angiographic flow across malpositioned/misplaced devices should be evaluated. If arterial flow is clearly obstructed to unintended vital structures or may become a significant nidus for thrombosis or hemodynamic stenosis, open surgical removal may be indicated or attempted repositioning of devices in areas of less critical hemodynamic significance (e.g., iliac arterial system).

POSTOPERATIVE CARE

- At the conclusion of the procedure, hemostasis is achieved with manual compression or, in cases requiring larger than 6-Fr sheath size, closure devices. Heparin reversal with protamine administration is also helpful unless anticoagulation is to be continued following the procedure.
- As is the case with all patients undergoing peripheral arterial intervention in our practice, patients are observed for a 6- to 24-hour period following device placement. During this period, access site hemostasis and ipsilateral pedal perfusion status is monitored periodically, along with hydration status/urine output and signs of unintended end-organ malperfusion.
- Patients treated with renal/visceral artery angioplasty or stenting receive exaggerated antiplatelet therapy in the immediate perioperative period. In our practice, we load patients with 300 mg of Plavix™ following the procedure, therapy continuing at 75 mg daily for 6 additional weeks.
- Postoperative surveillance of patients with renal/visceral artery interventions is necessary. Duplex evaluation of renal/visceral artery stents 1 to 3 months following intervention is

usually recommended, followed by repeat duplex evaluation every 6 months for at least 1 to 2 years. Afterward, stents with no evidence of in-stent restenosis or de novo disease progression may be imaged at yearly intervals. Evidence of restenosis, either by end-organ dysfunction or surveillance imaging studies, should prompt reevaluation and reintervention as necessary to maintain luminal patency and long-term success.

OUTCOMES

- Endovascular treatment of RAS has a reported technical success rate of 88% to 100%. Treatment effects on hypertension alone are quantitatively modest and inconsistent between studies.[24,25] Improvement in renal function is reported in approximately 25% of patients.
- Treatment of mesenteric occlusive disease has a reported technical success rate of 96%. Postoperative symptom improvement/resolution is reported in approximately 88% of treated patients. Primary patency is estimated at 65% to 92%, with primary assisted patency at 92% to 100%, and secondary patency at 99%.[26,27]
- Embolization and stent graft techniques for repair of renal and visceral artery aneurysms are limited to variably sized retrospective series but with acceptable technical success rates in appropriately selected patients.

COMPLICATIONS

- For renal artery interventions, complications most commonly arise from access site complications, contrast-induced nephropathy, or atheroembolization. Renal artery restenosis is reported between 5% and 66%, depending on duration of follow-up and criteria used for continued surveillance. The perioperative 30-day mortality is estimated at 0% to 5% and survival at 3 years is estimated at 74%.[28] Other less frequent complications include iatrogenic renal parenchymal perforation, capsular hematoma, arterial dissection, thrombosis, or distal plaque embolization into branch or accessory arteries.
- For mesenteric artery interventions, restenosis or occlusion of treated visceral vessels is documented in 10% to 27% of patients,[29] emphasizing the need for continued postprocedural surveillance. Less common complications include mesenteric artery perforation, dissection, or distal parenchymal embolization due to wire/catheter manipulation of areas with fresh thrombus or friable plaque. While treating branch artery aneurysms of the spleen, occasionally, portions of the splenic parenchyma may be lost due to coiling and branch occlusion, with attendant symptoms consistent with segmental splenic infarction.

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Chapter **20**

Visceral Reconstruction to Facilitate Cancer Management: Celiac, Mesenteric, Splenic, Hepatic and Renal Artery Disease Management

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DEFINITION

- This chapter assumes basic knowledge of surgical oncology principles and the management of patients with intraabdominal tumor pathology. For further review of these topics, please refer to relevant background sources.[1,2]
- Advanced primary and recurrent abdominal malignant tumors may frequently involve adjacent arterial and venous structures. Surgical management may require curative en bloc tumor resection, with the goal of achieving negative macroscopic and microscopic margins. Adjunct vascular reconstruction may be necessary to achieve complete tumor removal.
- A wide variety of malignancies may develop in the peritoneal space and retroperitoneum. A representative range of pathologies involving intraabdominal arterial and venous structures is summarized in Table 1.
- Primary vascular tumors are exceedingly rare, frequently mimic other oncologic disease processes, and may evolve slowly—leading to delay in diagnosis and treatment. Although most commonly arising from large vessels such as the aorta and vena cava, primary vascular tumors may also originate from distal branches of the iliac, mesenteric, and renal arteries. Classification systems (Wright/Salm classification) have broadly categorized primary vascular tumors as intimal (majority, 70%) and mural.[3]

Table 1: Range of Intraabdominal Oncological Pathologies that can Potentially Involve Arterial and Venous Structures

Arterial	
Aorta	Angiosarcoma,[a] paraganglioma, pheochromocytoma, leiomyosarcoma, rhabdomyosarcoma
Superior mesenteric artery	Adenocarcinoma, neuroendocrine carcinoma, adenosquamous carcinoma, cystadenocarcinoma
Iliac artery	Adenocarcinoma, leiomyoma, endometrial stromal carcinoma, fibrosarcoma, fibroma
Venous	
Inferior vena cava	Angiosarcoma,[a] adrenocortical carcinoma, teratoma, Wilms' tumor, pheochromocytoma, neuroendocrine carcinoma, intestinal carcinoma, hepatocellular carcinoma
Renal vein	Renal cell carcinoma, adrenocortical carcinoma, pheochromocytoma
Portal vein	Adenoma, adenocarcinoma, cholangiocarcinoma, neuroendocrine carcinoma, hepatocellular carcinoma
Iliac vein	Intestinal carcinoma, leiomyoma, endometrial stromal carcinoma, fibrosarcoma, fibroma, transitional cell carcinoma, liposarcoma. leiomyosarcoma

[a]*Primary vascular tumor.*

PATIENT HISTORY AND PHYSICAL FINDINGS

- Patients with complex intraabdominal oncologic pathology are best managed by a multidisciplinary care team at a tertiary care center. If tumor extension to adjacent vascular structures is suspected, surgical planning should include evaluation of potential revascularization options by a vascular surgeon.
- The initial assessment should include a thorough evaluation of the patient's presenting symptoms. This may include focal or regional abdominal pain resulting in tumor parenchyma pressing against adjacent structures. Patients may also present with gastrointestinal symptoms such as early satiety, nausea, and vomiting. Erosive gastrointestinal lesions may manifest with hematochezia, melena, or hematemesis. Constitutional flu-like symptoms, fevers, malaise, fatigue, night sweats, and muscle aches may also rarely present in patients with certain patients with rapidly expanding tumors.
- Depending on the primary site and tissue of origin, tumor-associated physical findings may not be obvious until relatively late in the disease process. Abdominal distension can result from increasing tumor volume or from serous ascites due to portal venous compression. Tumor mass effect or infiltration of the inferior vena cava (IVC) or iliac venous system may lead to unilateral or bilateral lower extremity edema, dilated abdominal wall veins, evidence of deep venous thrombosis (DVT), biliary symptoms, and renal insufficiency. Accordingly, physical examination should not only include a thorough abdominal exam with palpation of all nodal basins but also a complete vascular exam with evaluation of limb pulses, Doppler signals, and assessment of extent/grade of limb edema.
- Patient with primary vascular tumors, particularly ones with intimal expansion and growth, can present with evidence of venous or arterial embolization. Manifestations of recurrent venous pulmonary emboli include shortness of breath, respiratory distress, and hemodynamic changes including tachycardia and right heart failure. Depending on the volume of arterial emboli, symptoms can range from lower extremity pain to digital discoloration.

IMAGING AND OTHER DIAGNOSTIC STUDIES

- Tumor staging and classification systems are beyond the scope of this chapter. Please refer to other excellent references for tumor-specific staging modalities and requirements.[2,4]
- Patients deemed candidates for surgical resection by a multidisciplinary team should receive a high-resolution, thin-slice (at least 1 mm), multidetector computed tomography (MDCT) scan with intravenous contrast injection to allow for imaging during arterial and venous phases. Image acquisition should allow for multiplanar sagittal, coronal, and three-dimensional reconstructions. This type of detailed imaging provides valuable information regarding tumor margins, suspected histologic subtype, and grade and can also help determine the morphology, patency, and extent of involvement of adjacent vascular structures.
- In situations where mesenteric venous thrombosis is visualized on MDCT, specific postprocessing protocols may be further implemented to improve clarity regarding the extent of thrombus burden and associated and/or resultant venous congestion.
- Adjunct imaging studies may also include magnetic resonance imaging (MRI), ultrasonography, and rarely, angiography/venography. Particularly, in patients with concern for osseous or neurogenic tumor involvement, MRI may be particularly useful in defining tissue planes and tumor parenchyma boundaries. MRI also has a nearly 100% sensitivity for detecting intracaval tumor thrombus.
- Autogenous vascular conduit may be necessary for adequate revascularization, particularly following bowel resection and reconstruction. When anticipated, preoperative venous duplex scanning of the lower extremities will help document the presence and usage of superficial femoral vein as potential graft conduit. The presence of deep venous obstruction, either acute or chronic, may preclude venous harvest from that particular extremity. Similarly, the bilateral lower extremity greater saphenous veins should be evaluated for patency, diameter, and adequate length.
- Occasionally, preoperative or intraoperative transesophageal echocardiography may be needed to confirm the proximal extent of intracaval tumor thrombus visualized using other cross-sectional imaging modalities and determine whether the tumor thrombus is encroaching into the right atrium.[5]

SURGICAL MANAGEMENT

Patient Selection

- Whenever possible, the goal of surgical extirpation of abdominal solid organ tumors should be oncologic cure. This assumption presupposes tumor localization to a distinct anatomic region that will allow for resection with negative macroscopic and microscopic margins. Thus, the goals of the procedure should be clearly defined by sufficient preoperative high-quality anatomic cross-sectional imaging, multidisciplinary consultation, and discussions with the patient regarding the operative risks, benefits, expectant outcomes, and overall prognosis.[2,6]
- Abdominal solid organ tumors are traditionally considered unresectable when they involve the arterial or venous vasculature, are diffusely metastatic throughout the peritoneum or at remote sites, or involve the root of the mesentery or spinal cord to a significant extent. Patients with extensive tumor burden precluding resection may still be offered incomplete removal or debulking operations to potentially prolong survival and improve symptom palliation.[6]
- Equally as important as the anatomic considerations, preoperative patient functional status is a significant determinant of surgical eligibility. Performance assessments, such as outlined by the Karnofsky or Eastern Cooperative Oncology Group (ECOG) score, help predict patient-specific postoperative quality of life.[2,7] At our institution, patients who are bedridden at the time of initial assessment, severely disabled, or unable to independently perform activities of self-care are often not offered curative resection.
- Candidacy for intraabdominal vascular reconstruction is also contingent on the extent of potential or preexisting vascular compromise. As such, we have typically attempted arterial reconstruction when tumors involve critical arterial structures such as the aorta, celiac artery and its branches, proximal superior mesenteric artery (SMA), common/external iliac artery, and the internal iliac artery in the setting of an embolized, occluded, or resected contralateral internal iliac artery. Similarly, venous reconstruction is also anticipated when tumors margins appear to include the vena cava, portal, superior mesenteric, common, and external iliac veins.

Preoperative Planning

- Items to consider in preoperative multidisciplinary review include the extent of planned gross surgical resection margins, the need for preoperative arterial or venous embolization, the need for other prophylactic procedures such as placement of ureteral stents or nephrostomy tubes, and the likelihood for intestinal resection and/or reconstruction.
- Ureteral stent placement should be considered in all patients who demonstrate evidence of ureteral obstruction, renal hydronephrosis, or urinary obstructive signs or symptoms from either tumor mass effect or invasion of urologic structures. Moreover, ureteral stents should also be considered in patients with pelvic tumors where there is potential concern of ureteral injury during resection of the tumor or during vascular reconstruction.
- A thorough review of detailed preoperative imaging will greatly facilitate proper conduit selection and preparation and, ultimately, a successful outcome. Particular attention should be directed to the length of vascular segment involved by adjacent tumor, the branch points and bifurcations present along this length, and which segments, if any, are circumferentially encased by tumor parenchyma.
- Attention should be paid as to whether planned resection will include vessels which are already occluded with adequate collateral circulation already in place, or whether adjacent or contralateral vascular structures are capable of supplying adequate inflow and outflow. Vascular segments to be reconstructed should be patent and preserved to the greatest extent possible during the planned tumor resection.
- Endovascular embolization is the preferred method of preoperative vascular occlusion prior to open surgical resection. This strategy is commonly used for preoperative splenic artery/vein embolization prior to planned surgical splenectomy, internal iliac artery embolization prior to planned pelvic

tumor resection, and renal artery/vein embolization prior to planned nephrectomy with or without the need for further exposure of the retrohepatic IVC. For this purpose, the preferred size of coils/plugs is estimated based on the diameter and length measurements of the target vessel on preoperative cross-sectional imaging and is typically oversized by up to 20% of the target vessel diameter. For additional details regarding visceral embolization techniques, refer to Part 6, Chapter 19 (Stenting, Endografting, and Embolization Techniques: Celiac, Mesenteric, Splenic, Hepatic, and Renal Artery Disease Management). For additional details regarding internal iliac artery embolization techniques, refer to Part 6, Chapter 24 (Advanced Aneurysm Management Techniques: Management of Internal Iliac Aneurysm Disease).

- Aortoiliac arterial involvement often requires resection followed by reconstruction with patch angioplasty, interposition, or extraanatomic bypass. Type of reconstruction and conduit type (autogenous venous allograft, cryopreserved homograft, or synthetic conduit) is contingent on the type of tumor, extent of vascular segment involvement, and degree to which intestinal reconstruction is also anticipated. In the latter case, when contamination by succus entericus is likely, autogenous femoral vein conduits for iliac artery reconstructions and IVC or spliced femoral vein conduits for aortic reconstructions are preferred. Alternatively, when not available, rifampin-soaked, gel-sealed knitted Dacron conduit may serve as a potential substitute with acceptable results.[8]
- Reconstruction of the celiac trunk, common hepatic artery, SMA, portal vein, and superior mesenteric vein (SMV) are similarly contingent on the extent of involvement of these structures with tumor pathology. Unless the artery in question is circumferentially involved, it is our preference to resect only the portion of vessel wall directly involved with tumor while preserving the remaining vessel architecture with patch repair. Autogenous venous conduit (using superficial femoral vein or greater saphenous vein or femoral vein) is preferred for vessel segments requiring interposition grafting.
- The mainstay of treatment of primary and secondary tumors of the IVC is surgical resection and reconstruction. The extent of reconstruction is contingent on the type of tumor, extent of caval involvement, and the anatomic segments involved. Adequate retrohepatic caval exposure is challenging and may require total vascular isolation of the liver to minimize blood loss during this maneuver. In circumstances where the IVC is chronically occluded with tolerable lower extremity edema and adequate renal function, ligation and resection without reconstruction should be considered. On the other hand, patients with recent occlusion of the IVC, few venous collaterals, notable lower extremity symptoms, or renal insufficiency should be considered for either interposition grafting or patch venoplasty.

Operating Room Setup

- Preoperative endovascular embolization procedures should be performed in an angiography suite or hybrid operating room, equipped with a fixed-imaging apparatus, floating-point carbon fiber operating table, fluoroscopy platform, and monitor-viewing bank. A full complement of compatible guidewires, catheters, sheaths, coils, and plugs should also be available.
- Open tumor operative resection procedures are best performed in an operating room setting with adequate space to facilitate the maneuvering of multiple surgical subspecialty teams and their necessary operative trays/equipment.
- Most intraabdominal operative tumor resection and reconstruction procedures may be performed with the patient in the supine position. In the surgical field, the patient's lower extremities should be prepared for vein harvest if potentially necessary.
- In patients who require retrohepatic IVC exposure and reconstruction, the left lateral decubitus position should be employed to facilitate right thoracoabdominal exposure through the 8th or 9th rib interspace.
- Placement of ureteral stents will require initial positioning of the patient in lithotomy position and then subsequent repositioning of the patient to facilitate further planned surgical intervention.

AORTIC RECONSTRUCTION

- For a discussion of the technical exposure of the paravisceral, pararenal, and infrarenal aorta, please refer to Part 6, Chapters 14 (Exposure and Open Surgical Management at the Diaphragm), 15 (Retroperitoneal Aortic Exposure), and 22 (Advanced Aneurysm Management Techniques: Open Surgical Anatomy Repair).

First Step

- The surgical exposure of an intraabdominal tumor either directly adjacent or involving the aorta should aim to not only provide adequate exposure of tumor resection but also facilitate adequate proximal and distal arterial control. A traditional midline abdominal incision, extending from the xiphoid process to the pubis, can facilitate this in the majority of patients.
- In patients with wide costal margins or an anticipated need for wide parahepatic or parasplenic exposure, a bilateral subcostal incision (also known as Michigan smile) may also be useful.
- For large abdominal tumors, renal tumors, or tumors with cephalad intraabdominal extension to the level of the diaphragm, a lateral decubitus thoracoabdominal approach to facilitate both adequate tumor exposure as well as vascular proximal control and reconstruction is advised.

Second Step

- Proximal aortic control can often be obtained directly above the anticipated cephalad margin of the tumor. In this circumstance, via either retroperitoneal or transperitoneal approaches, the medial and lateral aortic margins are cleared for a distance of 2 to 3 cm proximal to the tumor margin. The exposed segment is inspected for lumbar vessel branches, which may be externally ligated as necessary to aid in exposure and control. A large, slightly curved vascular aortic clamp (e.g., DeBakey aortic occlusion clamp) is best suited to obtain proximal aortic control.

- Supraceliac or suprarenal aortic exposure may be necessary for optimal control (**FIG 1**).
- For control of the supraceliac aorta, the peritoneal cavity is entered below the level of the xiphoid process. With cephalad retraction of the left lobe of the liver, the left triangular ligament of the liver is divided and the lesser sac is entered via a longitudinal incision in the gastrohepatic ligament. Care should be taken here to avoid injury to the esophagus (identified by aid of orogastric/nasogastric tube placement) or a replaced left hepatic artery. For additional exposure, the median arcuate ligament and the right crus may be divided (**FIG 1**).
- Suprarenal aortic control is obtained following circumferential dissection and mobilization of the left renal vein off the ventral surface of the aorta. Left renal vein inferior lumbar branches should be ligated to facilitate mobilization. In rare circumstances, the left renal vein may need to be ligated during this maneuver. When this is anticipated, existing collateral veins such as the left gonadal, adrenal, or lumbar should be intentionally preserved prior to division of the left renal vein.
- Infrarenal aortic exposure can be achieved either via transperitoneal or retroperitoneal approaches. If the tumor has pelvic extensions or if exposure/control of the right iliac system is anticipated, a transperitoneal approach may be preferable.

Third Step

- Depending on the extent of aortic tumor involvement, durable repair may be achieved using either patch angioplasty or interposition grafting.
- Patch repair is commonly performed with a woven Dacron, bovine pericardium, or autogenous femoral vein. The patch is fashioned in a manner to facilitate a wide repair without narrowing the residual the aortic lumen. The anastomosis is usually performed with 4-0 Prolene sutures, in a running fashion, with one suture starting

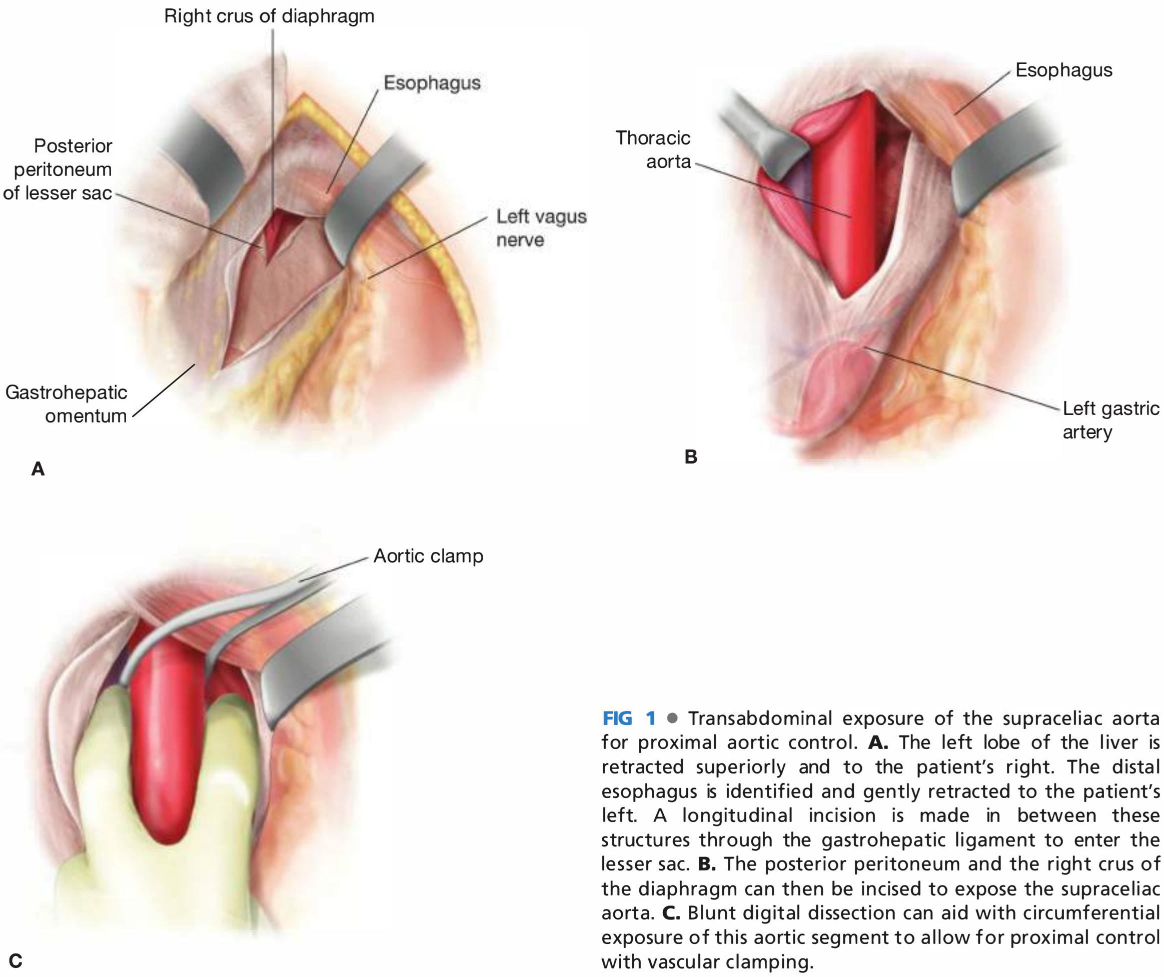

FIG 1 ● Transabdominal exposure of the supraceliac aorta for proximal aortic control. **A.** The left lobe of the liver is retracted superiorly and to the patient's right. The distal esophagus is identified and gently retracted to the patient's left. A longitudinal incision is made in between these structures through the gastrohepatic ligament to enter the lesser sac. **B.** The posterior peritoneum and the right crus of the diaphragm can then be incised to expose the supraceliac aorta. **C.** Blunt digital dissection can aid with circumferential exposure of this aortic segment to allow for proximal control with vascular clamping.

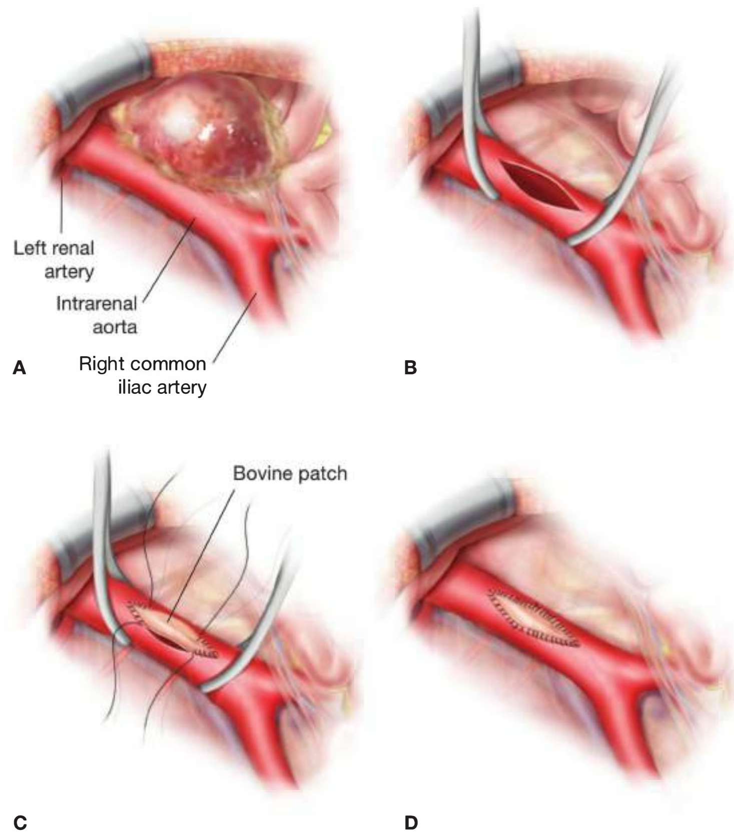

FIG 2 ● Patch angioplasty repair of infrarenal aorta. **A.** Transabdominal exposure of the infrarenal abdominal aorta and adjacent tumor mass. **B.** Following proximal and distal aortic control, mass is removed along with associated aortic wall. **C,D.** Aortotomy repaired with a abovine pericardial patch.

from each end of the patch repair. Depending on the age of the patient, presence and extent of retroperitoneal soilage by intestinal contents, and amount of retroperitoneal inflammation present, polyester pledgets may be required to minimize suture-related aortic injury and needle hole bleeding (**FIG 2**).

- Alternatively, when more extensive aortic segments are involved or the tumor cannot be safely mobilized circumferentially around the aorta, interposition grafting may be more appropriate. After resection, the residual aorta should be inspected for any intimal defects, tumor infiltration, or intraluminal thrombus. Once clean endpoints are determined, the interposition graft of choice can be brought to the field. Conduit choices include autogenous vena cava or spliced femoral veins, cryopreserved homogenous arterial conduit, or knitted or woven polyester and expanded polytetrafluoroethylene (ePTFE). Once selected, the proximal end is fashioned in such as way as to minimize diameter differences between the aorta and graft. The anastomosis is usually performed with a running 3-0 or 4-0 polypropylene suture. Once completed, the proximal clamp is temporarily released to allow the conduit to be routed in such a way to avoid redundancy, kinking, or twisting. After reclamping of the graft (to avoid repeated aortic clamping), the distal anastomosis is completed in a similar fashion after sufficient proximal and distal flushing maneuvers (**FIG 3**).
- Autogenous tissue repairs of the aorta are preferred in circumstances where intestinal continuity has been interrupted. However, if autogenous tissue is not available or not adequate for use, gel-impregnated woven polyester graft material immersed in rifampin solution is the prosthetic conduit of choice. To achieve adequate coverage, the graft is immersed in 50 mL of normal saline containing 600 mg of rifampin for at least 30 minutes.
- If the paravisceral or pararenal aorta reconstruction is required, visceral and renal vessels can be reimplanted to the interposition aortic graft. Alternatively, a premanufactured or surgeon-modified branched aortic graft can be used to facilitate end-to-end anastomoses to the visceral or renal vessels following aortic interposition graft repair, with side limbs typically 6 to 8 mm in diameter (**FIG 3**).

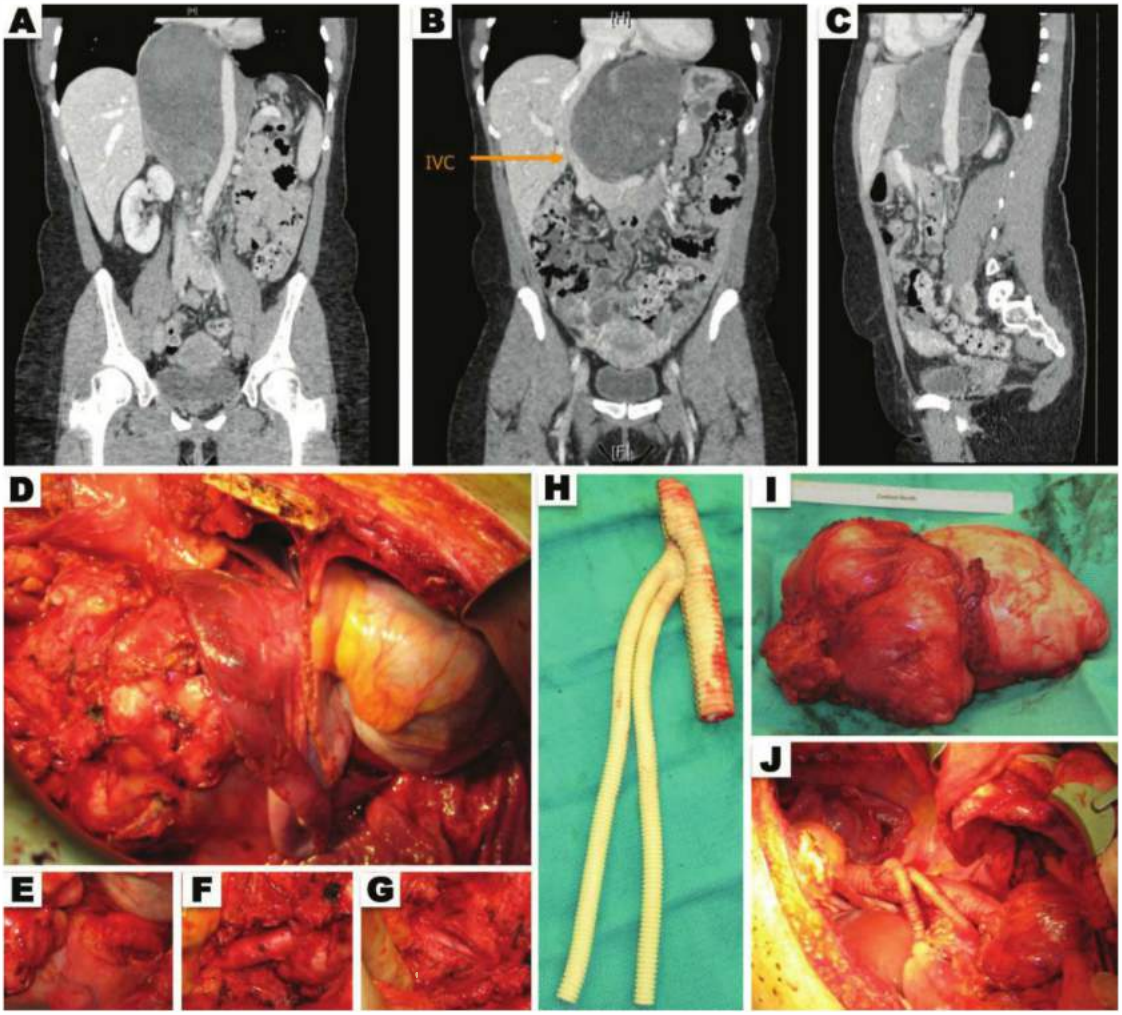

FIG 3 ● Branched aortovisceral repair following resection of a large retroperitoneal thoracoabdominal myxoid sarcoma mass. **A.** Coronal abdominal computed tomography (CT) demonstrates large thoracoabdominal and mediastinal mass directly adjacent to major organ structures and the paravisceral aorta. **B.** CT demonstrates retroperitoneal portion of tumor mass displacing IVC toward the patient's right. **C.** Sagittal CT demonstrates circumferential involvement of the paravisceral aorta with the tumor mass. **D**. Left thoracoabdominal exposure reveals a large retroperitoneal mass extending proximally directly underneath the diaphragm. The supradiaphragmatic aorta **(E)**, proximal left renal artery **(F)**, and proximal SMA **(G)** were all exposed to facilitate tumor resection and aortic branched repair. **H.** Aortic branch graft was constructed on the operative back table by attaching a 14-mm bifurcated Dacron graft to the side of a 16-mm Dacron tube graft. Following en bloc resection of the mass along with associated aortic segment **(I)**, the resected aortic segment was then repaired with the constructed graft. Branches were used for end-to-end anastomosis to the left renal artery and SMA.

SUPERIOR MESENTERIC ARTERY RECONSTRUCTION

First Step

- Exposure of the SMA, in situations where it is involved with the tumor, may be performed jointly with the surgical oncology team. Particularly in situations where the SMA is extensively involved, sufficient vascular control should obtained prior to significant debulking or resection maneuvers.
- To expose the SMA at the base of the mesentery, the transverse colon and omentum are elevated while packing the small bowel to the right. The peritoneum is then incised at the base of the transverse mesocolon, taking care to identify and preserve the middle colic and jejunal arterial branches. Judicious cephalad retraction of the inferior border of the pancreas may also improve exposure (FIG 4).

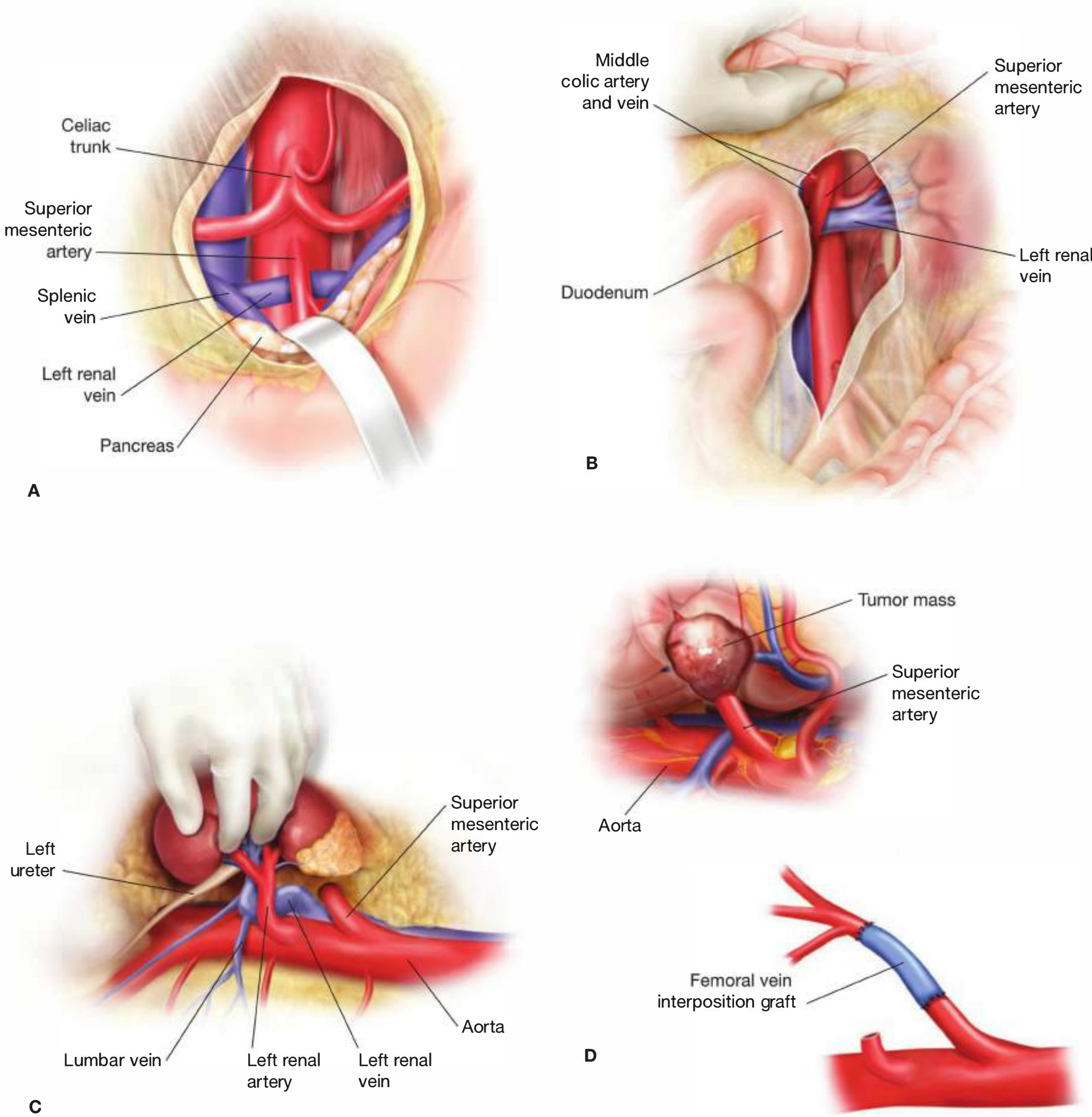

FIG 4 ● Transabdominal exposure and reconstruction of the SMA. **A.** The origin of the SMA may be exposed with mobilization and gentle retraction of the superior border of the pancreas along with extended cephalad exposure of the aorta to the level of the celiac trunk. **B.** Alternatively, the SMA can be exposed from a lateral approach with division of the ligament of Treitz and right lateral mobilization of the fourth portion of the duodenum. **C.** Exposure can be enhanced with gentle cephalad retraction of the inferior border of the pancreas and ventral mobilization of the left kidney. Care should be taken to not avulse left renal vein lumbar, gonadal, or adrenal branches during mobilization of the left kidney. **D.** Tumor mass resection with associated segment of SMA. The arterial segment is repaired with an autogenous interposition greater saphenous vein graft.

- Alternatively, proximal SMA exposure may be gained laterally, following division of the ligament of Treitz and mobilization of the fourth portion of the duodenum. Visualization of the underlying SMA can be further enhanced with gentle retraction of the inferior border of the pancreas to the level of the left renal vein (**FIG 4**).
- The splanchnic nerves must be sharply excised to effectively elevate the SMA off the anterior aortic wall.

Second Step

- Reconstruction approach is dictated by the extent of tumor ingrowth. SMA involvement may be tangential or require segmental resection to achieve appropriate tumor margins.
- Partial SMA involvement may only require resection and reconstruction of one of the SMA walls. With arterial control established, the tumor tissue and involved SMA can be sharply resected en bloc. Following inspection to ensure a disease-free patent lumen, the arteriotomy is repaired with a patch angioplasty technique. Autogenous vein is the preferred patch material when available, especially following interruption of intestinal continuity. When alimentary tract continuity is not disrupted, bovine pericardial tissue, polytetrafluoroethylene (PTFE), or polyester patch may be used for repair. 6-0 polypropylene monofilament suture is a good choice for arteriotomy closure and repair.

Third Step

- More extensive tumor involvement with the SMA may require segmental resection and interposition grafting. Variables to consider include the length of the defect, whether the SMA origin is also involved, and conduit material available for repair.
- For short segment replacement, reversed greater saphenous vein is the preferred conduit for SMA grafting. Appropriately sized saphenous vein is usually harvested from the thigh, distended, and prepared for interposition. The tumor tissue is resected en bloc with the involved segment of SMA. Following confirmation of adequate margins, sequential end-to-end proximal anastomosis is performed. The graft is then brought to length while avoiding any twisting or kinking of the graft. The distal end-to-end anastomosis is then similarly performed. Spatulation of both the arterial endpoints and saphenous conduit may or may not be helpful, depending on size discrepancy.
- For long segment resections or resections involving the origin of the SMA, a long retrograde "question mark" graft, so named for its appearance on contrast arteriography following the procedure, is used to route arterial blood from the right iliac artery around the base of the mesentery to the distal SMA. Alternatively, an antegrade bypass from the supraceliac aorta may be tunneled posterior to the pancreas and brought out coaxially along the course of the distal SMA. Finally, when the SMA origin is involved but sufficient distal SMA is present to allow mobilization, the SMA may be reimplanted on the distal aorta if a disease-free segment can be identified by palpation or from assessment of preoperative imaging studies. For bypass options under these circumstances, cryopreserved arterial homograft or 6-mm polyester or externally supported PTFE are typically preferred conduits. Care is once again taken to avoid conduit twisting or kinking during placement or tunneling.
- Although a potential option, direct bypass from the region of the origin of the SMA to the distal mesenteric artery is problematic in that fashioning the bypass requires elevation of the mesentery, with the distal anastomosis positioned on the posterior aspect of the distal mesenteric artery. Although the graft may function well with the mesentery elevated, reduction of the intestines into the abdomen invariably causes graft conduit, autogenous or prosthetic, to kink and potentially thrombose. In this circumstance, it is almost impossible to fashion an interposition graft of appropriate length, so approaches such as retrograde grafting or reimplantation should be considered as preferred alternatives.

SUPERIOR MESENTERIC VEIN OR PORTAL VEIN RECONSTRUCTION

First Step

- Exposure of the portal vein is facilitated via entry of the peritoneal cavity and interruption of the umbilical vein and falciform ligament. The porta hepatis can be better visualized with cephalad retraction of the right lobe of the liver, downward retraction of the colonic hepatic flexure, and medial mobilization of the first and second portions of the duodenum. The portal vein is then easily identified in the right posterior border of the hepatoduodenal ligament. This exposure can be extended from the hilum of the liver to the head of the pancreas inferiorly. Inferiorly, care should be taken to identify and preserve the coronary vein and splenic vein (**FIG 5**).
- In most instances, the neck of the pancreas is divided as part of the tumor exposure and resection, which improves caudal exposure of the portal vein, splenic vein, and SMV.
- Exposure of the SMV can be achieved via exposure distal to the splenic vein confluence or via similar techniques used to expose the SMA. At the base of the transverse mesocolon, the SMV can be found lying to the right of the SMA near the midline. Multiple dense lymphatics overlying the vein often require careful dissection and meticulous control. Care should also be taken to identify and preserve the middle colic vein proximally and ventral venous tributaries distally (**FIG 5**).

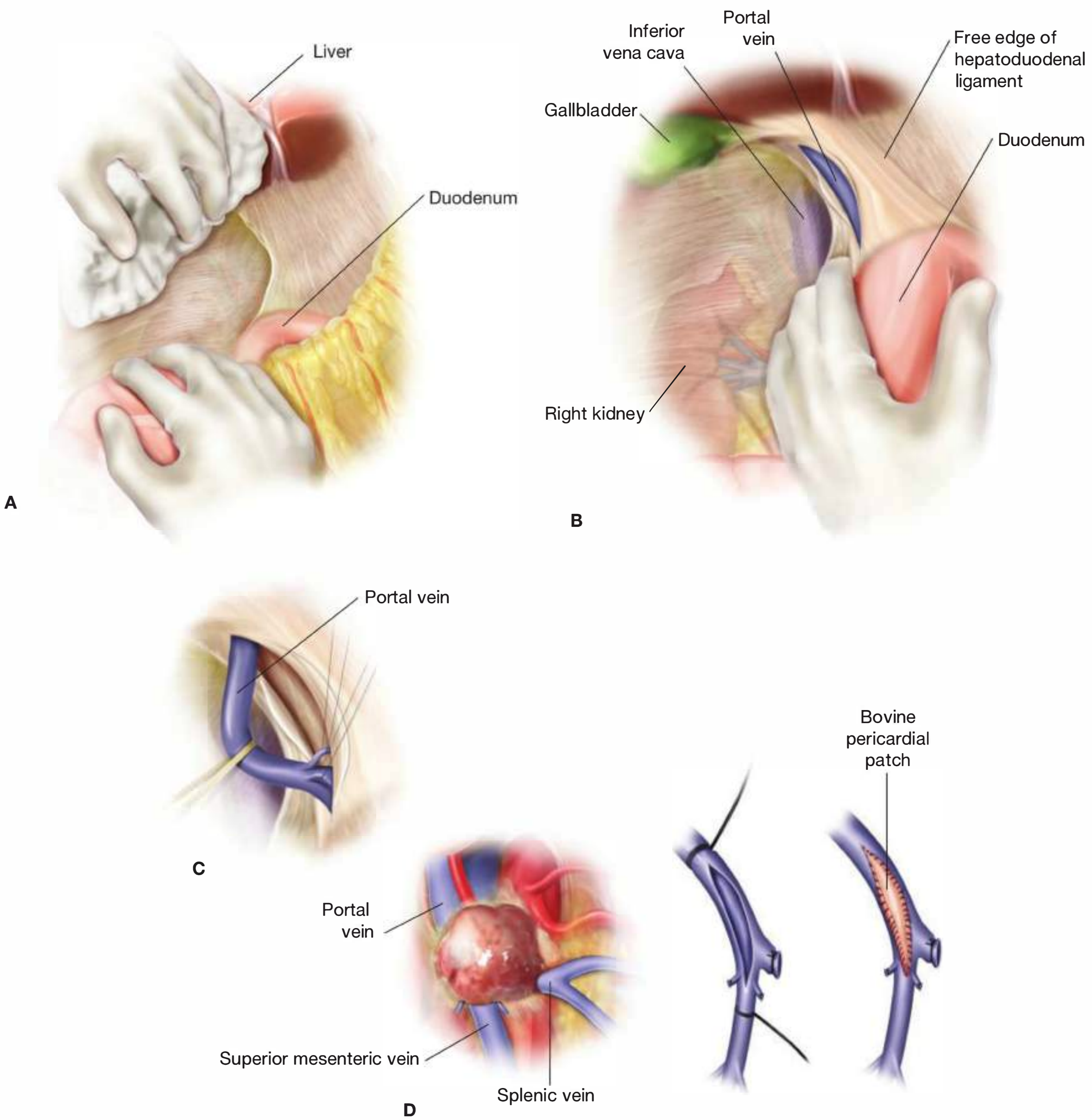

FIG 5 ● Transabdominal exposure and reconstruction of the portal vein and SMV confluence. **A.** With cephalad retraction of the right lobe of the liver, the posterior peritoneal attachments of the first and second portions of the duodenum may be visualized. **B.** The portal vein and proximal SMV may be exposed through a longitudinal incision along the lateral free aspect of the hepatoduodenal ligament. **C.** Venous tributaries draining into the portal vein and SMV confluence may be ligated to facilitate exposure and reconstruction of this venous segment. **D.** Tumor mass resection with associated ventral segment of the portal vein and SMV confluence and repair with a patch venoplasty using a bovine pericardial patch.

Second Step

- The extent of tumor involvement with the SMV and portal vein is variable. Reconstruction is often required to preserve mesenteric outflow.
- Following establishment of vascular control, en bloc resection of the tumor and associated venous structures can be performed. Partial involvement is best managed via patch venoplasty. Preservation of an intact back wall of the splenic SMV confluence is often beneficial in maintaining the structural integrity of the bifurcation. SMV and portal vein patch venoplasty repairs can be performed using autogenous saphenous vein or bovine pericardium. A 6-0 polypropylene suture repair is used to close the vein, running or interrupted (**FIG 5**).
- Tumor involvement requiring complete resection of the portal vein or SMV will require interposition graft reconstruction. Interposition grafting with autogenous superficial femoral vein or cryopreserved venous homograft is preferred when intestinal resection and reconstruction is anticipated. Alternatively, 6- or 8-mm ringed PTFE when venous conduit is unavailable or inadequate. The distal end-to-end anastomosis is completed first, followed by the proximal end, with either interrupted or triangulated running sutures to prevent purse-stringing and anastomotic narrowing (**FIG 5**).

INFERIOR VENA CAVA RECONSTRUCTION

First Step

- Infrahepatic IVC exposure can be facilitated either through right retroperitoneal or transperitoneal exposure. Exposure is typically dictated by the extent of other planned intraabdominal procedures and anticipated tumor resection margins.
- For right retroperitoneal exposure, the flank is elevated to 15 to 20 degrees with the patient positioned in the supine position. A transverse incision can then be made extending from the rectus abdominis to the tip of the 11th or 12th rib. The external oblique, internal oblique, transversus abdominis muscles, and transversalis fascia are divided to create the retroperitoneal plane via blunt dissection. With judiciously placed self-retaining retractors, a 6-cm segment of the right lateral aspect of the pararenal and infrarenal vena cava may be easily exposed (**FIG 6**).
- For a transperitoneal exposure, either a midline laparotomy or bilateral subcostal incision will facilitate adequate exposure. Once the peritoneal space is entered, the small bowel is retracted to the left and the lateral peritoneal attachments of the right colon are divided. This facilitates medial mobilization of the right colon and mesentery and provides access to the retroperitoneal attachments of the second and third portions of the duodenum. Once these attachments are divided, the underlying vena cava can then be adequately exposed from the suprarenal level to the common iliac veins. Ligation and division of the ventral pararenal lymphatics, right lateral lumbar veins, and anterior crossing left gonadal vein will aid in caval mobilization during proximal and distal circumferential dissection. Vascular tapes may be placed around the proximal and distal exposed segments of the vena cava to facilitate vascular control. Care should be taken to not avulse medial lumbar veins with over aggressive mobilization of the vena cava during these maneuvers (**FIG 6**).
- For extended retrohepatic IVC exposure, a right thoracoabdominal incision may be performed with the patient positioned in a left lateral decubitus position. Once the peritoneal cavity is entered, the right triangular ligament and lateral and posterior peritoneal attachments to the right hepatic lobe can be divided. Medial retraction of the right hepatic lobe can then be performed to facilitate visualization of the lateral surface of the retrohepatic IVC (**FIG 6**). Hepatic compression here, especially following placement of self-retaining retractors, can increase hepatic congestion and ischemia and should be minimized to the greatest extent possible. In situations where caval visualization is not adequate despite optimal hepatic retraction, proximal extension or even division of the sternum may be necessary to facilitate safe exposure. Once adequate exposure is achieved, circumferential control can be achieved following ligation and division of small hepatic venous branches that course between the caudate lobe of the liver and the IVC in this region.
- The suprahepatic IVC can be exposed following ligation and division of the round ligament and wide division of the falciform and coronary ligaments. Caudal retraction of the bare dome of the liver facilitates visualization of the suprahepatic vena cava and at least two of the three main hepatic veins. Careful dissection of the areolar tissue surrounding these veins allows for circumferential exposure of each of these veins as well as this segment of the vena cava.

Second Step

- Once the vena cava is controlled both proximally and distally, the tumor mass can be dissected off other pertinent structures to facilitate en bloc resection. Systemic anticoagulation is accomplished with unfractionated heparin sulfate (100 units/kg intravenous infusion) and reversed with protamine sulfate, 1 mg/100 units of heparin, when vascular reconstruction or retraction is complete.
- Prior to removal of the tumor mass, the patient is placed in Trendelenburg position and vascular clamps positioned proximal and distal to the anticipated margins of resection. If the involved segment of the IVC is limited to only a few centimeters or one side wall, a long Satinsky side-biting vascular clamp may be used for partial caval occlusion (**FIG 6**).
- Acute occlusion of the suprarenal or retrohepatic IVC may induce profound hypotension due to significant preload

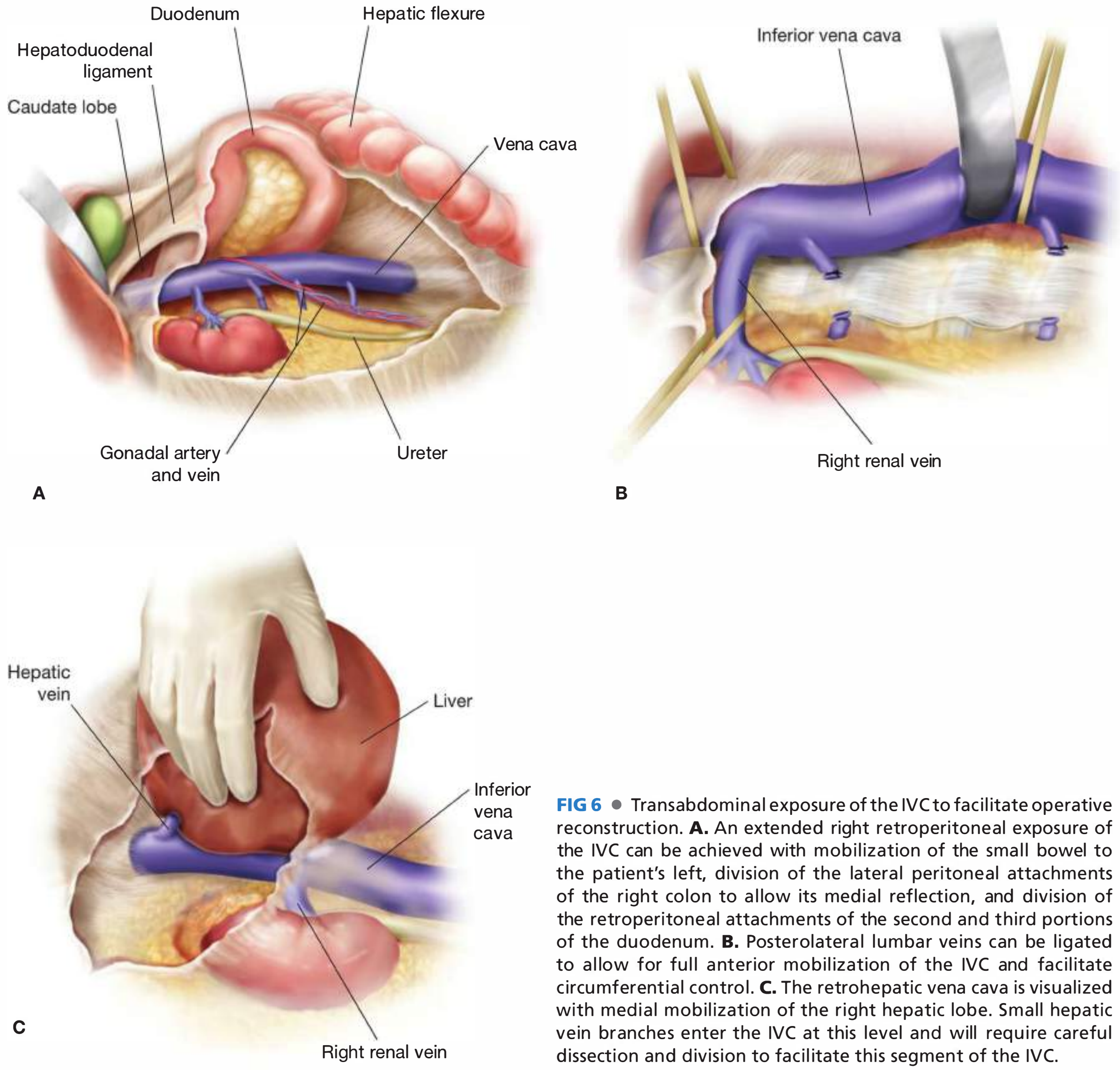

FIG 6 ● Transabdominal exposure of the IVC to facilitate operative reconstruction. **A.** An extended right retroperitoneal exposure of the IVC can be achieved with mobilization of the small bowel to the patient's left, division of the lateral peritoneal attachments of the right colon to allow its medial reflection, and division of the retroperitoneal attachments of the second and third portions of the duodenum. **B.** Posterolateral lumbar veins can be ligated to allow for full anterior mobilization of the IVC and facilitate circumferential control. **C.** The retrohepatic vena cava is visualized with medial mobilization of the right hepatic lobe. Small hepatic vein branches enter the IVC at this level and will require careful dissection and division to facilitate this segment of the IVC.

reduction. In these circumstances, preemptive aggressive fluid resuscitation, gradual clamping of the vena cava, or partial occlusion may be better tolerated. Alternatively, venovenous bypass or atriocaval shunt placement may be necessary. Please refer to prior references for further details regarding preparation and placement of atriocaval shunts.[9,10]

- Specific isolation of the retrohepatic vena cava requires control of both the hepatic inflow and outflow. Inflow control is achieved with cross-clamping of the infrahepatic vena cava as well as with a Pringle maneuver (clamping of the hepatic artery and portal vein). Outflow control is achieved with suprahepatic or infradiaphragmatic clamping of the IVC.

Third Step

- The strategy for reconstruction is dictated by the extent of the IVC defect and the concomitant need for other vascular reconstructions. Typically, the vena cava is repaired, when necessary, following arterial reconstructions to decrease end-organ ischemia. The duration of caval occlusion should be limited to less than 30 minutes to minimize venous congestion and resultant ischemia.
- For small caval defects, primary repair may suffice when the lumen diameter is reduced by less than 50%. Otherwise, autogenous internal jugular vein or bovine pericardial patch repair may be incorporated into the repair. Lower extremity vein harvest is not preferred for caval reconstruction due to increased risk for distal thrombotic complications.

- For replacement of the IVC, when necessary, interposition graft using externally supported ePTFE is the preferred conduit. Following resection of the involved segment, the transected ends of the vena cava are inspected for any residual disease within the lumen. Controlled sequential flushing of the transected ends also ensures patency. The graft diameter is chosen to be deliberately smaller than the caval segment being replaced to promote higher velocities within the graft segment following reconstruction. The proximal anastomosis is completed first using either a running 4-0 or 5-0 Prolene suture. The distal anastomosis is then similarly performed with the patient in Trendelenburg position. Prior to completion of the distal anastomosis, proximal and distal clamps are sequentially removed, a Valsalva maneuver is induced by the anesthesiologist, and the graft is filled with heparinized saline while flushing is performed to minimize retained air and the risk for air embolization.
- External support rings are maintained to the greatest extent possible to avoid compression of the graft, including at midgraft segments where end-to-side anastomoses are necessary for renal vein or common iliac vein reimplantation. For repair of the confluence of the common iliac veins, we have successfully modified this procedure by incorporating a short segment of nonsupported bifurcated ePTFE graft into the repair. Externally supported ePTFE grafts are then sutured to the nonringed segment with ePTFE suture. The suture lines are then covered with BioGlue or sterile Dermabond to prevent suture line bleeding and the graft is then placed in situ (**FIG 7**).

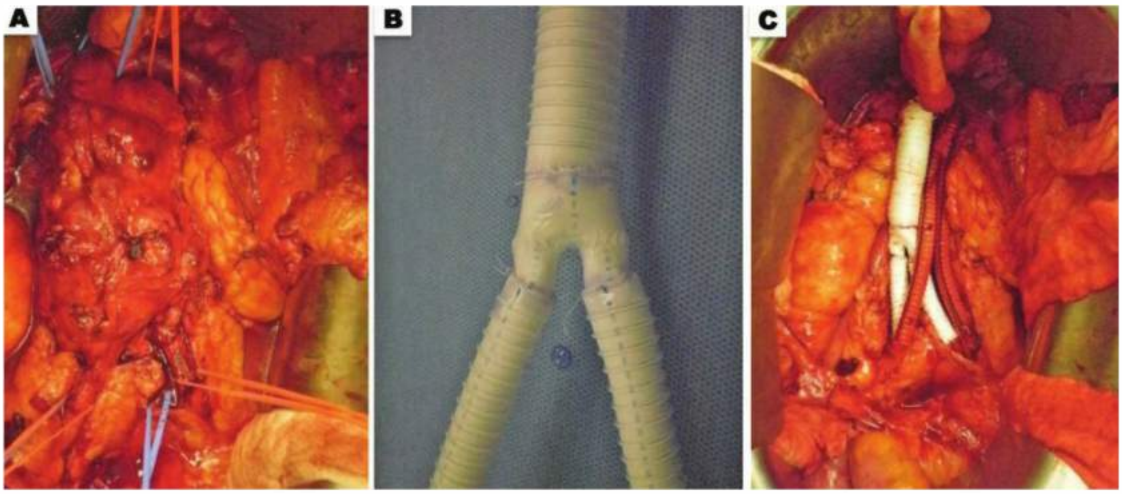

FIG 7 ● IVC and aortic reconstruction in the setting of intraabdominal resection of a large retroperitoneal high-grade leiomyosarcoma. **A.** Operative exploration demonstrated a large retroperitoneal mass with circumferential involvement with the infrarenal aorta and IVC. Proximal infrarenal aorta and distal bilateral common iliac arteries were circumferentially exposed and controlled. The proximal infrarenal IVC and distal left common iliac vein were also controlled. **B.** Back-table construction of a custom PTFE bifurcated graft for reconstruction of the IVC. This was performed by suturing a 16-mm ringed PTFE graft to two 10-mm ringed PTFE grafts using a 6-0 Gore-Tex suture. The anastomosis was reinforced with Dermabond. **C.** Following tumor mass resection along with associated IVC, infrarenal aorta, and proximal bilateral common iliac arteries, the vena cava is reconstructed using the custom-constructed bifurcated PTFE graft. The resected aortoiliac segment was reconstructed using traditional techniques using a bifurcated Dacron graft.

PEARLS AND PITFALLS

Preoperative workup	■ It is imperative that a comprehensive plan for resection and vascular reconstruction be developed and agreed upon by all participating surgical specialties well in advance of the procedure. ■ Adequate preoperative evaluation will facilitate discussion of planned vascular reconstructions as well as the risks and anticipated outcomes of the procedure.
Intraoperative anticoagulation	■ The presence of adequate systemic anticoagulation prior to vascular occlusion is essential to the optimal outcome of the procedure. Anticoagulation may be delayed to minimize tumor bed bleeding during resection but should be established well in advance of planned vascular reconstruction. ■ An activated clotting time (ACT) of greater than 250 seconds is recommended during vascular repairs to avoid thrombotic complications. Reversal of anticoagulation following completion of arterial repairs is also standard practice.

Arterial repairs	■ If the aorta is known to be involved with tumor, it is imperative that proximal control be established well proximal to the anticipated margin of resection. ■ To optimize outcome, the presence and extent of underlying vascular arterial disease should be fully appreciated. For example, complete aortoiliac or aortofemoral reconstruction may be necessary when significant atherosclerotic disease is present in the distal aorta (as an alternative to segmental patching or replacement). Similarly, endarterectomy of residual SMA or celiac artery diseased lumens may be necessary to optimize patency of patch or interposition graft repairs. ■ Attempts should be made to preserve as many SMA and celiac artery branches as possible during vascular reconstruction to maintain adequate bowel perfusion. This is particularly important if concomitant bowel resection is anticipated.
Venous repairs	■ In the setting of complete compression or occlusion of the IVC, the indications for reconstruction following resection may be less compelling. Reconstruction of chronically occluded iliac veins is generally not indicated under any circumstances during oncologic resections—particularly when patients are free preoperatively of significant lower extremity edema. ■ Air embolus is a significant potential complication of extensive venous reconstruction. The risk of air embolization may be minimized when repairs are performed with the patient in Trendelenburg position and with timely Valsalva induction by the anesthesiologist during retrograde flushing maneuvers prior to completion. If a large air embolus is suspected, blood can be aspirated directly from the vena cava or right atrium while the patient is maintained in Trendelenburg and left lateral decubitus position.
Renal vascular repairs	■ Right renal vein reconstruction and/or reimplantation to the vena cava is necessary because there is no adequate collateral venous outflow from the right kidney. During right renal vein reimplantation, the right renal artery should also be controlled and clamped to avoid venous congestion injury to the kidney. ■ Left renal vein can be sacrificed and ligated if the left adrenal and gonadal veins are intact. However, if left kidney venous outflow collaterals were ligated during exposure and reconstruction, the left renal vein should be preserved or reconstructed whenever possible.
Postoperative bleeding	■ In the immediate postoperative period, sudden or acute anemia, abdominal pain, abdominal distension, or hemodynamic instability should be approached with heightened awareness for possible intraabdominal bleeding. ■ Particularly in patients with recent pancreatic reconstructions, bowel-associated leaks may compromise arterial/venous repairs and can lead to acute catastrophic bleeding requiring urgent intervention.
Methods to avoid lower extremity edema	■ Patients are prone to increased lower extremity edema following lower extremity venous harvest or intraabdominal vena cava reconstructions. For these patients, lower extremity elevation in the immediate postoperative period is recommended. ■ Early compression therapy of the lower extremity can also significantly minimize the extent of lower extremity edema in the perioperative period. Arterial insufficiency should be ruled out prior to initiation of compression therapy to avoid compromise of already limited arterial inflow.

POSTOPERATIVE CARE

- Patients are typically managed in a monitored setting where periodic vascular examination is available and vasoactive agents are administered as necessary to maintain homeostatic arterial perfusion pressure.
- Intravenous fluid resuscitation is maintained in the short-term perioperative period until the patient resolves an anticipated course of intestinal ileus.
- All patients should be initiated and maintained on an antiplatelet agent, typically 325 mg aspirin daily.
- In patients who preoperatively received therapeutic anticoagulation, this should slowly be restarted 1 to 2 days following the patient's operation to minimize perioperative bleeding complications.
- Patients with large PTFE interposition caval grafts are typically anticoagulated for at least 6 months postoperatively and potentially lifelong depending on risk factors, history of prior DVT, and extent of reconstruction required to restore caval continuity.
- Early mobilization and DVT mechanical and/or chemical prophylaxis should be initiated as soon as safely possible in the postoperative period.

OUTCOMES

- Abdominal tumor resection with vascular reconstruction is feasible for many malignancies previously deemed unresectable.
- In a series of 47 patients who underwent IVC reconstruction with en bloc tumor resection, there was an 80% 5-year patency rate of the vascular reconstruction and a 45% 5-year survival.[11]
- In a series of 17 patients with SMA and portal vein reconstructions with pancreatic mass resection, there was an 88% primary patency rate. Two patients returned to the operating room for vascular-related complications. Eighty-two percent of patients were reported alive over follow-up period (4 to 48 months).[12]
- In a series of 14 patients receiving retroperitoneal sarcoma resection and major arterial and venous reconstruction, primary

arterial patency was 58% and primary-assisted patency was 83%. Venous patency was 78%. Local recurrence occurred in 21% of patients and 5-year disease-free survival was 52%.[13]

- In a series of 141 patients who underwent resection of retroperitoneal soft tissue sarcomas with either major arterial or venous structure involvement, arterial continuity was retained in all patients and venous continuity was retained in 80%. Perioperative morbidity was 36% and mortality was 4%. Midterm arterial patency was 88.9% and venous patency was 93.8%. The overall 5-year patient survival was 66.7%.[14]

COMPLICATIONS

- Intraoperative bleeding
- Perioperative infection
- Thrombosis or occlusion of repair or graft site
- Venous air embolism
- Wound complications due to poor nutrition or possible radiation to operative field
- DVT from hypercoagulable state

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Chapter 21

Hepatic- and Splenic-Based Renal Revascularization

Fred Weaver   Sung Wan Ham   Grace Huang

DEFINITION

- The hepatic and splenic arteries represent suitable alternative inflow sources for renal artery revascularization. The most common indications for basing bypass procedures from these arteries include abdominal aortic occlusion or insufficiency or, alternatively, a scarred or hostile periaortic retroperitoneum. Hepatic- or splenic-based renal revascularization also minimizes increases in cardiac afterload induced by aortic cross-clamping, which may be of benefit in patients with congestive heart failure. Alternative terms for hepatic- or splenic-based renal revascularization include hepatorenal bypass, splenorenal bypass, splanchnorenal bypass, or extraanatomic renal revascularization.

DIFFERENTIAL DIAGNOSIS

- Renal revascularization is most commonly performed to alleviate "resistant" renovascular hypertension. Resistant hypertension is defined by a systolic blood pressure greater than 140 mmHg in patients taking at least three antihypertensive medications, representing 5% to 10% of all hypertensives. A subsegment of these patients has secondary hypertension due to renal artery pathology or endocrine tumors. Alternative causes of resistant hypertension include
  - Renal artery
    - Atherosclerosis
    - Aneurysm
    - Arteriovenous fistula
    - Fibromuscular dysplasia
    - Takayasu arteritis
    - Other vasculitides involving the renal artery (i.e., Behçet's syndrome, polyarteritis nodosa)
    - Trauma
  - Endocrine tumors associated with hypertension
    - Pheochromocytoma
    - Primary aldosteronism
    - Cushing's syndrome
    - Primary adrenal hyperplasia
    - Hyperthyroidism
    - Acromegaly

PATIENT HISTORY AND PHYSICAL FINDINGS

- Patient age: In younger patients, renovascular hypertension generally arises from nonatherosclerotic pathologies, such as Takayasu's arteritis or fibromuscular dysplasia. In patients older than 50 years of age, atherosclerosis is most common etiology.
- Associated risk factors are those typical for all occlusive arterial disease: tobacco use, diabetes, hyperlipidemia, and hypertension.
- Length of the hypertensive diathesis: Was the hypertension easily controlled for a period of time, with a recent increase in the difficulty of control? Is the hypertensive diathesis severe and recent in onset? If either is true, the patient is more likely to have a secondary hypertension.
- Recognition of the systemic burden of vascular disease present provides important perspective on indications and treatment options. Many vascular maladies involve multiple vascular beds. Is there evidence of disease involving the carotid artery, lower extremity arterial tree, and/or thoracic and abdominal aorta?
- A history of postprandial pain, significant unintentional weight loss, and food avoidance is suggestive of mesenteric occlusive disease.
- Prior pancreatitis may complicate attempts at splenic-based renal revascularization.
- Prior Hodgkin's disease or other neoplasms requiring mantle or midline abdominal radiation
- For general operative risk considerations, recognition and documentation of the presence of coronary artery disease, previous coronary stents, or surgical coronary revascularization as well as valvular disease and congestive failure is fundamental to surgical planning.
- Documentation of renal function as evidenced by increased serum creatinine, pedal edema, or recent requirement for renal replacement therapy
- Recognition of prior aortic procedures, or intraabdominal nonvascular procedures such as a retroperitoneal lymphadenectomy for testicular cancer, which may complicate retroperitoneal dissection and aortic exposure
- Family history of syndromic aortic diseases such as Marfan's, Ehlers-Danlos, and Loeys-Dietz
- The specific antihypertensive regimen in place prior to surgery needs to be verified and documented.
- To obtain the most accurate baseline measurement, the highest pressure obtained from either arm should be recorded and retained.
- A complete vascular examination must be performed, with particular attention paid to pulse deficits and bruits. In particular, diminished femoral pulses or an abdominal bruit may indicate significant aortic or branch vessel occlusive disease, potentially complicating revascularization plans. The presence of concomitant carotid bruits may suggest carotid occlusive disease that should be assessed prior to renal revascularization. The presence of an aortic aneurysm should be excluded by abdominal palpation.

IMAGING AND OTHER DIAGNOSTIC STUDIES

- Laboratory assessment of renal function should include, at a minimum, serum creatinine, blood urea nitrogen (BUN), and electrolytes. Baseline glomerular filtration rate can be estimated from the serum creatinine level and body mass index using the Cockcroft-Gault equation.
- The co-occurrence of endocrine syndromes, such as pheochromocytoma or functional adrenal tumors that potentially contribute to resistant hypertension should be evaluated with appropriate serologic studies.

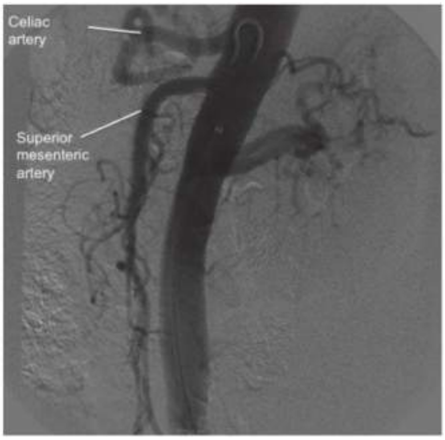


FIG 1 ● Abdominal angiogram with lateral view shows a normal celiac artery.

- Renal artery duplex ultrasonography is performed to document existing renal artery disease, renal mass, and intraparenchymal renal flow indices. Hemodynamically significant renal artery stenosis (>60%) are determined by duplex-derived assessment of peak systolic velocity measurements across lesions. Baseline characteristics (i.e., kidney size, velocity, spectral waveforms, resistive indices) serve as reference points for future surveillance imaging following revascularization.
- Selective visceral and renal arteriograms are obtained to define normal and variant vascular anatomy, including lateral imaging of both the celiac and superior mesenteric arteries (**FIGS 1** and **2**).
- Computed tomography (CT) arteriography of the abdomen and pelvis, with arterial and venous pelvis, may provide additional useful information regarding the extent of aortic disease and other associated abdominal pathology (**FIGS 3** and **4**). Catheter-based arteriography alone may not identify significant arterial wall disease or the presence of aneurysmal lesions. However, the expense, contrast load, and radiation associated with complementary arteriographic imaging modalities may not be justified or appropriate in every patient, so anatomic information obtained from these examinations should be integrated into the operative plan on an iterative basis. Preoperative, imaging-based planning is combined with direct intraoperative assessment to create the most effective and durable revascularization possible for each patient.
- Documentation of celiac, hepatic, splenic, and superior mesenteric artery patency is a mandatory prerequisite for these procedures. Significant stenosis of the celiac origin or hepatic or splenic artery occlusive disease will prevent successful renal revascularization from these arteries. Associated superior mesenteric artery disease also needs to be considered, particularly when the gastroduodenal artery provides significant collateral flow from the celiac plexus to the mesenteric bed. Renal artery anatomy, including branch vessel involvement and the presence of multiple renal arteries also needs to be documented.
- Bilateral lower extremity vein mapping is also necessary to identify potential graft conduit. Standard vein mapping techniques, including imaging in a warm room with the patient in reverse Trendelenburg position, should be employed to ensure accuracy and reproducibility.
- For selected patients, a more extensive preoperative evaluation for coronary artery or valvular disease should be considered. This may include both a transthoracic echocardiogram and cardiac stress evaluation. Selective pulmonary evaluation may be required in patients with chronic obstructive pulmonary disease (COPD)–associated respiratory

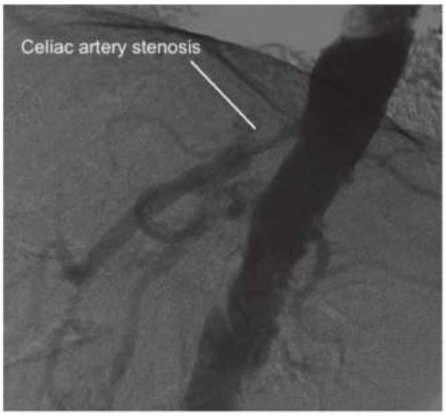


FIG 2 ● Abdominal angiogram with lateral view shows a stenotic celiac artery.

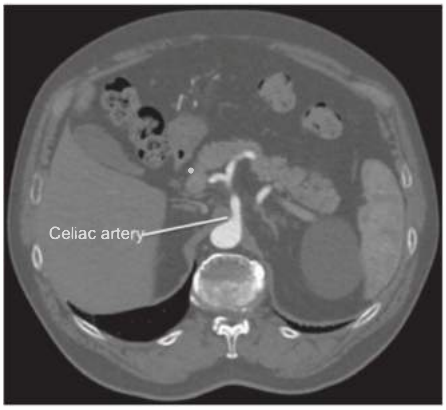


FIG 3 ● Axial CT scan image shows a normal celiac artery origin.

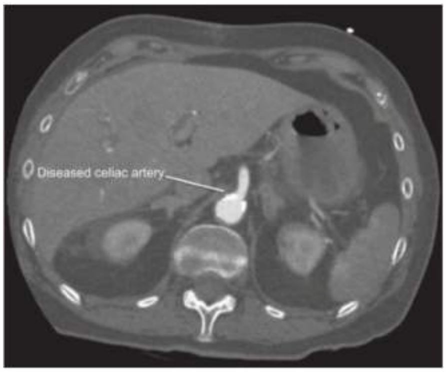


FIG 4 ● Axial CT scan image shows a diseased celiac artery origin.

compromise. Additional vascular assessments should be performed as indicated, including carotid duplex ultrasonography to assess the significance of carotid bruits identified on physical examination.

SURGICAL MANAGEMENT

Preoperative Planning

- The indications for hepatic and splenic artery–based renal revascularization are similar to those for aorta-renal revascularization and are discussed elsewhere.[1,4]
- Although aorta-renal bypass is most direct and generally most expeditious, extraanatomic renal revascularization may be preferable in selected circumstances as previously noted.
- Review of preoperative imaging is performed to determine variant vascular anatomy, if present. Anatomy of the existing renal artery disease is assessed.
- The hepatic–right renal bypass requires a conduit, preferably autogenous vein.
- The spleno–left renal bypass may be performed with or without graft conduit. The native splenic artery is sufficient length, usually to extend directly to the left renal artery, when fully mobilized. When necessary due to variant anatomy, or prior inflammation or scarring around the pancreas, venous conduit can also be employed.
- Planning for availability of duplex ultrasonography in the operating room (OR) will facilitate intraoperative confirmation of adequate target revascularization and renal perfusion.

Positioning

- Patient is placed in supine position with both arms tucked.
- A small bump is placed under the respective flank.
- The operative field is prepped from the nipples to the knees.

HEPATORENAL BYPASS

Placement of Incision

- Optimal access is gained through a right subcostal incision extending from the midline to the tip of the 12th rib. In large or obese patients, the medial extent of the incision can be extended across the midline as a chevron (FIG 5).
- When necessary, an upper midline incision may also provide sufficient exposure.

Hepatic Artery Exposure

- The hepatoduodenal ligament is exposed by retracting the right lobe of the liver cephalad.

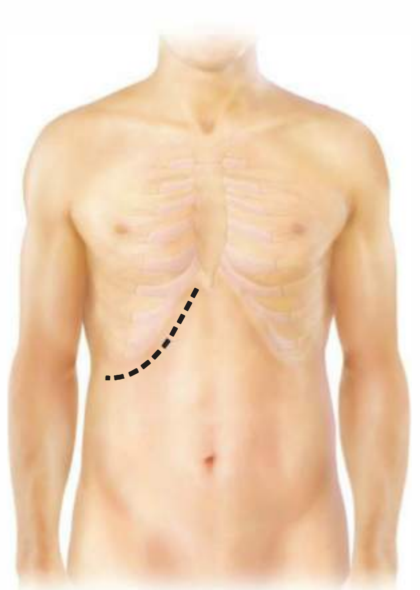


FIG 5 ● Right subcostal incision extended to the tip of 12th rib.

- The right colon and duodenum are reflected anteriorly and to the left (Kocher maneuver). The small intestine is packed toward the pelvis with moist laparotomy pads.
- The hepatoduodenal ligament is incised longitudinally. The hepatic artery is located in the porta hepatis medial to the common bile duct (FIG 6).
- The gastroduodenal artery is identified as the first large branch coursing caudad and encircled with a silastic loop. The gastroduodenal artery should be preserved in the presence of superior mesenteric artery occlusive disease as it provides important collateral circulation to the small intestines.
- The hepatic artery is controlled proximally and distally with silastic loops (FIG 7).

Right Renal Artery Exposure

- The right colon and duodenum are reflected as detailed earlier to expose the inferior vena cava and right renal vein.
- The right renal artery is located posterior and superior to the main renal vein. Depending on its position, the renal vein is retracted either cephalad or caudad. To ensure the main renal artery is exposed, the dissection should be carried to its aortic origin. This requires medial retraction of the inferior vena cava and division of lumbar veins when necessary.
- The right renal artery is controlled using a silastic loop.
- The main renal artery is exposed circumferentially and then distally to the three segmental renal artery branches. Each branch is identified and controlled with a silastic loop. This is a critical operative maneuver that excludes the presence of branch disease and ensures a successful renal artery revascularization (FIG 7).

Distal Anastomosis

- The distal anastomosis is performed first to take advantage of the additional degrees of freedom provided by the mobile graft.
- An appropriate length of greater saphenous vein is harvested from the thigh. The patient is heparinized 100 units/kg. The vein itself is reversed before placement.

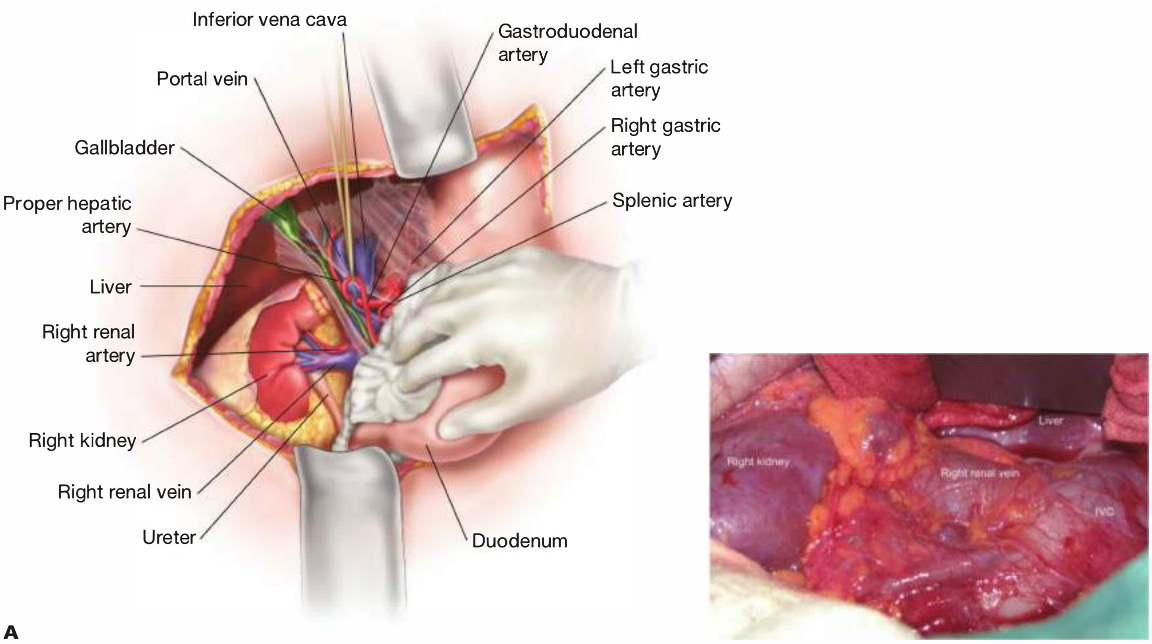


FIG 6 ● **A,B.** Kocher maneuver with porta hepatis dissected. IVC, inferior vena cava.

- The proximal renal artery is mobilized following its division from the aorta, at its origin. The proximal stump is oversewn with 5-0 polypropylene suture.
- Redundant renal artery is trimmed distally from its origin until the disease-free segment is reached. The mobile renal artery is then transposed anterior to the inferior vena cava.
- The vein graft and renal artery are spatulated and the end-to-end anastomosis created with continuous 6-0 polypropylene suture, knotted at opposite ends of

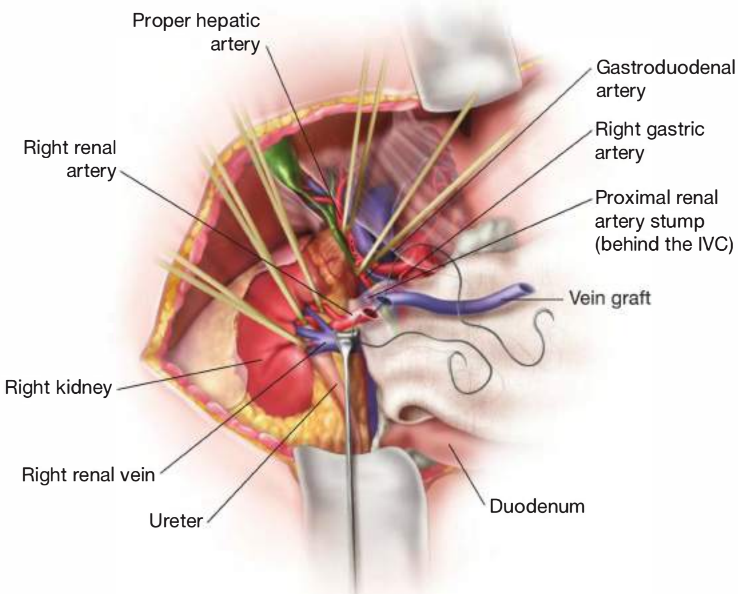
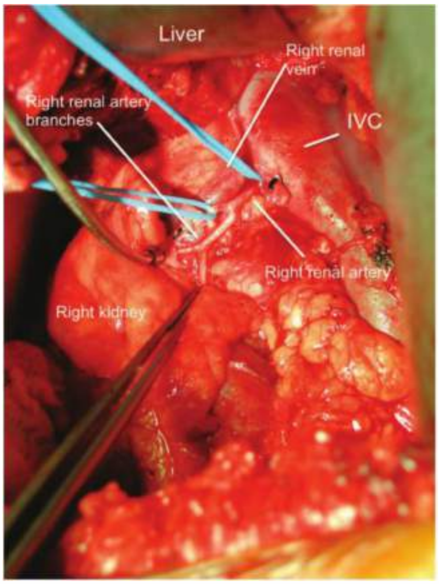


FIG 7 ● **A,B.** Right renal artery and distal branches encircled with silastic loops. Distal anastomosis is performed first. IVC, inferior vena cava. *(continued)*



B

FIG 7 ● *(continued)*

the anastomosis to prevent purse-stringing. Alternatively, depending on renal artery diameter, eight interrupted sutures may be distributed circumferentially around the lumen. The smaller the renal artery diameter, the more advantageous the interrupted technique. Loupe magnification is necessary to ensure optimal results regardless of which suture technique is chosen (**FIG 7**).

- Once the distal anastomosis is completed, the vein graft is oriented longitudinally to prevent twisting or kinking prior to completion of the proximal anastomosis.

Proximal Anastomosis

Hepatic artery

- Small vascular clamps or removable clips are used to control the proximal and distal hepatic artery.
- An arteriotomy is made on the hepatic artery and extended using Potts scissors.
- The vein is spatulated and an end-to-side anastomosis is again performed with running polypropylene suture (**FIG 8A**).

Gastroduodenal artery

- The gastroduodenal artery may be used as an alternative inflow vessel if sufficiently large (4 to 6 mm in diameter). This anastomosis may be performed either end-to-end or end-to-side, but prior to division of the gastroduodenal artery, consideration should be given toward its contribution to the mesenteric circulation (**FIG 8B**).

Intraoperative Duplex Ultrasonography

- We recommend insonation of the graft and both anastomoses using appropriately sized 7-MHz scan heads to ensure technical proficiency following completion of the bypass. In recent years, our practice has come to rely on

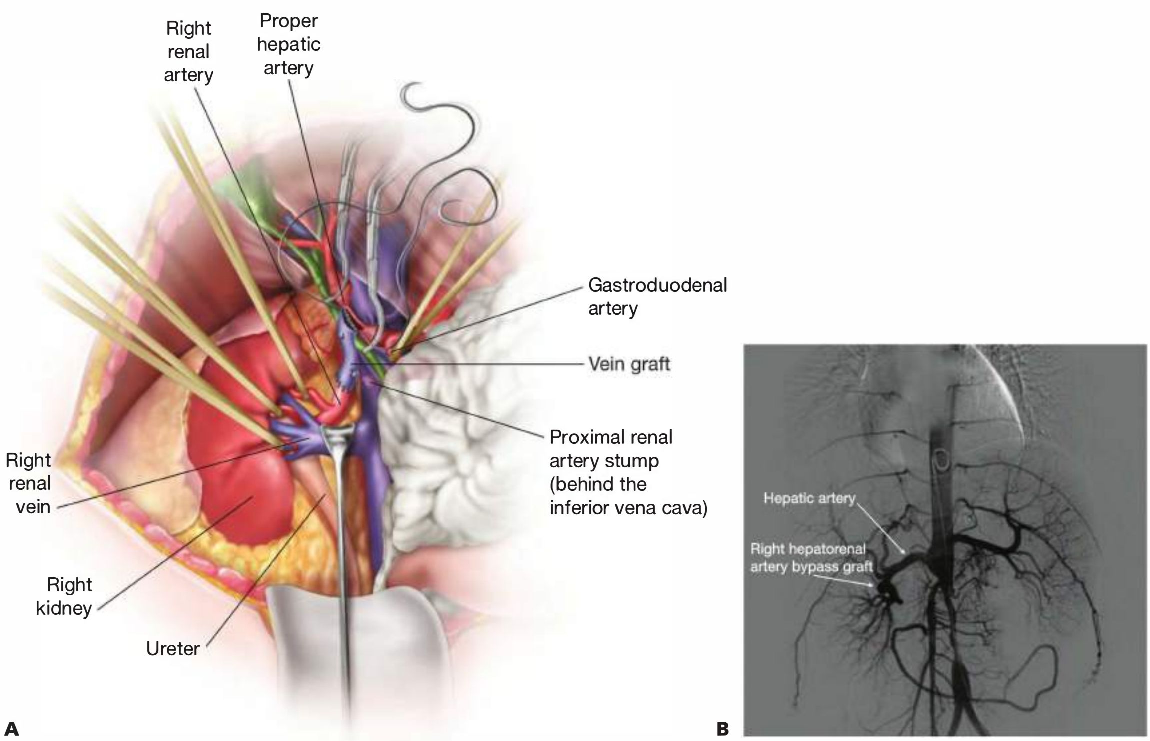


FIG 8 ● **A.** The proximal anastomosis between the hepatic artery and vein graft. **B.** Anterior-posterior angiographic image demonstrates a hepato-renal artery bypass.

duplex ultrasonography for intraoperative assessment of all small and medium size autogenous reconstructions, especially in light of the reduced frequency of such procedures in the era of endovascular and hybrid reconstructions. Renal artery reconstruction is unforgiving in that failure in the perioperative period cannot be expeditiously addressed after the abdomen is closed, almost always precipitating kidney infarction and permanent reductions in creatinine clearance.

- Spectral waveforms, velocities, and B-mode are all employed to detect technical errors requiring immediate repair.

SPLENIC–RENAL BYPASS

Placement of Incision

- Exposure is obtained through a left subcostal incision extending from the midline to the tip of the 12th rib. In large or obese patients, the medial extent of the incision can be extended across the midline as a chevron (FIG 9).
- As was the case on the right side, the upper midline incision may also provide sufficient access depending on body habitus, prior surgeries, and operator experience.

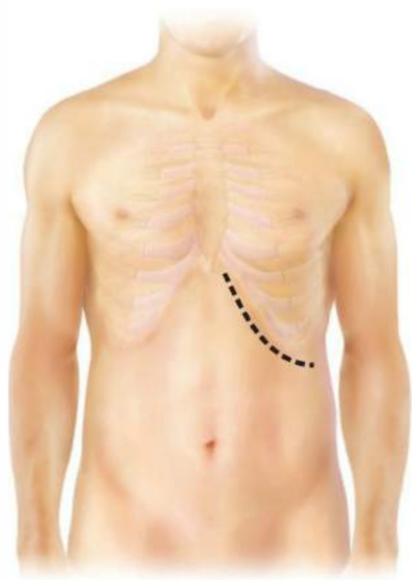


FIG 9 ● Left subcostal incision extended to the tip of 12th rib.

Splenic Artery Exposure

- The greater omentum is elevated exposing the transverse mesocolon. The ligament of Treitz is taken down and the inferior mesenteric vein is ligated and divided. The plane between the pancreas and kidney is entered and the pancreas elevated. The splenic vein is embedded in the body of the pancreas—avoid injury during mobilization of the distal pancreas. The splenic artery should be palpable along the cephalad border of the pancreas. It is mobilized free of surrounding parenchyma moving medially and laterally until sufficient length is obtained to fashion either a primary bypass or support an autogenous vein conduit (FIG 10).

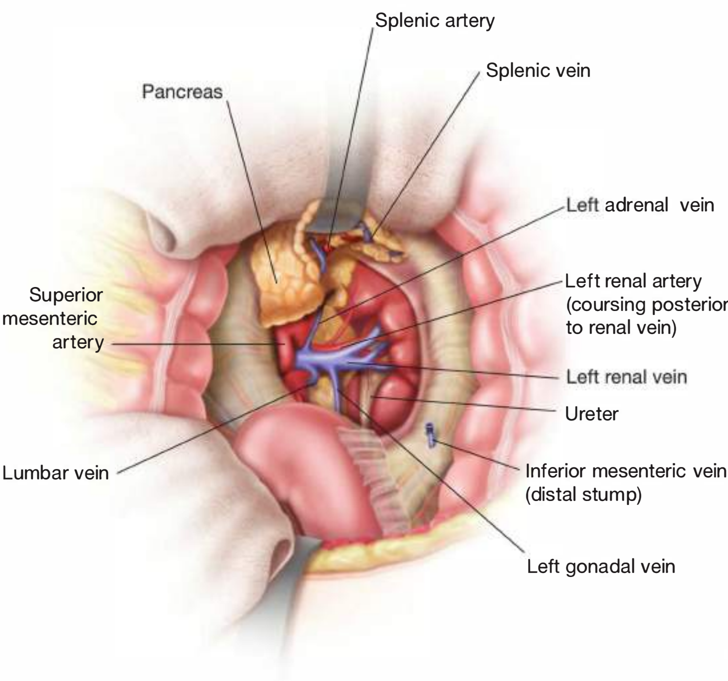


FIG 10 ● Left renal artery and vein exposure. Division of the inferior mesenteric vein allows cephalad retraction of the retropancreatic plane, which allows visualization of the splenic artery.

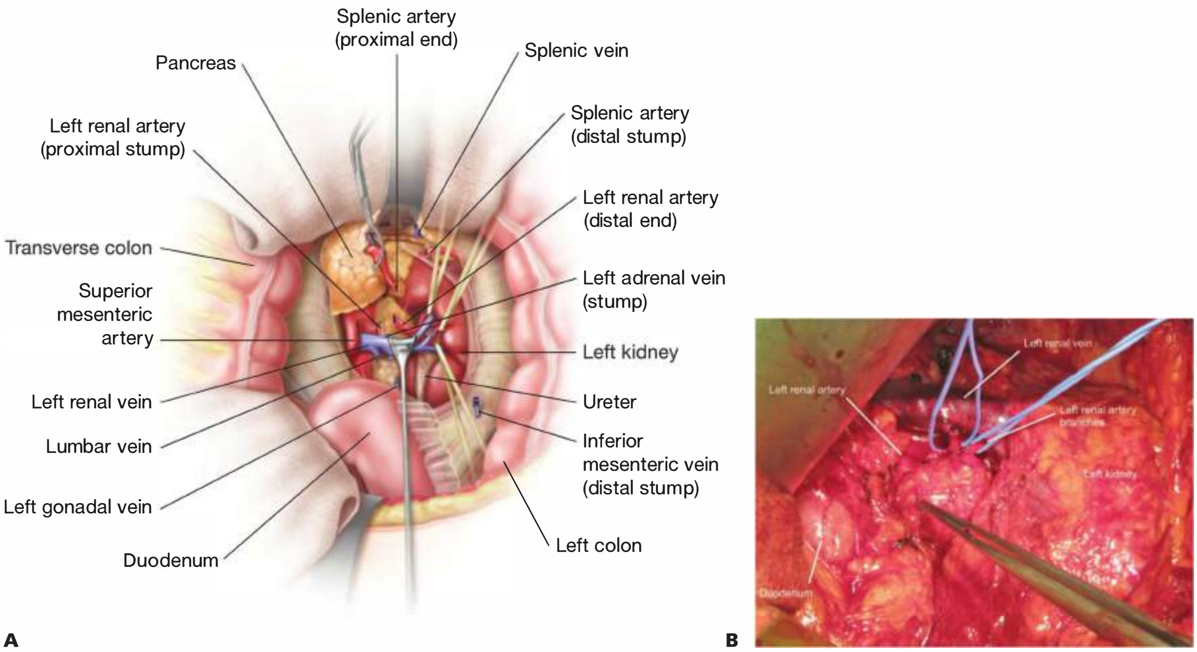


FIG 11 ● **A,B.** The splenic artery and left renal artery are divided. The gonadal, adrenal, and lumbar veins are ligated and divided, allowing complete mobilization of the left renal vein.

Left Renal Artery Exposure

- After mobilizing the distal pancreas, the left renal vein is located just inferior and slightly caudad.
- The left renal vein is circumferentially mobilized. This requires division of its nonrenal tributaries: the gonadal, adrenal, and lumbar veins. Dividing these veins greatly enhances renal vein mobility, facilitating renal artery exposure from its position just cephalad and posterior to the vein.
- As previously described on the right, the left renal artery is dissected to its aortic origin and controlled with a silastic loop. The distal artery and its three segmental branches are identified and encircled with silastic loops. The importance of mobilization is again emphasized (**FIG 11**).

Splenic–Renal Anastomosis

- The patient is heparinized with 100 units/kg of unfractionated heparin. The left renal artery is clamped at the origin and divided. The renal stump is oversewn with a 5-0 polypropylene suture. The distal main renal artery is spatulated distal to the existing renal artery disease.
- The mobilized splenic artery is divided with sufficient length to extend behind the pancreas to the left renal artery without undue tension. The distal splenic artery is oversewn.
- The mobilized splenic artery is spatulated and anastomosed end-to-end to the left renal artery, again with either running or interrupted polypropylene suture depending on the respective arterial diameters (**FIG 12**).
- Alternatively, when splenic artery length is insufficient, reversed saphenous vein may be employed as a bridge graft. Again, to optimize the degrees of freedom, the distal anastomosis is performed first, followed by end-to-end or end-to-side anastomosis to the splenic artery. The vein graft is positioned posterior and inferior to the body of the pancreas.

Intraoperative Duplex Ultrasonography

- As described earlier

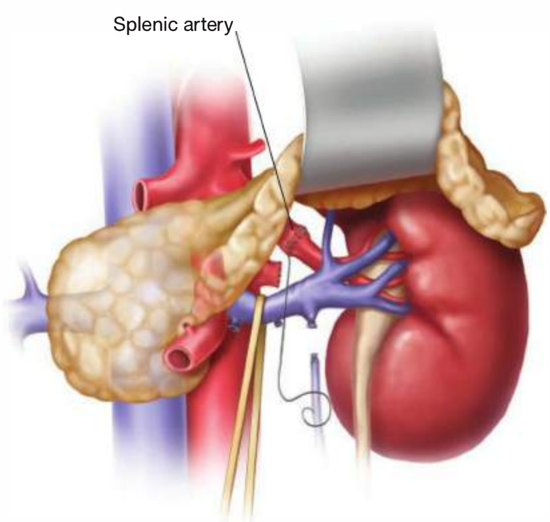


FIG 12 ● Completed anastomosis between the splenic artery and left renal artery.

FINAL INSPECTION

- With completion of the revascularization procedures, all anastomoses and oversewn renal artery origins are inspected for hemostasis. Heparin anticoagulation is reversed with protamine, in a quantity sufficient to normalize the activated clotting time (ACT). Palpation of the SMA at the base of the mesentery is performed to confirm a pulse. Operative traction and/or preexisting disease may compromise SMA flow or precipitate an occult dissection. If the SMA pulse is absent, or the intestinal viability uncertain, mesenteric artery revascularization may be necessary.

PEARLS AND PITFALLS

Preoperative imaging	■ Surgical planning may require CT and catheter-based arteriography as complementary references for surgical planning. ■ Celiac artery stenosis is an absolute contraindication for hepatic- and splenic-based renal revascularization.
Preoperative vein mapping	■ Autogenous vein is the preferred conduit for renal revascularization. ■ Lower extremity vein mapping allows assessment for suitable conduit.
Exposure of the renal artery	■ Circumferential exposure of the entire main renal artery and the three segmental branches is imperative for placement of the renal anastomosis distal to existing disease
Graft orientation	■ Longitudinal orientation needs to be confirmed repeatedly during graft tunneling and orientation. Excessive reliance on graft marking or "striping" as the sole method of orientation may lead to inadvertent kinking or twisting.
Intraoperative duplex	■ Completion duplex scanning is easy, quick, and invaluable in identifying technical errors, which may compromise graft patency and renal viability. ■ Unlike lower extremity bypass procedures, perioperative graft occlusion cannot typically be identified expeditiously to prevent end-organ compromise.

POSTOPERATIVE CARE

- Postoperative care typically involves central venous and arterial pressure monitoring in an intensive care unit (ICU) environment, at least for the first 24 to 48 hours.
- Serial monitoring of serum creatinine, urine output, and acid–base status is essential in the early postoperative period. Unexplained changes in acid–base or elevation of serum creatinine could indicate occlusion of the revascularization itself or progressive mesenteric ischemic.
- Blood pressure is maintained in a physiologic range with vasoactive medications as necessary. Oral antihypertensives are resumed on postoperative day 1 and adjusted depending on the response to renal revascularization.
- Diet is resumed as bowel function returns; nasogastric suction is usually not required.
- Blood pressure and antihypertensive medication requirements may decrease after renal revascularization and should be adjusted prior to discharge.
- Follow-up surveillance duplex ultrasonography is performed at 6 and 12 months then annually thereafter. Detected abnormalities suggesting stenosis of the renal reconstruction may be addressed with remedial endovascular intervention or surgical revision when indicated.

OUTCOMES

- Large case series documenting the outcomes following isolated hepatorenal and splenorenal artery bypass are sparse. Published results are derived from two relatively large series, generally demonstrating acceptable perioperative morbidity and mortality with improved renal function and blood pressure and durable patency.
- Moncure et al. reported 77 patients who underwent 79 procedures (29 hepatorenal, 50 splenorenal bypass) for the treatment of renovascular hypertension and renal preservation. The perioperative mortality was 6%. Deterioration in renal function occurred on three occasions but only in patients with bilateral simultaneous repair. Cure or improvement in hypertension was observed in 52 of 63 patients. Renal function was preserved or improved in 67 of 77 patients.[2]
- Another series by Geroulakos et al. document similar outcomes with extraanatomic renal artery revascularization for atherosclerotic renal artery disease. Forty-five hepatorenal and/or splenorenal bypasses were performed in 38 patients for the treatment of renovascular hypertension, renal preservation, or both. There was one postoperative death from myocardial infarction and two cases of early graft

thrombosis. There was a significant decrease in postoperative mean serum creatinine as well as the average number of antihypertensives. Over a median follow-up of 33 months, there were 10 deaths all from cardiac issues.[3]

COMPLICATIONS

- Bypass graft thrombosis
- Intestinal ischemia due to preexisting disease or traction injury to SMA during operative procedure
- Bleeding from renal, hepatic, splenic anastomosis, ligated renal artery stump, portal vein if injured
- Acute renal failure requiring temporary or permanent dialysis
- Pancreatitis, splenic infarction, common duct injury
- Incisional hernia

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Chapter 22

Advanced Aneurysm Management Techniques: Open Surgical Anatomy and Repair

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DEFINITION

- An aneurysm is defined as a permanent, focal dilation of an artery to a size that is greater than 50% of the normal or expected transverse diameter of the vessel. Although dimensions differ slightly for men and women, practically speaking the normal diameter for the abdominal aorta is 2 cm; therefore, the abdominal aorta is considered aneurysmal when it reaches 3 cm in transverse dimensions.
- *Fusiform* aneurysms are the most common configuration and are a symmetric enlargement of the entire vessel, whereas a *saccular* aneurysm is a focal outpouching that results in an asymmetric bulge of the vessel wall.
- Aneurysms may occur in virtually any vessel in the body but are most commonly seen in the infrarenal abdominal aortic aneurysm (AAA). The *neck* is the length of normal aorta between the osteum of the lowest renal artery and the beginning of the aneurysmal aorta. The term *juxtarenal* is used to describe AAAs that do not involve the renal arteries but because of proximity (<1 cm neck) require clamping above the renal arteries to complete the proximal aortic anastomosis. In a *suprarenal* aneurysm, at least one of the renal arteries arises from aneurysmal aorta, implying the need not only for a proximal clamp but also renal artery reconstruction at the time of the repair (**FIG 1**). This chapter will focus on the indications and techniques for repair of infrarenal and juxtarenal AAA.
- AAA size and/or expansion rate is an important predictor of rupture, and as such guides indication for repair in asymptomatic patients.[1]
- Other predictors for increased risk rupture include female gender, positive family history of aneurysms, smoking status (higher for current smokers versus never smokers and previous smokers), hypertension, and chronic obstructive pulmonary disease (COPD).[2–5]

PATIENT HISTORY AND PHYSICAL FINDINGS

- A thorough history and physical exam is imperative in the evaluation of a patient being considered for aneurysm repair.
- History of present illness: Determine how the aneurysm was discovered. Often, AAAs are an incidental discovery on an imaging test done for another purpose. Be sure to ask about abdominal or back pain, which may indicate this is a symptomatic aneurysm that would require more urgent repair.
- Past medical history: Patients with concomitant renal, cardiac, or lung disease tend to have more complications perioperatively and should be medically optimized prior to proceeding with elective repair. Although there is no benefit to preoperative cardiac revascularization in asymptomatic patients, those with known cardiac disease or risk factors should be evaluated by a cardiologist.[6]
- Family history: Close to 15% of patients with AAA will have a first-degree relative with aneurysmal disease. Patients with AAA should be counseled to alert their siblings and children to this condition, so they may be screened appropriately.[3]
- Social history: Smoking has been linked to increased risk of aneurysm formation and rate of expansion. Patients should be counseled on smoking cessation.
- Review of systems: In addition to the generalized systems review appropriate for all patients undergoing major surgery, particular attention should be directed to other vascular comorbidities. In particular, query about previous cerebrovascular accident (CVA) or transient ischemic attack (TIA) symptoms, amaurosis fugax, mesenteric ischemia, lower extremity ischemic symptoms (claudication, rest pain, ulcers), and work up positive symptoms as appropriate.
- On physical exam, perform a thorough abdominal exam, although be aware that the positive predictive value for localizing a small- to moderate-sized AAA on exam is poor.

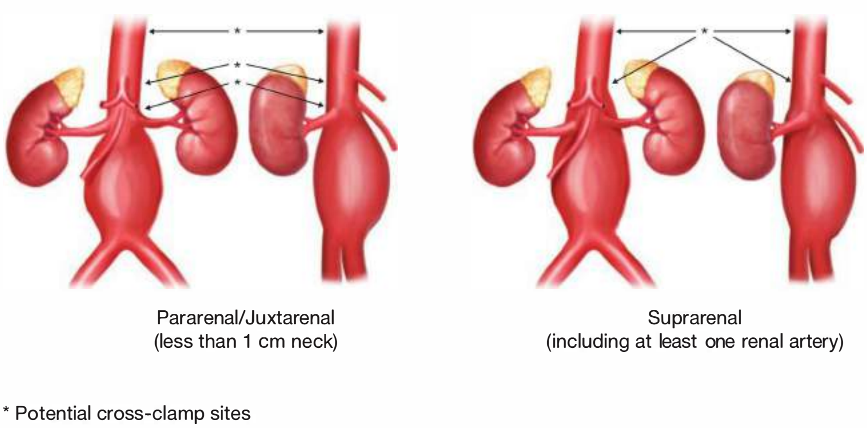

FIG 1 • Anatomic differences between a juxtarenal AAA, where the neck of normal aortic diameter is less than 1 cm, and a suprarenal AAA, where the takeoff of at least one renal artery arises from the aneurysm.

A small proportion (1% to 10%) of patients with AAA will have a concomitant aneurysm elsewhere, so be cognizant that those patients with known AAA and a prominent femoral or popliteal pulse may need further imaging to exclude an aneurysm in these locations.[7]

- Conversely, patients who initially present with peripheral aneurysms such as femoral (85%) or popliteal aneurysms (60%) have a much higher rate of concomitant AAA and aortic screening should be performed in these patients.[7,8]

IMAGING AND OTHER DIAGNOSTIC STUDIES

- Of all imaging techniques used for AAA surveillance, B-mode ultrasonography is the least expensive and does not expose the patient to radiation. Currently, the U.S. Preventative Services Task Force (USPSTF) recommends an ultrasound as a screening test for males between the ages of 65 and 75 years who have ever smoked 100 or more cigarettes over a lifetime. There are no official recommendations for women. It is generally accepted that a negative screening ultrasound exonerates the patient from further screening or surveillance imaging, as the likelihood of new aneurysm development of clinical significance after the age of screening is extremely low. If a screening ultrasound detects a small aneurysm, yearly ultrasounds are indicated until the sac approaches a size where repair may be indicated, at which time further imaging with computed tomography (CT) is recommended.[7,9]
- Computed tomography angiography (CTA) provides a more accurate assessment of aneurysm size, extent, branch vessel proximity and involvement (which may determine if the aneurysm is amenable to endovascular or open repair, and if open repair is to be done, where the proximal clamp should be applied) and is the test that should be used for planning open AAA repair. A thorough exam should include thin (1.5 cm or smaller) cuts of the chest, abdomen, and pelvis with contrast administered in the arterial phase (**FIG 2**).
- It is important to note the location of the aneurysm and its relationship to the renal arteries. Renal anatomy should be noted as well, including any accessory renal arteries and the presence of a pelvic or horseshoe kidney. The renal vein usually travels anterior to the aorta but can be posterior and this should be noted as it may influence operative approach. Other venous anatomy such as a duplicated or left-sided inferior vena cava (IVC) should be noted as well.

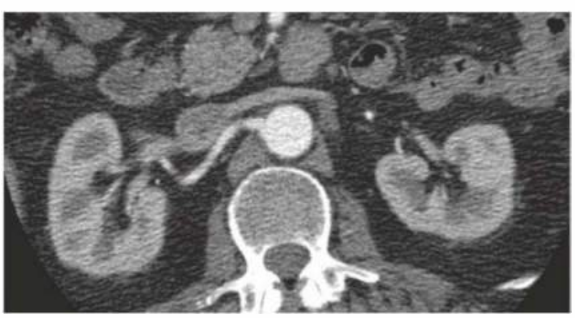

FIG 2 ● Axial cut of a CTA showing the takeoff or the right renal artery and the more commonly seen renal vein lying anterior to the aorta.

SURGICAL MANAGEMENT

- The decision to operate on an asymptomatic patient is based on three primary factors: the risk of the aneurysm's rupturing, the risk associated with aneurysm repair, and the patient's life expectancy. The operative risk and overall life expectancy should be assessed. Assuming that a patient is fit enough to proceed with repair, size is currently our best predictor of rupture. The UK Small Aneurysm Trial and ADAM VA Trial recommend treatment for all patients with an infrarenal AAA larger than 5.5 cm in size, with consideration for repair in women with AAA of 5.0 cm given their higher risk of rupture and likely smaller baseline aortic size. These studies also support repair for those patients who have an increase in diameter of greater than 0.5 cm over a 6-month period (Table 1).[10,11]
- Although there are no large trials looking specifically at iliac aneurysms, repair is generally recommended when they reach 4 cm or greater in size. Iliac aneurysms are more often seen in patients with a concomitant aortic aneurysm and only a quarter of patients with iliac aneurysms will have isolated disease.
- All open repairs should be performed under general anesthesia. It is preferable for the anesthesia team to evaluate the patient prior to the day of surgery so that appropriate time for developing an anesthetic plan, lines, and other means of hemodynamic monitoring is allowed. The use of an epidural for pain control in the postoperative period is useful. In addition, arrangements should be made for autotransfusion given the unavoidable amount of intraoperative blood loss.
- Preoperative understanding of anatomy is of the utmost importance. The surgeon must understand the proximity of the aneurysmal aorta to the renal and visceral vessels and if these branch vessels are affected, as this will impact where the proximal cross-clamp will be applied. If at all possible, clamping should only be done on nonaneurysmal aorta with minimal thrombus or calcification to minimize risk of distal embolization of debris or clamp injury, and all aneurysmal aorta should be resected even if this means involvement of the visceral or iliac segment. If the aorta contains a significant amount of debris or there is little space between branch vessels, a more proximal clamp site in the supraceliac aorta should be considered. It is important to discuss the proposed clamp site with anesthesia preoperatively, as this will affect their management of the patient. The choice of clamp site should be made during the preoperative stage, as the intraoperative need to move the clamp higher is associated with adverse outcomes.

Table 1: Indications for Repair of Abdominal Aortic Aneurysm

- Leak or frank rupture
- Size (5.5 cm in males, 5 cm in females for aortic aneurysm, 4 cm for iliac aneurysms)
- Increase in size of >0.5 cm over a 6-month period
- Symptomatic (pain, compression on adjacent structures)
- Dissection within aneurysm

- Planning for the distal anastomosis requires review not only of the aortic bifurcation but the iliacs as well. If there is aneurysmal or occlusive disease within the iliac arteries, concurrent repair with a bifurcated graft may be appropriate; otherwise, the majority of AAAs are repaired with a tube graft to the iliac bifurcation. Anastomosis may predicate method of distal control, which can be obtained with a single clamp across the bifurcation or both iliac origins, or occlusion balloons (Foley catheters or Pruitt occlusion balloons) for heavily diseased vessels.
- Key pre-operative planning concerns are summarized in Table 2.

Table 2: Operative Planning

- Is a retroperitoneal or transperitoneal approach better?
- Where is the best location for proximal control? Are there any alternatives should intraoperative findings preclude using this site?
- Will clamping involve renal or visceral ischemia?
- Will the renal or visceral arteries need to be reconstructed as part of the repair? If so, what size grafts should be used for the bypass?
- Where is the renal vein? Does it pass anteriorly or posterior to the aorta? Will the kidney be taken up or left down?
- How will distal control be obtained? Will reconstruction involve the iliac arteries or can the distal anastomosis be to the bifurcation?
- What size/type graft should be used?

- There are two approaches for the open repair of the infrarenal or juxtarenal aortic aneurysm: transperitoneal or retroperitoneal (**FIG 3**). Which approach is used for an infrarenal AAA is based on several factors: body habitus (obese patients are often best approached via retroperitoneal), prior surgery (concern for intraperitoneal adhesions), and location of clamp (above the renal arteries may favor a retroperitoneal approach), whereas planned intervention on the right renal or iliac artery would be better approached from the front (transperitoneal).

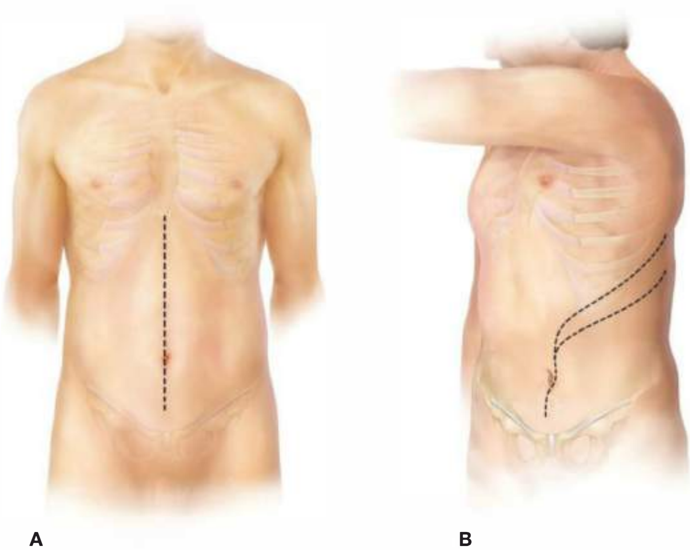

FIG 3 ● Incision for the two approaches to aneurysm repair. **A.** Transperitoneal and **(B)** retroperitoneal. The retroperitoneal approach can be modified for higher exposure on the visceral aorta.

TRANSPERITONEAL APPROACH

- Positioning: The patient is positioned supine on a standard operating room (OR) table with both arms extended. The area from the nipple line to midthighs should be included in the prep field to allow exposure for a high incision as well as the groins should access to the femoral vessels be needed. The hair is clipped and a towel is placed over the perineum. Any previous incisions within the prep field are marked. A Steri-Drape or Ioban is used to secure the drapes in position. Once in position, check pulse volume recording (PVRs) and/or distal pulses.
- Incision: A generous midline incision from the xiphoid to the pubis is made and dissected until the peritoneal cavity is entered (**FIG 3**). It may be necessary to extend the incision cephalad lateral alongside the xiphoid if higher exposure is needed or in emergent situations such as a rupture where immediate supraceliac control is needed. A self-retaining retractor system should then be positioned. We prefer the Omni retractor as the open configuration of the system does not limit the width of exposure.
- Dissection: Reflect the greater omentum and transverse colon cephalad and pack these structures away in a moistened towel or lap pad on top of the patient's chest. The small bowel should be retracted to the right and packed within a separate moistened towel.

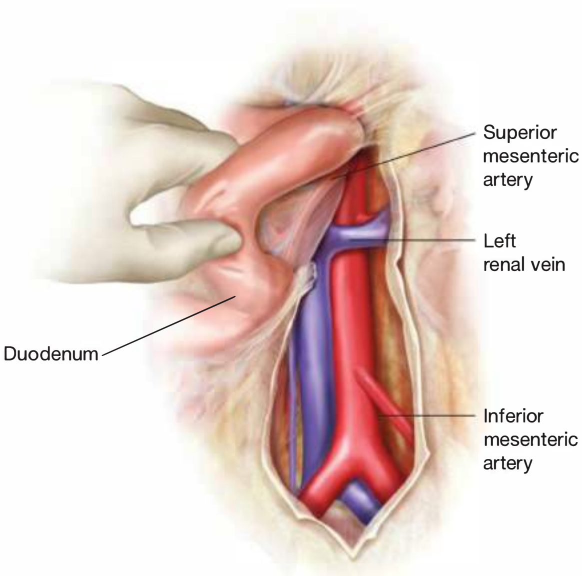

FIG 4 ● Division of the ligament of Treitz (LOT). After reflecting the colon cephalad and the small bowel to the patient's right, the LOT can be divided to expose the infrarenal aorta.

The small bowel is gently placed behind a self-retaining retractor, taking care not to compromise the superior mesenteric artery (SMA). This exposes the ligament of Treitz, which can be divided along the jejunum to the level of the aorta (**FIG 4**). Reposition the retractor to allow as much small bowel to be out of the field as possible, and take down the ligament of Treitz with electrocautery, taking care not to injure the bowel. The inferior mesenteric vein is usually ligated during this dissection. This allows access to the infrarenal aorta where the overlying retroperitoneal tissue can be dissected free. Depending on how much aorta is needed for an adequate cuff of the proximal anastomosis, an anterior renal vein may need to be mobilized cephalad, with ligation of the gonadal and/or adrenal vein for better exposure (**FIG 5**).

- Exposure of the supraceliac aorta (**FIG 6**): The maneuver is only needed in cases where high abdominal aortic exposure is needed, such as in a rupture. The left lobe of the liver must be retracted laterally by taking down the triangular ligament. Next, identify and dissect free the gastroesophageal junction after dividing the gastrohepatic ligament, which is most expeditiously done by palpating for the nasogastric tube and applying caudal traction. Division of the gastrohepatic ligament must be done with the thought that a replaced left hepatic artery would be coursing beneath this structure. The esophagus can be retracted to the patient's left, and this maneuver will expose the aorta. An aortic compressor can be used in extreme circumstances; however, dissection of the aorta circumferentially and surrounding the aorta with a shoestring if the patient's condition allows is preferable. This exposure, although useful when urgent supraceliac control is needed, will not allow access to the visceral segment of the aorta. In order to gain this exposure, a right or left medial visceral rotation should be incorporated into the dissection. The use of a right medial visceral rotation will allow access to the right renal artery, as well as placing the SMA on 90-degree tension and is useful for clearing a clamp site in those patients with a juxtarenal aneurysm who have very little room between the renals and SMA (**FIG 7**). The use of a left medial visceral rotation also allows for exposure to the entire visceral segment of the aorta as well as the left renal artery. Care in this approach must be made to avoid injury to the spleen and tail of the pancreas.

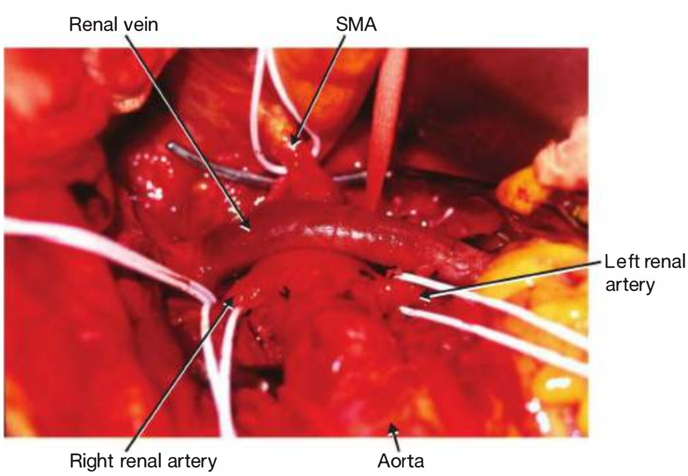

FIG 5 ● (illustration and photo): Mobilization of the left renal vein. Cephalad or caudal mobilization of the left renal vein to expose the origin of the renal arteries. Ligation of several venous sidebranches may be needed for safe mobilization. (*continued*)

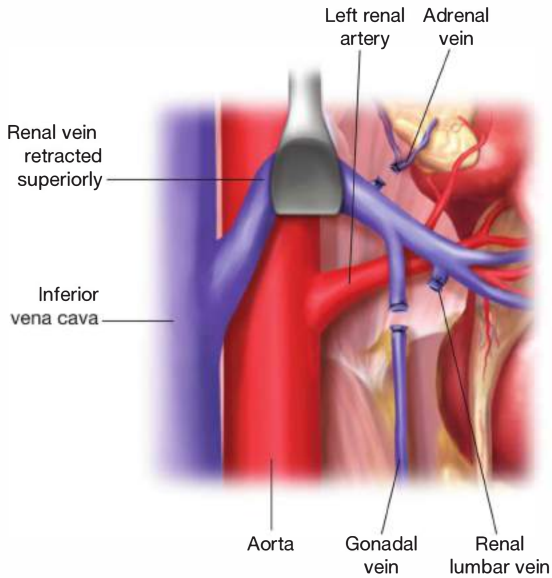

FIG 5 ● (*continued*)

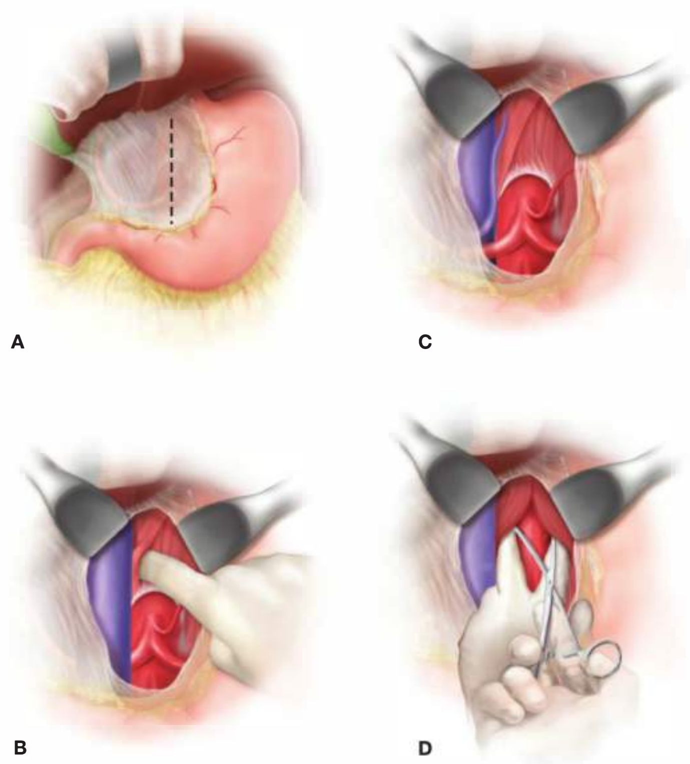

FIG 6 ● Gaining control of the supraceliac aorta. **A.** *Dotted line* shows the location for division of the gastrohepatic ligament. **B.** Once the ligament is divided, the crus is encountered. **C.** Bluntly divide the fibers of the crus. **D.** Using fingers for retraction, control of the aorta can be gained with a clamp, although circumferential control is optimal.

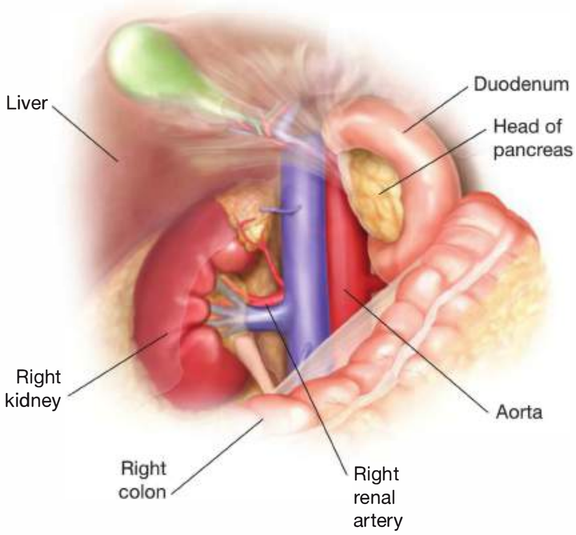

FIG 7 ● Exposure of the aorta and right renal artery via right medial visceral rotation.

RETROPERITONEAL APPROACH

- Positioning: Once asleep, position the patient in the lateral position with the left side up at an approximately 60-degree angle (**FIG 8**). Extend the right arm on an armboard, being sure to leave room for an Omni or other self-retaining retractor post. The upper left arm should be placed on another armboard and padded to prevent neural injury. The bed should be flexed at the patient's flank to open up the area between the ribs and the anterior superior iliac spine. Position the legs so that the lower leg is straight and the upper leg is bent. Use two pillows as padding between legs. A beanbag can be inflated to keep the patient in place, and use thick cloth tape over the hip to secure the patient on his or her side. Ideally, the patient should be placed on a beanbag; however, blanket rolls can be used anteriorly and posteriorly to further secure the patient. Be sure to allow access to prep from the spine posteriorly to the umbilicus anteriorly and from the nipple line to the groins. All bony prominences and pressure points should be well padded to avoid injury. Use clippers to remove hair within the prep area. Prep from the axilla and nipple line to the upper thigh. Mark all previous incisions and use a Steri-Drape or Ioban over the entire prepped area to secure the drapes. Once in position, check PVRs and/or distal pulses.
- Incision: Unless clamping is planned at or above the level of the SMA, a standard retroperitoneal incision over the 11th rib will provide adequate exposure (**FIG 3**). Carry the incision from the posterior axillary line to the anterior border of the rectus. Avoid entry into the pleural cavity if possible, being cognizant that the further posterior the incision is carried, the higher likelihood this will occur.
- Divide the transversalis fascia and enter the retroperitoneal space down to but not violating Gerota's fascia. This space can be more easily identified by resecting a distal segment of the 11th rib, as the tranversalis fascia and transversus abdominal musculature inserts along the inferior border of this rib. It is possible to stay entirely within a retroperitoneal plane; however, if the peritoneum is violated, the abdominal contents can be packed away with retractors or the peritoneum can be repaired with a running 3-0 chromic

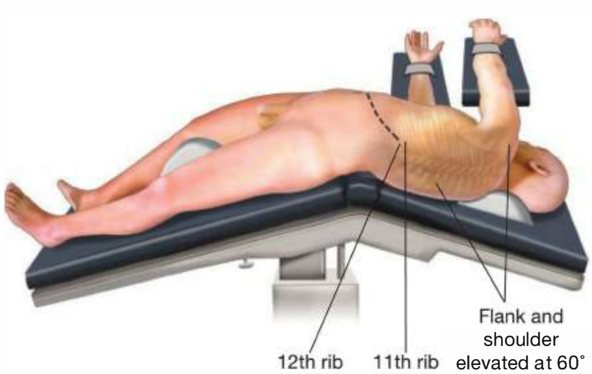

FIG 8 ● Positioning for retroperitoneal incision.

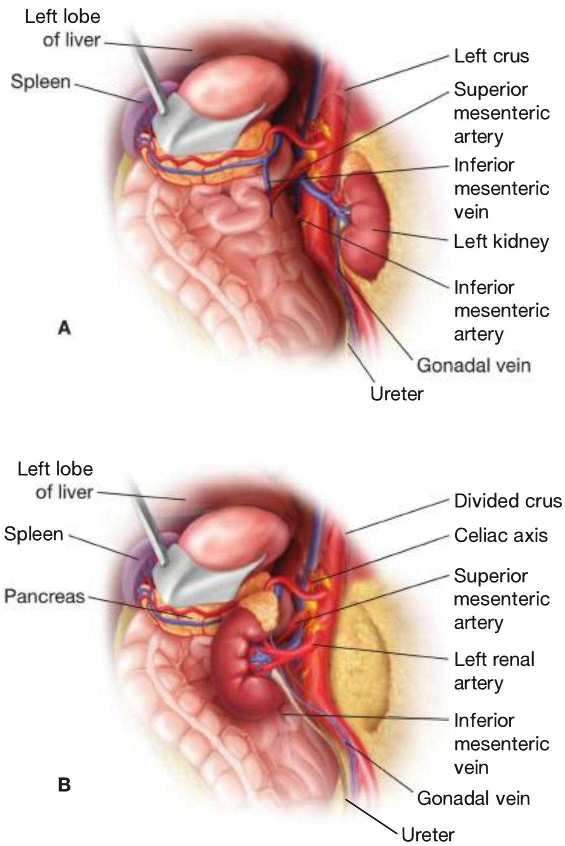

FIG 9 ● The aorta can be approached in an anterorenal plane **(A)** or a retrorenal plane **(B)**.

suture. The aorta may be approached via an anterorenal (colloquially referred to as "leaving the kidney down") or retrorenal plane ("taking the kidney up") (**FIG 9**). Generally, the aorta is approached via a retrorenal approach unless there is a renal vein running posterior to the aorta. As the retroperitoneal dissection continues, the left ureter should be identified and swept toward the midline and placed behind a retractor to avoid injury during dissection of the aorta. The renal artery is identified and dissected back to its origin to identify the aorta

- Dissection: The renal artery should be cephalad to the vein, and once this is identified, it can be used as a landmark and dissected back to the aorta.The renal lumbar vein should be identified and ligated to avoid injury and excessive bleeding. Once the origin of the renal artery is identified, a right angle can be placed along the surface of the aorta and the overlying retroperitoneal tissue divided with electrocautery. It is imperative here to get on the aorta and stay on the aorta to avoid excessive bleeding from the retroperitoneal tissue. The aorta is exposed to the bifurcation and can be dissected circumferentially here if a clamp site is planned; however, the left iliac vein can course posterior to the bifurcation and should be avoided. It is often easier to expose an area of the left common iliac artery for clamping and control the right common iliac artery with an occlusion balloon from within. It is unwise to gain circumferential control of the iliacs in this situation as the iliac veins are often adherent to the posterior aspect of the artery and are easily injured, leading to rapid exsanguinating blood loss. Identify and isolate the inferior mesenteric artery (IMA) with a vessel loop. Pay particular attention to identifying and not injuring the ureters, which will eventually cross anterior to the iliac vessels. If necessary and if the incision is placed along a higher rib space, the dissection can be carried caudal to expose the entire visceral segment if need be (**FIG 10**).

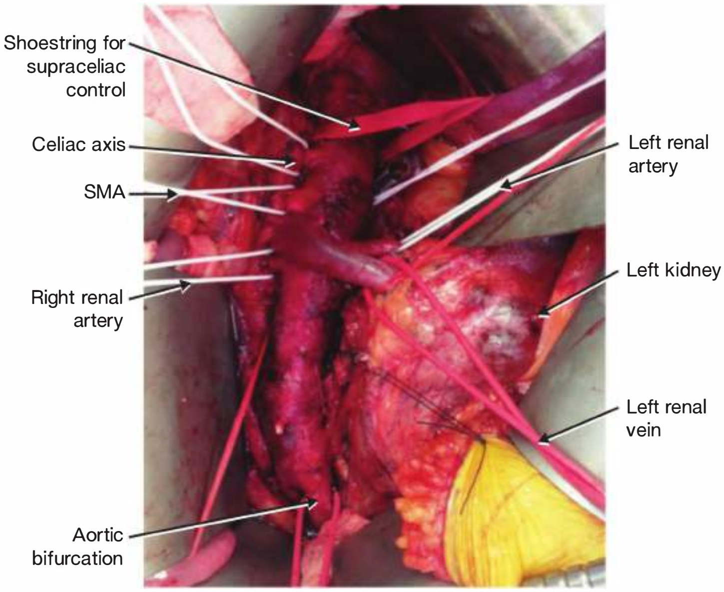

FIG 10 ● Exposure of the entire abdominal aorta from a retroperitoneal approach. Here, the kidney is "left down" in an anterorenal plane. All vessels are surrounded with vessels loops.

AORTIC CLAMPING AND REPAIR

- Regardless of approach, it is important during circumferential dissection of the aorta to avoid injury to the posterior lumbar arteries, which are usually paired. If they are encountered and require ligation, carefully circumferentially dissect out the artery, tying the proximal side of the vessel, and using another tie, double clip on the distal side prior to dividing. When dissecting on the aorta, care must be taken to minimize aggressive manipulation and subsequent atheroembolization, particularly if preoperative imaging shows extensive mural debris.
- Choice of graft: There are several choices for conduit during repair. Generally, a polytetrafluoroethylene (PTFE) or Dacron tube graft is sewn from the proximal aorta to the bifurcation. In those patients with extensive bifurcation or iliac disease, a bifurcated graft may be used. If this is the case, the proximal single lumen portion of the graft should be as short as possible to prevent kinking, ideally less than 4 cm. Tunneling the limb to the femoral level should be done only if necessary, and if so, care must be taken to run the graft posterior to the ureter. The aorta can be measured for the appropriate graft with aortic sizers, but often, an estimation of size can be made from the preoperative CTA. Regardless, the majority of patients can be repaired with an 18- to 22-mm graft (**FIG 11**).

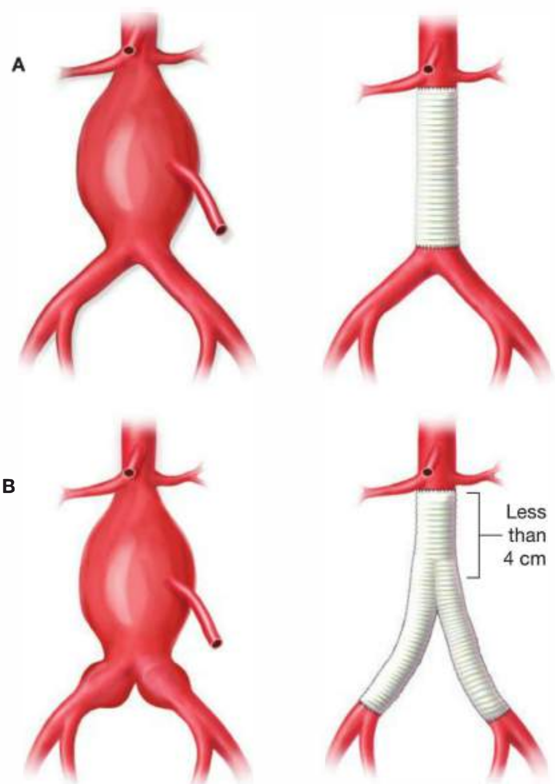

FIG 11 ● **A.** Tube graft from infrarenal aorta to bifurcation and **(B)** bifurcated graft from infrarenal aorta to iliac or femoral vessels.

- Choosing the site of the proximal anastomosis: This will depend on the quality of the proximal neck of the aneurysm and the vicinity of the visceral vessels. In the most straightforward scenario, an adequate cuff of normal aorta is present below the renals to allow for infrarenal clamping and an end-to-end anastomosis. A suprarenal clamp can be used to provide space to sew to a short infrarenal cuff. If aneurysmal tissue extends to the visceral branches, or if there is significant antherosclerotic disease of the branches, a beveled anastomosis may be required, possibly including an endarterectomy of the origin of a branch vessel or a bypass to the left renal artery (**FIG 12**). This should be apparent based on careful review of preoperative imaging and planned for well before clamping of the aorta. From the retroperitoneal approach, every effort should be made to incorporate the right renal artery into the anastomosis.
- In preparation for clamping, the patient should be systemically heparinized at a dose of 70 units of heparin per kilogram and allowed to circulate for 3 to 5 minutes. It is important to communicate with anesthesia prior to clamping and unclamping so they may anticipate and address subsequent hemodynamic shifts. Generally, the systemic pressure should be dropped in preparation for the proximal clamping. If the visceral segment is involved, bulldog clamps should be applied to the visceral vessels prior to aortic clamping to avoid embolization. The proximal clamp is carefully applied and secured with a shoestring around the clamp. The aortic sac is then opened with electrocautery and heavy scissors proximally and distally. Mural debris should be carefully removed to identify all patent lumbar arteries. Distal control can then be obtained with balloon occlusion into each iliac with Foley catheters if external control was not previously done due to calcific disease. All lumbar vessels with back-bleeding into the aorta should be suture ligated with 2-0 silk in a figure-of-eight fashion. In heavily calcified aortas, focal endarterectomies may be necessary for effective ligation of each vessel.
- Sewing of the proximal anastomoses: There are several ways to complete the anastomosis, and choice is based on a combination of surgeon preference and tissue quality. Regardless of technique, the posterior row of sutures should be done first. Ensure that there is adequate exposure of the proximal aorta; this may require the use of a self-retaining retractor within the opened sac or stay sutures on the edges of the sac. Place the graft on the patient's chest upside down, so the posterior aspect of the graft lies anteriorly. If the posterior row is to be done in an interrupted fashion, the first mattress suture is placed in the middle of the graft from outside to in, placing a snap on the needled ends of the sutures. Place four more mattresses, two on each side, working your way to the 3 o'clock and 9 o'clock positions on the graft. Care must be taken to ensure there are no gaps between sutures; all travel must be within a mattressed stitch and not between stitches. Once all sutures are placed in the graft, begin placing the aortic sutures from inside to outside on the aorta. The proximal aorta is usually not completely transected and the posterior wall can be used to create

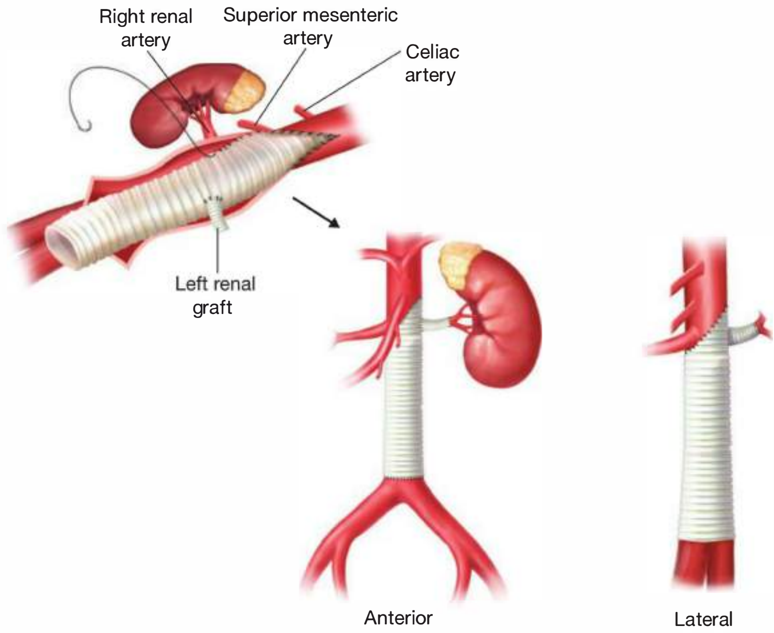

FIG 12 ● Beveled anastomosis with bypass to the left renal artery. The suture line runs just inferior to the right renal artery.

a Creech bite that uses the aortic wall as a pledget. Once all sutures are placed, each individual stitch is pledgeted and tied down snugly. The anterior row is then completed, starting from each side and working your way to the center, such that the anterior-most stitch is the final stitch placed. These are also pledgeted and tied into place. Once the proximal anastomosis is completed, an atraumatic clamp should be applied to the body of the graft, and the proximal aortic clamp slowly released to test for integrity of the repair. Any leaks in the suture line should be addressed at this time, particularly along the posterior row, as this will be inaccessible once the distal anastomosis is in place. It is unwise to attempt to place stitches on a fully perfused aorta, and the proximal clamp should be reapplied if repair stitches are necessary. In addition, pledgets should be used with these stitches. A running anastomosis can also be performed with a 3-0 Prolene and an atraumatic needle. The back row is again began in the middle of the graft with deep Creech bites on the aorta. The graft can be parachuted in to make the suture line taut. The back row should be inspected to ensure that it is snug and additional sutures are used at the 3 o'clock and 9 o'clock positions to secure the back row and run to the top of the aorta (**FIGS 13** and **14**).

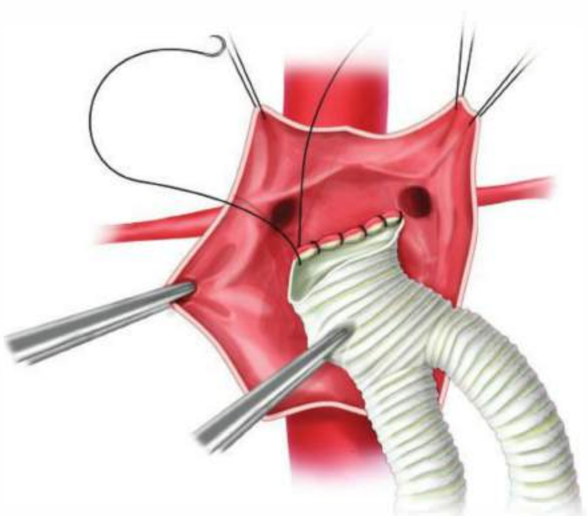

FIG 13 ● Construction of the posterior row of the proximal anastomosis. Note that the anterior and lateral aspects of the aorta is divided but the posterior wall is left intact in this figure, using "Creech" suturing technique.

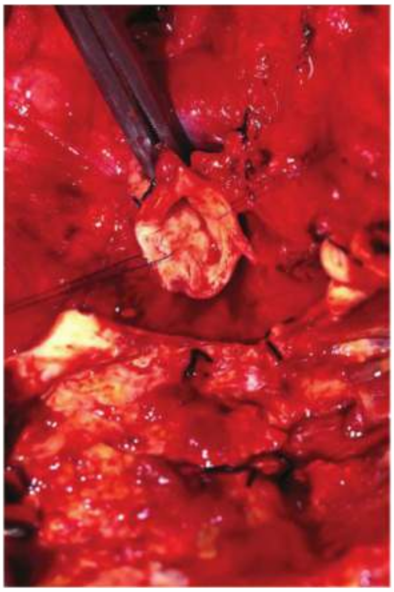

FIG 14 ● Aortic cuff. The aorta can be totally transected and stay sutures applied in preparation for the anastomosis.

- IMA implantation: Although the IMA can generally be ligated without clinical consequence, there are certain situations where it may be beneficial to reimplant the vessel to avoid bowel ischemic complications. Patients with altered pelvic blood flow, such as those with prior gastrointestinal surgery or occluded hypogastric arteries, should especially be considered for IMA reimplantation. Furthermore, visual inspection of the sigmoid colon prior to closure should be done, and IMA reimplantation done if there appears to be questionable viability of the bowel. Additionally, prior to IMA ligation, an assessment of back-bleeding (and thus the collateral circulation to the IMA territory) should be performed and reimplantation considered in cases where the back-bleeding is poor.
- Creating the distal anastomosis: After the proximal anastomosis is completed and hemostasis is ensured, the graft should be pulled taut to the location of the distal anastomosis (or anastomoses if a bifurcated graft is to be used). The graft should be measured to ensure no redundancy or kinking occurs but not so tight as to put undue strain on the proximal anstomosis. The distal can be done in a running or interrupted fashion, as described previously. When sewing, the assistant should use a forceps to pull the graft distally and remove tension on the anastomosis, decreasing the chance the sutures will be too loose.
- Flushing and unclamping: Just prior to the completion of the distal anastomosis, the graft will need to be flushed proximally and distally to remove clot, air, and debris. After flushing, irrigate the graft with heparinized saline and complete the anastomosis. Once both anastomoses are completed, communicate with the anesthesiologist that the clamps are ready to be removed. There is often a substantial drop in systemic blood pressure as the lower extremities are reperfused, and they will need to prepare to react accordingly. It is more appropriate to tolerate a slightly longer clamp time and allow the anesthesiologist to regulate the blood pressure accordingly then unclamp a hypotensive patient. As the surgeon slowly unclamps, the assistant can hold manual pressure at the level of the femoral arteries to allow any debris to flush into the pelvis, which may tolerate embolization better due to the extensive collateral network. Pressure is then released on the femoral vessels and systemic pressure is monitored. If there is a substantial hypotensive response, partial or complete reclamping may need to be performed to allow the anesthesia team time to treat the hemodynamics. Once unclamped, inspect the anastomosis and sac for bleeding. There may be new lumbar bleeding as a result of pelvic reperfusion that was not apparent during the graft placement. Diffuse oozing can be treated with Surgicel and Gelfoam. Once unclamped, check pulses and Doppler signals in iliacs and any clamped branch vessels, as well as distal pulses and/or PVRs. If lower extremity PVRs are significantly worse than preoperatively, this should raise concern for embolization and may warrant a groin exploration and thrombectomy.
- Sac closure: This is especially important during the transperitoneal approach, as an uncommon but disastrous late complication from open aortic surgery is the aortoenteric fistula, which occurs when graft and/or anastomosis erodes into the bowel. To help prevent this, the walls of the now decompressed aortic sac should be closed over the graft, and sewed in a running fashion with a long 3-0 silk or chromic suture. If there is insufficient sac to close, a flap of omentum can be mobilized and placed over the graft prior to returning the visceral to its anatomic location. The sac of the aorta can be a not insignificant source of bleeding, so electrocautery should be used along the cut edge of the sac to ensure hemostasis prior to sac closure, and persistent bleeding should be suture ligated.
- Drainage and closure: If the pleural cavity was entered, drainage will be required either by use of a red rubber suction catheter placement during diaphragmatic repair or postoperative chest tube placement. Additional placement of a closed suction Jackson-Pratt (JP) or Blake drain in the peritoneal or retroperitoneal (RP) cavity can be done on a selective basis; we generally place a drain if there is some concern over excessive mobilization near the tail of the pancreas and thought a pancreatic leak may occur, or in coagulopathic patients where ongoing bleeding may be of concern. Special attention should be paid to inspecting the spleen, and we have a low threshold for splenectomy if there is any injury to the organ. The abdominal wall should then be closed in layers.

PEARLS AND PITFALLS

- Ideally, proximal clamp time should be less than 30 minutes. It is therefore imperative to have all tools and grafts ready and all team members briefed on the operative plan prior to clamping. However, for an infrarenal clamp, the operator will have several hours if necessary to complete the anastomosis. If the clamp is suprarenal, complications begin with more than 40 minutes of ischemia.
- Injury to the common iliac vein or distal IVC during dissection is a potentially lethal complication. It is important to completely mobilize the vein and perform a primary repair under direct vision. Blind suturing in a bleeding field will only lead to disaster. If exposure cannot be obtained, it is acceptable to transect the overlying artery (aorta or iliac) to allow access to the vein. This is a complication that is much better to avoid than treat.
- The ureters can be injured during the transperitoneal or retroperitoneal approach, and every time the retractors are repositioned or as you begin to dissect a new plane, the ureters should be identified.

POSTOPERATIVE CARE

- Patients should be monitored in an intensive care unit (ICU) postoperatively, with blood pressure goals generally of a systolic blood pressure from 100 to 140 mmHg for a straightforward infrarenal or juxtarenal repair. Blood pressure goals should be higher for thoracoabdominal repairs to promote spinal cord perfusion.
- Patient may be weaned to extubated as soon as possible after the operation, even in the OR if appropriate.
- An NGT is kept in place given the bowel manipulation, and this is left in place for the first postoperative day. Although it is not imperative to keep in place until there is full return of bowel function, we will keep in place an additional day if outputs are unusually high. We generally start standing rectal suppositories on the first postoperative day.
- If there is a chest tube in place, we leave this to suction until removal, which is done when output is less than 150 mL per 24 hours and the chest x-ray (CXR) shows no large effusion.
- Mobilization should be done as soon postoperatively as possible. These patients will require physical therapy and many will ultimately require inpatient rehab.

OUTCOMES

- Mortality for an elective, open infrarenal AAA repair is less than 5%, and although the risk increases for those with a juxtarenal or suprarenal repair, our recent experience shows that 30-day mortality in patients with juxtarenal repair is 2.5%. Mortality increases in the instance of an urgent or rupture to as high as 70%.[1,5]
- Patient-specific predictors of postoperative complications include older age, COPD, chronic renal disease (creatinine >1.8) or history of myocardial infarction (MI)/congestive heart failure (CHF).[1]
- Operative-specific predictors of postoperative complications include long OR or clamp times, hypothermia, high blood turnover, and a high perioperative fluid requirement.

COMPLICATIONS

- Bleeding
- Infection
- Splenic injury (consider adding splenectomy to operative consent)
- Renal failure
- MI
- CVA
- Spinal cord ischemia (increased risk with suprarenal and thoracoabdominal repairs)
- Anastomotic breakdown
- Aortoenteric fistula
- Pancreatitis

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Chapter 23

Advanced Aortic Aneurysm Management: Endovascular Aneurysm Repair—Standard and Emergency Management

Vinit N. Varu Ronald L. Dalman

DEFINITION

- An abdominal aortic aneurysm (AAA) is defined as a localized enlargement of more than 1.5 times the diameter of the most adjacent, proximal uninvolved aorta; by consensus, this represents more than 3.0 cm in most persons. Definitions vary somewhat between men and women, most likely normalized by body surface area or body mass index (BMI).
- The most common etiology of AAAs is progressive, transmural degeneration of the aortic wall. The full scope of pathogenetic considerations and relevant mechanisms is beyond the scope of this chapter but, in summary, although aneurysm disease shares many important risk factors for aortic and peripheral vascular occlusive disease, important differences exist, and current thinking regarding pathogenesis recognizes that aneurysmal and occlusive disease of the aorta are distinct pathologic processes. Hence, the colloquial term "atherosclerotic aneurysm," although in common use, is an inaccurate and potentially misleading characterization of the most common clinical presentation for AAA.
- Risk factors for development, expansion, and rupture are multifactorial[1] (Table 1). Smoking is the only modifiable risk factor that has been associated with all three.
- The risk of AAA rupture increases with progressive diameter enlargement.[2] Rupture and subsequent aneurysm-related mortality may be prevented by elective surgical repair, either by open interposition grafting or endovascular aneurysm repair (EVAR).
- EVAR provides similar long-term survival versus traditional open repair, as well as enhanced perioperative survival. The perioperative survival benefit is sustained for several years following surgery.[3] EVAR is now the de facto standard of care for both elective and ruptured AAA repair in patients who are anatomically suited to receive currently available devices.

Table 1: Risk Factors for Aneurysm Development, Expansion, and Rupture

Symptom	Risk Factors
AAA development	• Tobacco use • Hypercholesterolemia • Hypertension • Male gender • Family history (male predominance)
AAA expansion	• Advanced age • Severe cardiac disease • Previous stroke • Tobacco use • Cardiac or renal transplant
AAA rupture	• Female gender • ↓FEV_1 • Larger initial AAA diameter • Higher mean blood pressure • Current tobacco use (length of time smoking >> amount) • Cardiac or renal transplant • Critical wall stress—wall strength relationship

AAA, abdominal aortic aneurysm; FEV1, forced expiratory volume in 1 second.
From Chaikof EL, Brewster DC, Dalman RL, et al. The care of patients with an abdominal aortic aneurysm: The Society for Vascular Surgery practice guidelines: executive summary. J Vasc Surg. 2009;50(4):880–896.

PATIENT HISTORY AND PHYSICAL FINDINGS

- Patients may be entirely asymptomatic despite suffering from large, advanced AAAs. Most commonly, AAAs are found incidentally on imaging studies obtained for other reasons. Occasionally, they may be identified by the presence of prominent aortic pulse, proximal to the umbilicus, on physical exam. Less frequently, AAAs may cause distal limb ischemia secondary to embolization, or fulminate congestive heart failure if they rupture into the adjacent inferior vena cava, creating an acute aortocaval fistula. Only 30% to 40% are noted on physical examination, with detection of pulsatile abdominal mass dependent on aneurysm size. As noted by Sir William Osler, prior to the era of ubiquitous availability and use of cross-sectional abdominal imaging in the evaluation of abdominal pain: "There is no disease more conducive to clinical humility than aneurysm of the abdominal aorta."
- Patients with a ruptured AAA may present with moderate or extreme back and abdominal pain, syncope, hypotension, and mottling of the lower extremities, in conjunction with progressive abdominal distension. When sufficiently stable to remain conscious and conversant, pain is reproducibly elicited by direct palpation of the abdominal aorta. Many patients with ruptured AAA present in extremis, others with progressively hemodynamic deterioration and pain of several hours duration. Patients may actually linger for several days with "contained" retroperitoneal hemorrhage following AAA rupture.
- A thorough vascular history should be noted and modifiable risk factors, including smoking, hyperlipidemia, and hypertension, addressed in patients with AAAs. Smoking cessation is recommended to reduce the risk of aneurysm growth and rupture, and statins may also be beneficial in this regard.
- AAAs occur almost exclusively in the elderly (mean age of repair 72 years of age) and male patients outnumber female by 4 to 6 is to 1.[1] When AAA is recognized in younger patients, it is usually in association with hereditary risk, syndromic aortic conditions such as Marfan syndrome, or in the setting of focal aortitis or mycotic aneurysms. The latter tend to occur most frequently in the suprarenal abdominal aorta, at or directly proximal to the origin of the celiac artery, underneath the crus of the diaphragm. Aneurysmal degeneration of the abdominal aorta may also occur late following thoracic and abdominal aortic dissection.

- Factors associated with increased risk of rupture include female gender, large initial diameter, low forced expiratory volume in 1 second (FEV_1), current smoking history, and elevated mean blood pressure.

IMAGING AND OTHER DIAGNOSTIC STUDIES

- Screening decreases aneurysm-related mortality in AAA disease.[4] Current guidelines recommend a screening ultrasound for 65- to 75-year-old at-risk individuals, defined as men who have smoked more than 100 cigarettes in their lifetime or men or women with a family history of AAAs.[5]
- Thin-slice computed tomography (CT) imaging, with intravenous contrast injection timed to opacify the abdominal aorta and runoff vessels, remains the standard modality for operative planning. The extent, morphology, and accessibility of the aneurysm via retrograde iliofemoral access determine the suitability for an endovascular repair. Other relevant anatomic considerations include the location and volume of laminar intraluminal thrombus in the region of the "surgical" neck (defined as the length between the lowest renal artery and the start of the aneurysm); angulation of the surgical neck, size and tortuosity of access vessels; presence and significance of anomalous and accessory renal arteries; diameter at the aortic bifurcation; and diameter of the more proximal abdominal aorta (provides useful guidance as to the likely long-term diameter of the surgical neck).
- For cases of suspected AAA rupture, bedside transcutaneous ultrasonography may be used to detect the presence of intra- or retroperitoneal fluid (or blood) or assess for confounding conditions eliciting abdominal pain. When sufficiently hemodynamically stable, however, CT aortography should be obtained to assess for suitability for endovascular repair.[6]

SURGICAL MANAGEMENT

Indications

- Patients with "symptomatic" AAAs (e.g., pain likely originating from the aneurysm despite absence of retroperitoneal hemorrhage on CT aortography) are at increased risk of rupture and urgent intervention is recommended. Of those AAAs that rupture, more than half will die prior to hospitalization. Of those that undergo attempted operative repair, approximately 50% mortality is to be expected. The latter estimate is highly dependent on hemodynamic conditions, duration of symptoms, and comorbid conditions present at the time of surgery and is not useful in predicting survival of individual patients.[1]
- For asymptomatic AAAs, management is determined by the maximal orthogonal transverse diameter at the time of evaluation or rate of aneurysm enlargement over time. AAAs less than 4.0 cm are at low risk of rupture and should be monitored with serial imaging; those larger than 5.4 cm are at high risk of rupture and should be repaired. Surveillance is recommended for most patients in the range of 4.0 to 5.4 cm, although young healthy patients and especially women may benefit from repair in AAAs between 5.0 and 5.4 cm.[1]

Preoperative Planning

- Anatomic measurement obtained from high-quality CT aortography, preferably reconstructed with millimeter or submillimeter slices, is paramount to successful endovascular repair. Ideally, precise diameter and path length measurements are derived from three-dimensional (3-D) reconstruction of the two-dimensional (2-D) source images (via TeraRecon™, OsiriX™, or similar software).
- Precision is most essential in determining diameter throughout the surgical neck and common iliac landing zones proximal to the bilateral iliac bifurcations. Graft oversizing of 10% to 20% is typically used in the region of the surgical neck. Length measurements are obtained from the lowest renal artery to the iliac bifurcation, using path lengths, when available, from image reconstruction software noted earlier.
- Multiple aortic endografts are approved for use in the United States at the current time, and device selection should be tailored to individualized anatomic requirements. Contraindications to endovascular repair may include inadequate neck length, diameter, and angulation; thrombus volume and distribution in the neck; insufficient iliac artery diameter, and excessive iliac or aortic tortuosity. It is the responsibility of the operating surgeon to ensure that for each selected device, the instructions for use (IFU) are understood and appropriate for the planned repair. Experienced operators, with careful planning, may knowingly place devices in off-label circumstances, depending on the patient-specific anatomic and physiologic risk assessment, with the expectation of reasonably long-term results. In off-label applications, however, the onus is on the surgeon to confirm that sufficient proximal and distal fixation and sealing zones exist to ensure a reasonable result.[7]
- Femoral access must also be evaluated with ultrasound or CT imaging to determine if the patient is a candidate for percutaneous repair. The "preclose" technique (see the following text) can be used for arteriotomy closure for devices up to 21 French (Fr) in diameter. Contraindications to percutaneous repair include calcification of the anterior femoral artery wall, diameter less than 7 mm, the presence of an aneurysmal femoral artery, and excessive scaring at the access site.
- The superior mesenteric artery (SMA) and celiac arteries should be examined for patency and the presence of flow-limiting stenosis or occlusion; if found, revascularization of the SMA and celiac artery should be considered prior to attempted EVAR, or open repair is considered as an alternative approach. In planning for EVAR, attention must be paid to the status of the inferior mesenteric artery and the total visceral vascularity assessed in terms of consequences of obligate inferior mesenteric artery (IMA) coverage during EVAR. Occasionally, depending on anatomic circumstances, custom fenestration or parallel grafting options may be considered as alternatives, allowing for EVAR management despite the presence of significant celiac or SMA disease. The latter options again, however, should only be considered by operators experienced in these techniques or facile with rapid open conversion when indicated to preserve intestinal perfusion.
- Facilities are an essential consideration. Fixed imaging is the preferred option for procedural guidance and aortography, preferably when available in a "hybrid" operating room configuration. This is especially true when tolerances are low regarding IFU status and related anatomic considerations. Anesthesia can be either general or local with conscious sedation, depending on the habitus of the patient, their suitability for conscious sedation, and the potential likelihood of open conversion. In our practice, all patients are consented for open conversion, even though in practice this happens in less than 1% of cases.

ENDOVASCULAR ANEURYSM REPAIR STANDARD

Percutaneous Access

- Using ultrasound guidance to determine the location of the femoral bifurcation and potential presence of anterior calcified atherosclerotic plaque, bilateral common femoral arteries (CFAs) are accessed with 0.018-in micropuncture kits. Femoral arteriography is performed to confirm suitability of the selected access site within the CFA prior to serial dilation.
- A 0.035-in general purpose wire (e.g., Bentson, Cook Medical, Bloomington, IN) is advanced into the aorta through the micropuncture sheath and 11-cm, 7-Fr sheaths are exchanged over the Bentson into the external iliac arteries (EIA) under continuous fluoroscopic guidance. Full intravenous anticoagulation is established with unfractionated heparin (at least 100 units/kg) and confirmed by subsequent determination of activated clotting time (ACT) greater than 250 seconds.

Preclose Technique

- In all circumstances, the surgeon should consult the respective IFUs for all devices employed during these procedures.
- While the assistant maintains direct compression proximal to the inguinal ligament to maintain hemostasis, the 7-Fr sheaths are individually removed over each respective wire and replaced with a Perclose ProGlide™ (Abbott, Abbott Park, IL) device. This is back-loaded on the wire and advanced until the guidewire exit line on the device. The wire is then temporarily removed and the device advanced until pulsatile blood is visualized through the pilot tube lumen. The first device is turned to the 10 o'clock position and foot plate activated. Holding back tension on the device, the suture is deployed, and the ends are removed from the device and controlled with a padded suture clamp. After the wire is repositioned through the wire port into the aorta under fluoroscopic guidance, the foot plate is released and the device is backed out of the femoral artery. Pressure is reapplied over the puncture site during this maneuver (**FIG 1**).
- A second Perclose ProGlide™ (Abbott) device is back-loaded on the wire and the aforementioned steps are repeated with the device turned to the 2 o'clock position.
- After both ProGlides™ (Abbott) are deployed, the 7-Fr sheath is reformed and replaced over the wire to maintain hemostasis. The suture clamps are positioned consistent with the clockface orientation of each suture placement.
- The procedure is then repeated for the contralateral femoral access site.

Delivery and Deployment of Endograft

- Wire exchange is performed through a guiding catheter (e.g., 100-cm Glidecath™, Terumo Medical, Somerset, NJ) for a stiffer access wire (e.g., Lunderquist™, Cook Medical). Serial dilation is preformed over the stiff wire, under fluoroscopic guidance, to gently distend and enlarge the respective arteriotomy sites. Following dilation to at least 14 Fr, the primary and secondary access sheaths are advanced under fluoroscopic guidance into the aorta.

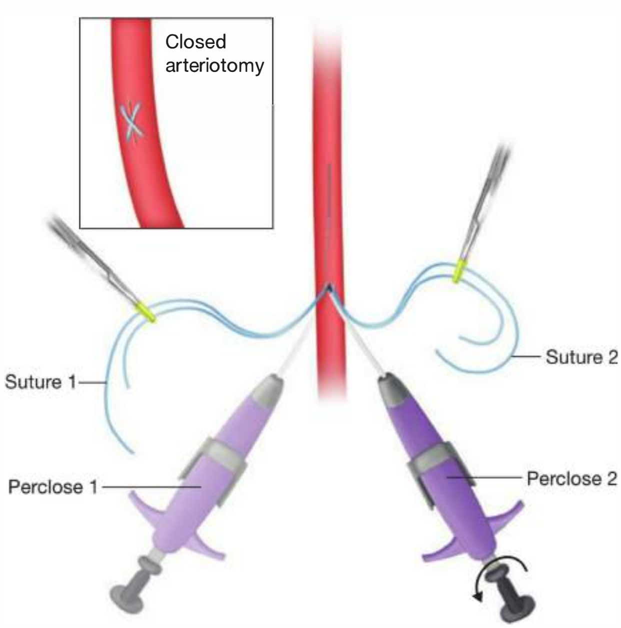

FIG 1 ● Preclose technique. Two ProGlides™ are deployed, one at the 10 o'clock position and the other at the 2 o'clock position before beginning serial dilation maneuvers and deployment of delivery catheters. Once the procedure is complete, and large diameter devices are removed, both knots are seated to close the arteriotomy (see inset). Until closure, the free sutures are controlled on suture boots. Once the procedure is complete, both knots are pushed down to close the arteriotomy.

- The main body endograft is placed up the ipsilateral iliac artery to the level of the renal arteries. Laterality of main body deployment is determined based on the tortuosity and diameter of the access arteries, as well as the desired angle at which the main body will interface with the renal arteries. The main body should be oriented so that the gate deploys in anterolateral fashion for easy contralateral limb access. The image intensifier should be adjusted to limit parallax by accounting for some degree of anterior angulation (usually in the range of 10%, occasionally more) and lateral angulation in the surgical neck, based on preprocedural assessment from the reformatted CT aortogram (**FIG 2A**).
- An Omni Flush catheter (AngioDynamics, Latham, NY) is placed up the contralateral iliac artery to the level of the renal arteries. The gantry position is then confirmed to be appropriate for the patient's anatomy, ensuring that the image plane is orthogonal to the takeoff of the lowest renal artery. Usually, a "20 for 10" contrast run is performed during breath-hold under magnification views, delivering 10 mL of contrast at a rate of 20 mL per second, to confirm the device position vis-a-vis the renal artery origins.
- The main body endograft is then deployed according to the IFU, with the proximal fabric margin positioned just below the lowest renal artery. Deployment continues until the contralateral gate is fully open (although techniques may vary between devices). Depending on the device-specific IFU, the main body may be resheathed and repositioned, if necessary, to obtain optimal positioning (**FIG 2B**).
- Repeat aortography is performed to ensure adequate placement. The side-hole, aortic flush catheter is withdrawn into the aneurysm through the proximal landing zone, over a wire. If the device uses suprarenal stent fixation, the suprarenal stents are deployed when main body placement is deemed sufficient. Care should be taken to prevent pulling the main body of the endograft down into the aneurysm.

Gate Cannulation

- The contralateral sheath is placed 1 to 2 cm distal to the contralateral gate. Using an Omniflush™ (Angiodynamics) or Glide™ catheter (Terumo), the gate is cannulated with an angled Glidewire™ (Terumo). When successful, the Omniflush catheter should be exchanged over a wire and reintroduced into the endograft. The tip is allowed to reform by withdrawing the wire and the curled flush catheter is spun 360 degrees several times to confirm gate cannulation. Failure to confirm this step may result in deployment of the contralateral limb outside of the gate, likely generating "endotrash" (e.g., graft limb free in the aneurysm, outside the main body, which will not remain in circulation) (**FIG 2C**).
- If the contralateral gate cannot be successfully cannulated using standard guidewire and catheter techniques (different-shaped catheters should be employed, as well as repositioning the sheath in relation to the contralateral gate), cannulation may be accomplished by advancing a snare up the contralateral sheath into the aneurysm and engaging the main body endograft bifurcation with a Sos Omni or similar curved catheter. The ipsilateral wire is then advanced through the gate, to be snared from the contralateral side. Once the wire is withdrawn through the contralateral sheath, a catheter may be back-loaded and advanced into the main body, which in turn allows an exchange to a stiffer wire through the gate. When necessary, a wire can also be advanced from brachial artery access for the same purpose.

Limb Extension

- Retrograde iliac angiography is performed through the sheath, with the gantry position in the contralateral oblique position. This will identify the origin of the internal iliac artery. Once this is confirmed, distance from the gate to the internal iliac is measured using a marker catheter and an appropriately sized limb is chosen.

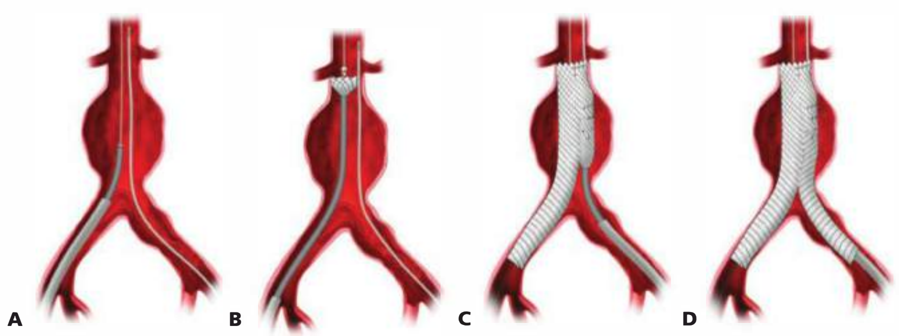

FIG 2 ● Delivery and deployment of endograft. **A.** The main body is brought up the ipsilateral iliac artery to the level of the renal arteries. An Omni Flush catheter is brought up the contralateral iliac artery and an angiogram is performed. **B.** The main body endograft is deployed under fluoroscopic guidance until the contralateral gate is opened. **C.** The contralateral gate is cannulated. **D.** An extension limb is placed proximal to the iliac bifurcation on the contralateral side and the ipsilateral endograft is finished being deployed (one docking limb systems) or an extension limb is placed (two docking limb systems) to the level of the ipsilateral iliac bifurcation.

For three-piece bifurcated devices (e.g., TriVascular Ovation™, Cook Zenith™), this procedure has to be performed on both sides. Optimal limb deployment maintains sufficient contact with the gate to maintain seal (see respective IFU) and sufficient distal coverage to completely exclude the common iliac artery without impinging on the origin of the internal iliac artery (**FIG 2D**).

- Occasionally, when the distance required for proper limb placement does not precisely correlate with the sizes available, the next size–longer limb may be deployed into the gate and slowly along its length. During deployment (once out of the gate), continued upward pressure on the deployment handle is maintained to encourage the graft to take a somewhat more serpiginous route, taking up some of the additional leak. Partial coverage of the ipsilateral internal iliac artery orifice is also appropriate when deployment can be precisely monitored in the contralateral oblique gantry position.

Balloon Molding

- An appropriately sized semicompliant balloon (e.g., Coda™, Cook Medical) is expanded with dilute contrast solution at all three landing zones and overlap areas within the gate(s) as appropriate for the specific device (**FIG 3**). When existing common iliac artery stenosis is present, kissing balloons should be deployed to obtain optimal internal diameter and prevent limb kinking or occlusion. Similarly, the aortic bifurcation should also be dilated when necessary. Occasionally, self-expanding bare metal nitinol stents may be deployed at areas of stenosis or from the distal limb into external iliac artery, to prevent kinking of the endograft or native external iliac artery distal to the device.

Completion Arteriography

- Completion arteriography is performed with higher volume and longer injection time to completely fill the endograft, ensure limb patency, and identify endoleaks (**FIG 4**). All type I or III endoleaks, when present at the end of the case, should be addressed with additional maneuvers to ensure seal. This may include deployment of proximal endograft cuffs, prolonged molding balloon inflation time, or, on occasion, placement of embolism coils in recalcitrant leaks. When small leaks persist, even when anatomic coverage seems adequate, anticoagulation should be reversed and sheaths removed with the plan for follow-up CT aortography within a few days. Care should be taken to carefully evaluate the nature of all leaks (type, volume, location in regard to lumbar branches, status of graft limb deployment, adequacy of molding, etc.) before secondary interventions are considered for persistent leaks. The majority of type II endoleaks resolve in the first year. In our practice, we never resort to deployment of a large diameter, balloon-expandable stent in the proximal neck—accurate sizing and deployment of this stent may be difficult and "stretching" the proximal orifice of the main body in this way may damage the graft, without sufficient assurance that the proximal type I leak will be adequately addressed.

Closure

- The contralateral sheath is removed over the wire and manual pressure is held. The previously placed preclose polypropylene sutures are deployed sequentially in each access site and cinched down with a knot pusher over a wire. When initial hemostasis appears adequate, the wire is removed and slightly more pressure is applied to the knot pusher. After both sutures are deployed in one groin, determination is made as to which of the two appears to provide more effective hemostasis and manual pressure is held to this suture for 5 additional minutes. This is repeated for the ipsilateral side.
- Procedural anticoagulation is reversed once all sheaths and clamps are removed. It is essential to wait for final introducer device removal before reversing the anticoagulation, because the large diameter sheaths used to deliver EVAR devices may almost entirely occlude the ipsilateral external iliac artery, causing potentially catastrophic graft limb and iliac artery thrombosis in the absence of full anticoagulation.

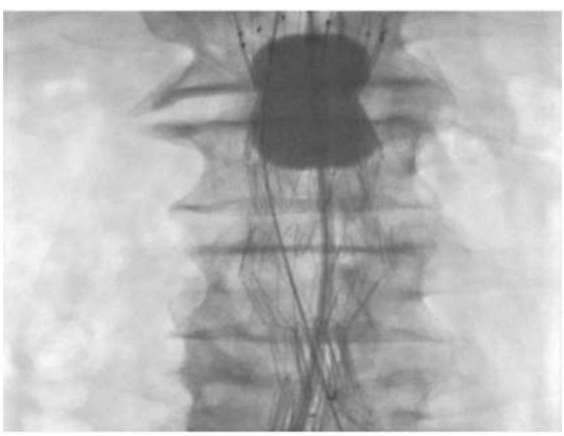

FIG 3 ● Balloon molding. A semicompliant balloon is inflated at proximal and distal landing zones as well as at all overlapping endografts.

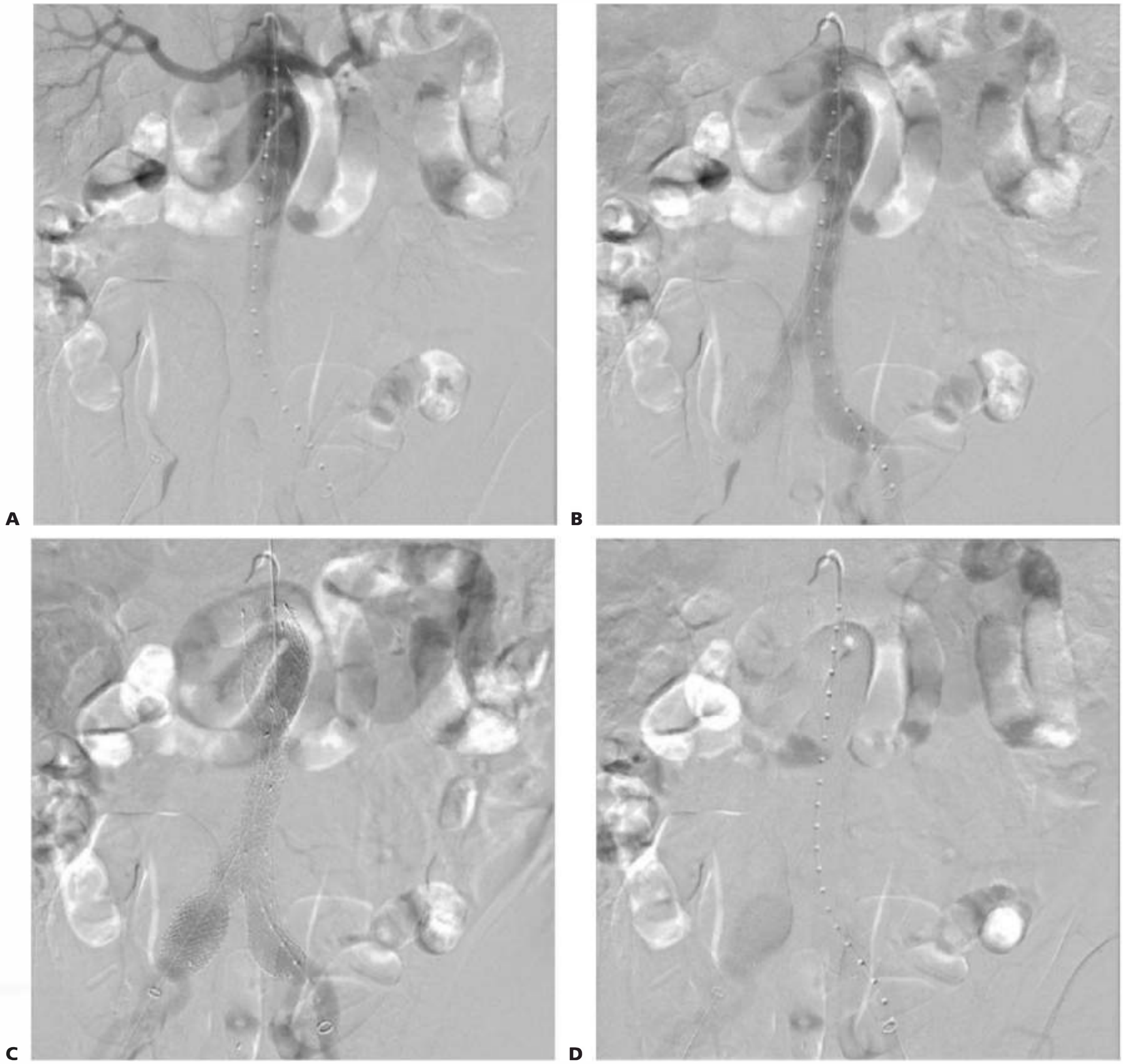

FIG 4 ● Completion arteriography. Special attention is paid to ensure the renal and iliac arteries are patent, as well as to identify if an endoleak is present. The endograft itself should be scrutinized for any evidence of limb kinking. **A.** Renal artery patency confirmed. **B.** No Type 1A endoleak confirmed. **C.** External and internal iliac artery patency confirmed and endograft itself should be scrutinized for any evidence of limb kinking. **D.** No type 1B, 2, 3, or 4 endoleak identified with delayed imaging.

ENDOVASCULAR ANEURYSM REPAIR FOR RUPTURED ANEURYSMS, OR REVAR

Percutaneous Access

- Bilateral CFA access is obtained under local anesthesia. The preclose technique (described in the previous section) can be employed when time and conditions permit, but if not possible, the case can proceed percutaneously initially, with conversion to open femoral closure when the endograft is fully deployed and internal bleeding has stopped.
- Rapid catheter and guidewire exchanges are performed, with sheath upsizing as noted in the previous section. The use of intravenous anticoagulation is controversial in this setting—again it is highly dependent on the hemodynamic status of the patient, presence of active bleeding, and existing consumptive coagulopathy. Often when treating ruptured aneurysms, the case begins without anticoagulation, which is subsequently instituted once the main body and extension limbs are deployed.
- In the case of rupture procedures, preoperative CT aortography may not exist or may not provide sufficient

anatomic detail to guide deployment. In this circumstance, catheter arteriography with a marker flush catheter should be employed to determine path lengths, landing zones, and optimal graft sizing.

Aortic Balloon Control

- Following access and wire exchange, a Lunderquist™ (Cook Medical) or similar stiff wire is advanced into the aorta, over which a 14-Fr × 55-cm braided sheath is advanced to the level of the renal arteries. Once localization is confirmed, the sheath is sutured to the skin at the access site.
- A semicompliant balloon (Coda™, Cook Medical) or similar aortic occlusion balloon is directed to a position immediately proximal to the visceral arteries under fluoroscopic guidance (**FIG 5**). Once positioned, it can be maintained in the deflated site until or unless the patient's hemodynamic status requires inflation and aortic occlusion.
- Once bilateral therapeutic sheath access is obtained and the deflated occlusion balloon is positioned properly, general anesthesia may be induced.

Endograft Delivery and Deployment

- Aortography is performed through the contralateral sheath below the balloon to localize the origins of the renal arteries.
- The main body endograft is placed up the ipsilateral sheath to the level of the renal arteries. It should be oriented so that the gate deploys in anterolateral fashion.
- The main body endograft is then deployed according to the IFU, just distal to the lowest renal artery. Deployment continues until the contralateral gate is fully deployed (**FIG 6**).
- The ipsilateral limb of the endograft is cannulated and the sheath advanced into the main body of the endograft.
- A second Coda balloon is placed in the ipsilateral sheath and inflated in the main body (**FIG 7**). The first balloon is deflated and removed through the contralateral sheath. Balloon placement should be performed in such a way that time without balloon coverage is kept to an absolute minimum. Retroperitoneal hemorrhage can continue at a rapid rate throughout this procedure, and in the absence of external bleeding, neither the surgeons nor the anesthesiologists may appreciate true magnitude of blood loss and circulatory reserve. Under these circumstances, hemodynamic collapse can be precipitous and, unfortunately, calamitous, unless an occlusion balloon is properly positioned and immediately inflated at the first indication of rapid hemodynamic deterioration.

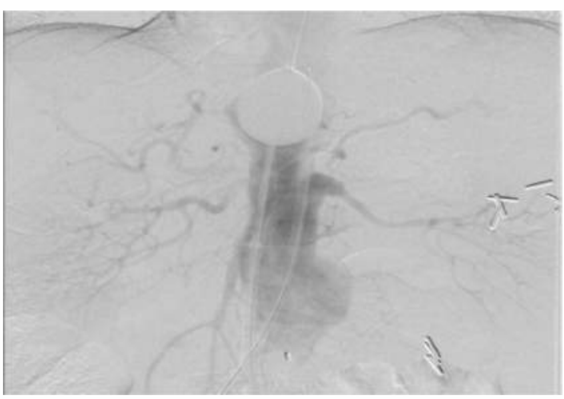

FIG 5 ● Aortic balloon control for REVAR. A semicompliant balloon is placed up the contralateral iliac artery proximal to the celiac trunk. It can be inflated depending on hemodynamic instability.

FIG 6 ● Main body deployment for REVAR. After an angiogram is performed to identify the renal arteries and aortic neck, the main body is deployed up the ipsilateral iliac artery. This can be done with the semicompliant balloon inflated.

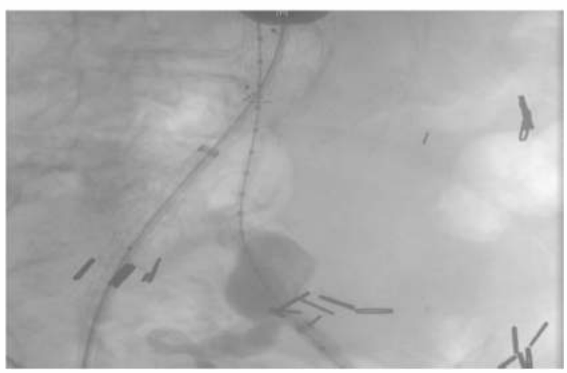

Figure 7 ● Balloon exchange and gate cannulation for REVAR. The entire ipsilateral gate is deployed prior to contralateral gate cannulation. A second semi-compliant balloon is placed up the ipsilateral endograft limb (top of image) and placed into the main body of the endograft. It can be inflated depending on hemodynamic instability. The first semi-compliant balloon is removed and the sheath is brought to distal to the contralateral gate to prepare for gate cannulation. Retrograde angiography with a marking catheter is performed through the contralateral sheath to identify the iliac bifurcation and desired limb extension length.

Gate Cannulation

- Gate cannulation proceeds in a standard fashion during REVAR.

Limb Extension

- Limb extension proceeds in a standard fashion during REVAR. Time awareness is critical during standard EVAR steps to ensure that aneurysm sealing is accomplished in the most expeditious manner possible.

Balloon Molding

- Coda™ balloon (Cook Medical) molding is performed at all seal zones to optimize hemostasis. Only after molding is complete is hemostasis assured.

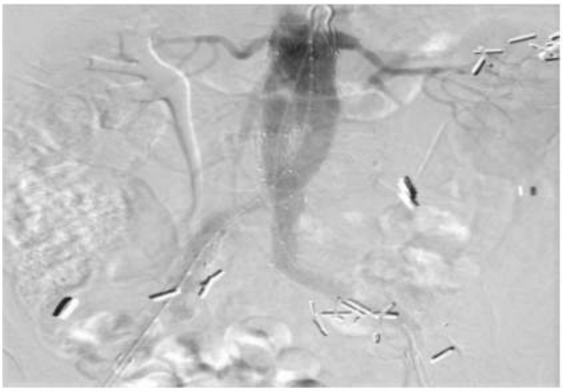

FIG 8 ● Completion aortography for REVAR.

Completion Aortography

- Completion aortography is performed as previously described. Attention should be paid to all the usual considerations, including presence and nature of endoleaks, iliac limb or arterial kinking, sufficient overlap in the landing zones to meet IFU, and so forth (**FIG 8**).

Closure

- Closure proceeds as indicated for standard EVAR, with caveat that if ProGlides were not deployed prior to percutaneous access, then surgical incisions will need to be made to expose the femoral artery sites for control and closure under direct vision as the therapeutic sheaths are withdrawn.

PEARLS AND PITFALLS

Access	▪ Ultrasound guidance is essential to limiting access complications. Visualize the needle tip entering the anterior artery wall, in an area deemed appropriate for access.
Gate cannulation	▪ In general, main body should be advanced through the more tortuous of the two iliac arteries to allow a more "straight shot" for the contralateral gate cannulation. This preference is not always practical, however, and laterality may need to be decided based on more practical considerations (e.g., Is the tortuosity sufficient to prevent main body positioning and deployment altogether?).
Tortuous iliacs	▪ Perform the completion aortogram with soft catheters instead of stiff wires in place. Stiff wires may straighten out a tortuous vessel, which may end up kinked when the wires are removed and lead to limb occlusion. Also, retention of stiff wires at the time of completion aortography may mask the development of type I proximal endoleaks, which may develop situationally when stiff wires are removed.
Closure	▪ Tie down the sutures of the closure device with the wire in place. If there is still significant bleeding, either deploy another closure device or place an occlusive sheath and proceed with open conversion of the femoral artery closure under more controlled circumstances.
Ruptures	▪ Outcomes are vastly improved when REVAR protocols are established and practiced. Abdominal compartment syndrome is a real and frequent complication following REVAR—if there is any indication that ventilation pressures are rising or abdominal pressures are significantly elevated at the end of the procedure by measuring bladder pressure, strong consideration should be given to decompressive laparotomy at the initial setting.

POSTOPERATIVE CARE

- Patients should remain supine for a minimum of 3 hours and are free to ambulate thereafter. Most elective EVARs can be discharged on postoperative day 1 or 2. For cases well within the IFU, same-day surgery is now a reality and can safely be offered to patients who can remain in reasonably close proximity to the hospital the evening after surgery.
- Following REVAR, consideration should be given to decompressive laparotomy whenever abdominal pressures are elevated at the end of the initial procedure. When decompressive laparotomy is performed, free peritoneal blood should be evacuated but retroperitoneal hematomas should not be explored or evacuated. Abdominal wound suction systems should be deployed to control drainage and provide a moist environment for intestinal viability. Dressing changes should be performed daily or every other day until the wound can be safely closed.
- Initial postprocedural CT aortography is performed at 1 month to document presence or absence of endoleaks

FIG 9 ● Postoperative imaging. 3-D reconstruction of a CT aortogram in a patient who have undergone successful EVAR at 1 month follow-up.

and graft position and confirm visceral perfusion (**FIG 9**). Follow-up imaging is performed with either ultrasound +/− noncontrast CT scanning or by CT aortography, based on the last known status of endoleaks (presence or absence), symptomatic status, and comorbid conditions such as chronic renal insufficiency. In general, we prefer serial ultrasound evaluations, with CT scanning reserved for aneurysms which are enlarging following endografting or evidence of significant changes in endoleak volume or location.

OUTCOMES

- All-cause mortality is similar in patients undergoing open or EVAR for AAA at 2 years.[3,8,9]
- There is higher perioperative survival in patients undergoing EVAR, which is sustained for several years.[3] The loss of this is due to late ruptures in the EVAR group.
- Secondary interventions are similar in open and EVAR.[3]

COMPLICATIONS

- Endoleak
- Delayed rupture
- Renal dysfunction
- Thromboembolism
- Limb occlusion
- Colon ischemia
- Abdominal compartment syndrome (ruptured EVAR)

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Chapter 24

Advanced Aneurysm Management Techniques: Management of Internal Iliac Aneurysm Disease

W. Anthony Lee

DEFINITION

- Iliac aneurysm is defined as an iliac artery whose diameter is 20 mm or more. Iliac aneurysms are present in up to 20% of abdominal aortic aneurysms,[1] and common iliac aneurysms occur far more frequently than internal iliac aneurysms.
- Isolated iliac aneurysms represent less than 5% of all aortoiliac aneurysms.
- External iliac aneurysms are extremely rare and mostly either associated with underlying connective tissue disorders or represent traumatic pseudoaneurysms.

DIFFERENTIAL DIAGNOSIS

- Differential diagnoses of iliac aneurysm are limited to true degenerative aneurysms, which are most common; mycotic, traumatic, or surgical pseudoaneurysms; or aneurysmal enlargement of the false lumen from a primary dissection.

PATIENT HISTORY AND PHYSICAL FINDINGS

- Most iliac aneurysms are clinically silent (asymptomatic). Rarely, in very thin individuals with large aneurysms, a pulsatile aneurysm may be palpable on physical examination. Even more rarely, a patient being evaluated for hydroureter may be determined to have an iliac aneurysm. Ureteral obstruction in this circumstance derives from perianeurysmal inflammation (similar to retroperitoneal fibrosis) rather than mechanical compression by the aneurysm.

IMAGING AND OTHER DIAGNOSTIC STUDIES

- Although a plain abdominal x-ray can detect an aortoiliac aneurysm if there is heavy mural calcification, the most common imaging modalities include ultrasound, computed tomography (CT), and magnetic resonance imaging (MRI).
- Thin-cut (1 mm), intravenous contrast-enhanced, spiral CT (CT arteriogram) represents the "gold standard" for diagnosis and anatomic evaluation of abdominal aneurysms. Even in patients with stage III/IV chronic kidney disease, high-quality imaging may be obtained relatively safely using reduced volumes of isoosmolar, nonionic contrast with multidetector (32, 64, 128, or 220) scanners, particularly following preprocedural intravenous hydration. The CT dataset is rendered into three-dimensional (3-D) images for dimensional postprocessing, a critical requirement for complex endovascular case planning.
- Conventional arteriography adds little to the identification and analysis of iliac aneurysms; penetrating ulcers may appear like saccular aneurysms, and large aneurysms with circumferential mural thrombus may appear to have a normal contour.

SURGICAL MANAGEMENT

- In general, iliac aneurysms are repaired when they reach 30 mm in diameter, become symptomatic, or rupture.
- Due to the relatively inaccessible location of iliac aneurysms, situated deep in the pelvis, as well as densely adherent pelvic veins posterior to the arteries and frequent co-occurrence of calcific occlusive disease, conventional surgical repair is challenging and fraught with risk of significant hemorrhage. Thus, evolving endovascular methods of repair have largely supplanted open surgical reconstruction.
- A variety of off-label devices and hybrid techniques have been applied to iliac aneurysm management. The variability derives, in large part, from uncertainty regarding the need to preserve antegrade internal iliac artery flow in most patients. Indications for internal iliac preservation remain controversial due to the added complexity, cost, and uncertain benefit derived from such procedures; analysis of the relative merits of intentional unilateral occlusion versus preservation in the management of iliac aneurysm disease is beyond the scope of this chapter.

Preoperative Planning

- As in all things endovascular, high-quality imaging is critical for precase planning and, as previously mentioned, CT arteriography is optimal for this purpose. Using a combination of axial imaging and 3-D postprocessing, complete evaluation should, note the following:
  - Locations, diameter, and length of proximal and distal landing zones
  - Iliac artery tortuosity and angulation
  - Presence and severity of associated occlusive disease
  - Ipsilateral and contralateral internal iliac artery patency
  - Status of the ipsilateral deep femoral artery
  - Concomitant abdominal or thoracic aortic pathology
- In general, landing zones are sited in nonaneurysmal arterial segments, manifesting minimal occlusive disease, with relative absence of angulation or tortuosity. The allowable diameter range for treatment may vary, depending on the particular device to be deployed. In all circumstances, reference should be made to the "Instructions for Use" included in the package insert.
- Device selection is based on the need for durable aneurysm exclusion and endograft fixation, accomplished with the fewest component pieces possible.
- This chapter focuses on endovascular and hybrid management strategies for the iliac bifurcation in the context of large common or internal iliac aneurysms. Standard techniques suffice for management of smaller (<24 mm) aneurysms that do

not involve the bifurcation, either in isolation or associated with larger proximal aortic aneurysms.

Positioning

- Nearly all endovascular aortoiliac aneurysm repairs are performed with the patient in the supine position, with both arms tucked. The operative team stands on the patient's right, with the C-arm brought in from the left. Although some operators prefer to access the left groin from the left side of the table, for a right-handed operator, it is ergonomically more natural to access both groins from the right.
- Electrocardiogram (EKG) leads and other monitoring cables and lines are positioned so that they are not in the x-ray beam and do not entangle the C-arm gantry.
- The left arm should be available for brachial artery access when necessary; it is not routinely prepped into the surgical field.

ENDOVASCULAR COMMON ILIAC ARTERY ANEURYSM REPAIR WITH INTERNAL ILIAC ARTERY OCCLUSION

- After obtaining bilateral femoral access, a shepherd's hook–type (e.g., Omni™ Flush) side-hole catheter is advanced from the contralateral side for pelvic arteriography. Typical injection technique is 10 to 15 mL contrast at 15 mL per second. Following satisfactory anatomic delineation, a steerable hydrophilic 0.035 guidewire (e.g., angled Glidewire®, Terumo) is advanced through the same catheter into the ipsilateral external iliac artery. Following exchange for a stiffer guidewire (e.g., Rosen®), the flush catheter and contralateral femoral sheath are removed and replaced with a 45-cm 6-French (Fr) guide sheath (e.g., Balkan® or similar braided sheath), positioning the tip in the distal third of the common iliac aneurysm (**FIG 1**).
- A 65-cm 4-Fr angled catheter (e.g., Kumpe®) is advanced through the sheath and, under digital subtraction roadmapping guidance, directs the hydrophilic guidewire into the ipsilateral internal iliac artery (**FIG 2**). The catheter is then advanced securely into either the anterior or posterior divisions. The C-arm gantry is positioned at approximately 30 degrees contralateral anterior-oblique for optimal visualization during this maneuver. With access secured, the 6-Fr sheath is then advanced over the 4-Fr catheter into the proximal internal iliac artery.
- A selective internal iliac arteriogram is obtained through the 6-Fr sheath, and the angle catheter is retracted to the first bifurcation of the internal iliac artery. Typically, distal access is maintained with the wire during this maneuver.
- [Alternate technique] Depending on anatomic considerations (e.g., tortuosity, iliac bifurcation angle, internal iliac branch anatomy, etc.), ipsilateral access may be

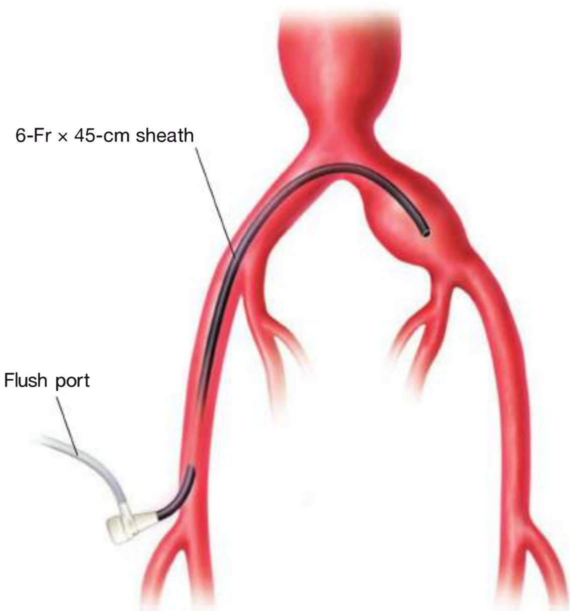

FIG 1 ● A 45-cm, 6-Fr guide sheath is introduced from the contralateral femoral access. This provides a stable platform for interval angiography, selective catheterization, and coil embolization of the internal iliac artery.

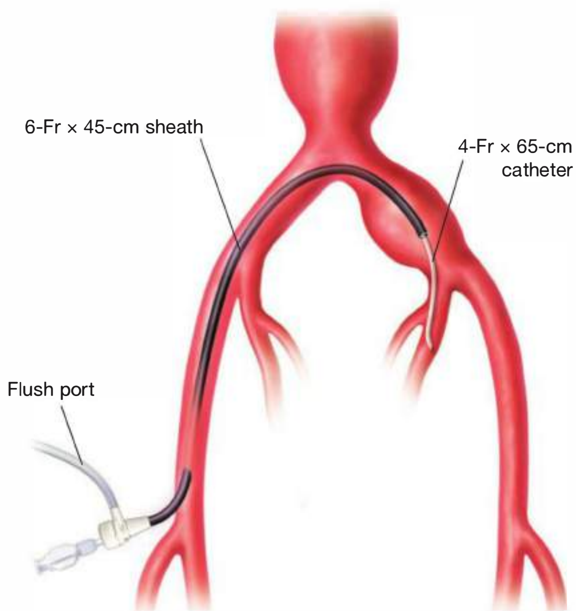

FIG 2 ● A 65-cm, 4-Fr angled catheter is used to selectively engage the internal iliac artery. Typically, the catheter is used in combination with a soft-tipped angled hydrophilic guidewire. After the guidewire crosses the origin of the internal iliac artery, it is advanced deep into any one of its distal branches, and the catheter advanced over the guidewire. The hydrophilic guidewire is removed, and an angiogram is performed through the catheter to confirm correct position in the main trunk of the internal iliac artery. The 6-Fr guide sheath may be optionally advanced closer to the origin of the artery before removing the guidewire to gain additional stability.

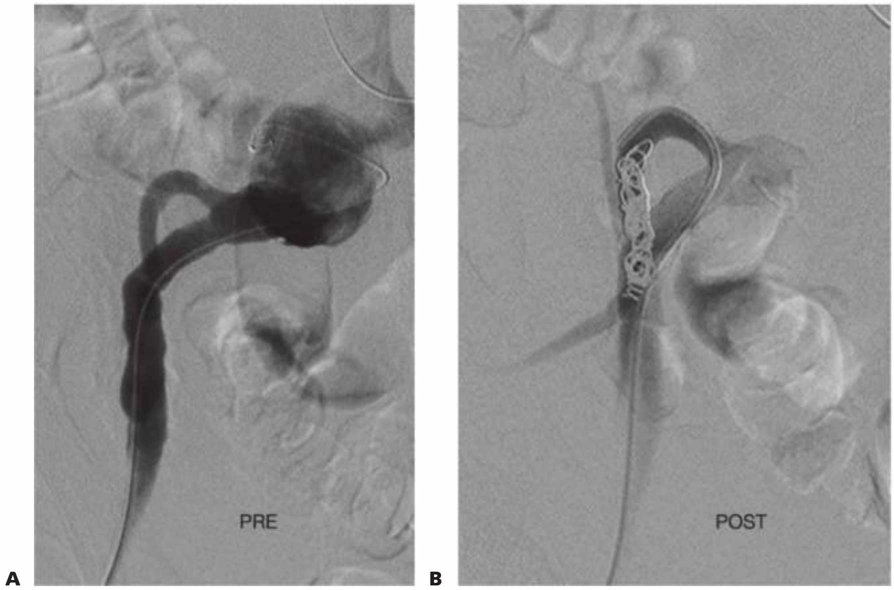

FIG 3 ● **A,B.** When using the ipsilateral approach, a variety of catheter shapes may be used depending on the angle of the internal–external iliac bifurcation and the luminal diameter of the common iliac aneurysm. The three most useful are the shepherd's hook, Cobra®, and right-angle curved catheters.

feasible. In this case, a 25-cm, 6-Fr sheath is advanced from the ipsilateral femoral artery. A 4- or 5-Fr appropriately shaped catheter (curve or reverse curve) directs the hydrophilic guidewire into the internal iliac artery (**FIG 3**). If a shepherd's hook catheter type is employed, the hook may be reformed either in the iliac aneurysm or in the aorta, depending on their respective luminal diameters. The ipsilateral approach is more demanding technically and is not recommended when concomitant internal iliac aneurysm embolization is also indicated.

- Size-appropriate platinum occlusion coils are deployed through the 4-Fr catheter into the main internal iliac artery trunk, with care taken to avoid placement or distal migration into arborizing branches or reflux back into the main iliac circulation. Alternative vascular occlusion devices may also be used for internal iliac embolization, including hydrogel coils and nitinol mesh (e.g., Amplatzer®) plugs. Interval arteriograms are obtained using small volume hand injections through the sheath or catheter to guide deployment and confirm positioning. Complete occlusion of the target artery during deployment is not necessary or even desirable. Following subsequent endograft deployment over the internal iliac artery orifice, in the absence of antegrade flow, the extensive surface area of the coils induces rapid thrombosis following reversal of anticoagulation at the end of the procedure. Usually less than five coils will suffice to ultimately induce complete occlusion.
- [Alternate technique] The presence of an internal iliac aneurysm, either with or without an associated proximal common iliac aneurysm, deserves special consideration. In these situations, more extensive embolization of the internal iliac circulation will be necessary to prevent retrograde (type II) endoleak. Individual internal iliac branches must be separately embolized at the initial procedure (**FIG 4**).

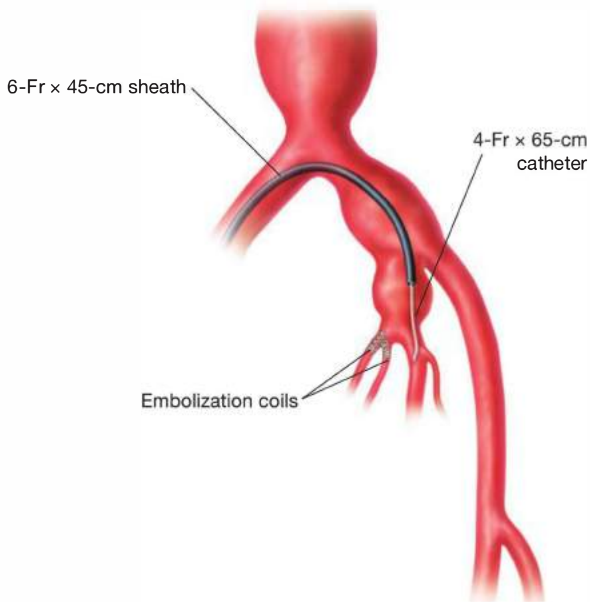

FIG 4 ● In the setting of ipsilateral concomitant internal iliac aneurysm treatment, the contralateral approach should be used, and guide sheath advanced well within the internal iliac artery itself. Individual branches arising from the internal iliac aneurysm may prove difficult to identify and catheterize. Multiple projections of the C-arm gantry, both in lateral oblique and craniocaudal directions, should be employed to visualize the branches.

If left untreated, due to collateral pelvic flow, these branches unfortunately remain patent following endograft deployment, severely limiting options for secondary procedures. Complete branch vessel embolization can be time consuming and tedious, due to the sheer number, anatomy and sizes of the branches that must be occluded, requiring patience, expert catheter and guidewire skills, and excellent intraoperative imaging.

- [Alternate technique] When the common iliac aneurysm tapers to a funnel near the iliac bifurcation, the so-called sleeve technique may be employed to occlude the adjacent internal iliac artery. In this method an appropriately sized aortic cuff is deployed into the distal common iliac artery and over the internal iliac artery origin. The distal end of this cuff is partially extended into the external iliac artery. The iliac limb is next passed through the aortic cuff and deployed normally from its proximal landing zone and into the external iliac artery 20 mm distal to the aortic cuff (**FIG 5**). The putative benefit of this technique is avoidance of potential atheroembolization that may occur during standard coil occlusion techniques from catheter manipulation, which some speculate is the cause of ischemic complications following internal iliac artery occlusion.
- Following internal iliac occlusion, subsequent aneurysm exclusion procedures vary as functions of landing zone and aneurysm anatomy. Endograft deployment nearly always follows management of the internal iliac artery in some form or another. In the typical scenario, following internal iliac embolization, the endograft positioning and deployment proceeds in the standard fashion except for extension of the ipsilateral distal landing zone beyond the iliac bifurcation to the external iliac artery. At least 20 mm of purchase into the external iliac artery is recommended.
- In the unusual case of an isolated common iliac aneurysm without aortic involvement, with a proximal uninvolved segment at least 20 mm in diameter and 15 mm in length, a short endograft may be deployed to bridge the proximal common and external iliac arteries.[2] Device options for this approach include either the "off-label" deployment of an aortouniiliac converter graft or placement of a flared or "bell bottom" iliac endograft limb that has been previously deployed, reversed, and reloaded into the delivery sheath at the back table (way off-label). These adaptations are often necessary because although nonaneurysmal, the common iliac artery is still too large to securely seat the proximal end of most iliac limbs. To obtain a satisfactory proximal seal, the distal flared segment, commonly available in diameters up to 24 mm, is deployed proximally by simply reversing the limb in the sheath (**FIG 6**).

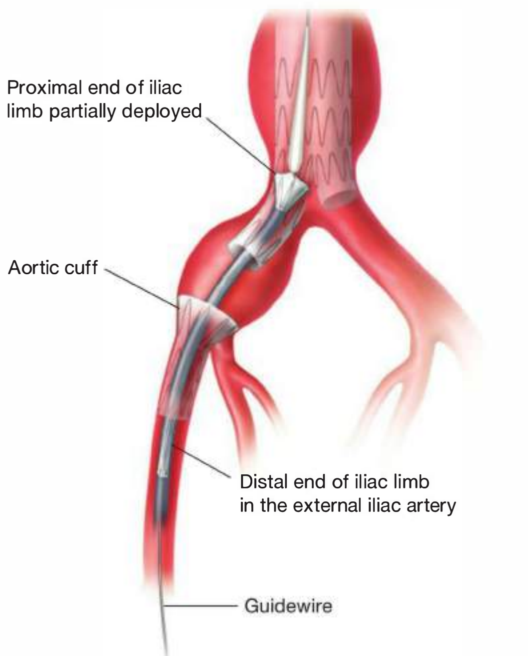

FIG 5 ● Note that in this technique, the distal segment of the common iliac aneurysm must funnel down so that the aortic cuff will coapt securely against the internal iliac orifice. The aortic cuff should be expanded following deployment with a compliant molding balloon to securely seat in position to prevent subsequent inadvertent dislodgement when advancing the iliac limb delivery system.

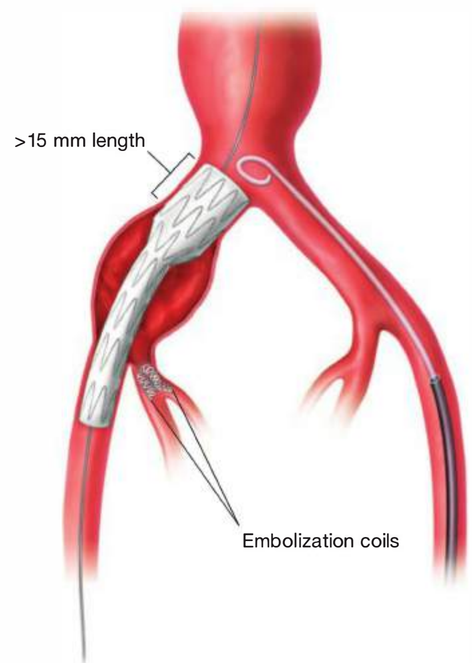

FIG 6 ● Not all endograft systems have an aortouniiliac device or converter. Similarly, not all endografts can be deployed ex vivo and resheathed. Currently, the only system is the Zenith Flex® (Cook, Bloomington, IN). If the origin of the contralateral common iliac artery is partially covered and flow compromised for any reason, a bare metal balloon-expandable stent should be deployed in a "kissing" manner.

ENDOVASCULAR COMMON ILIAC ARTERY ANEURYSM REPAIR WITH INTERNAL ILIAC PRESERVATION

- These techniques specifically pertain to common iliac aneurysms without an associated ipsilateral internal iliac aneurysm. In cases of an internal iliac aneurysm (see exception below), preservation methods are not possible and selective branch occlusion (see above) and endovascular exclusion are necessary.
- Indications for internal iliac artery preservation may include the following:
  - Routine revascularization as procedural preference
  - The presence of contralateral internal iliac occlusion
  - Active patient with concern/potential for buttock claudication
  - Diabetic with diseased ipsilateral deep femoral artery (reduced potential collateral supply)
  - Prior thoracic endograft repair (concern regarding anterior spinal artery collateral flow arising from the internal iliac circulation and potential for postoperative paraplegia)
- The simplest internal iliac preservation technique involves deployment of flared or so-called bell-bottom devices. Although anecdotally applied to larger aneurysms, conventionally, this technique is limited to common iliac artery aneurysms with 24-mm or shorter diameter distal landing zones. As an off-label modification of this technique, for common iliac aneurysms with larger or poorly defined distal landing zones, the maximal diameter flared iliac limb is intentionally deployed approximately 2 cm proximal to the internal iliac artery orifice. An aortic extension cuff without a proximal uncovered stent (typically 28 mm) is then deployed halfway into the unsecured iliac limb and flared out into the distal aneurysm, essentially creating a larger landing zone than that conventionally available (**FIG 7**). Although strictly speaking, cuff deployment is essentially in the aneurysm itself; late outcomes from these procedures appear favorable, with a low reported incidence of migration or type Ib endoleak.
- Direct internal iliac artery revascularization can also be accomplished by surgical bypass from or transposition to the ipsilateral external iliac artery distal to the ipsilateral endograft limb. Like all open vascular procedures, exposure is the most critical requirement for technical success.
- Proper incision placement and entry into the retroperitoneal space is tantamount to gaining adequate and safe iliac bifurcation exposure and minimizing postoperative discomfort. For these exposures, the primary surgeon stands on opposite side of the table. The incision is centered over either lower quadrant and starts at a paramedian location at level of the umbilicus and gently curves toward the midline over the first third of the distance from the umbilicus to the symphysis pubis (**FIG 8**). Exposure proceeds through the anterior rectus sheath following the hockey-stick shape of the skin incision. Care is taken not to divide the rectus muscle—this is a complete "muscle-sparing" technique. The sheath itself is incised at least 3 to 5 cm medial to the semilunar line. Keeping the rectus muscle intact reduces incisional hernia risk and decreases postoperative pain.
- The rectus muscle is dissected away from the sheath and retracted medially. The retroperitoneal space is developed below the arcuate line (linea semicircularis) just superior to the inferior epigastric vessels, which are

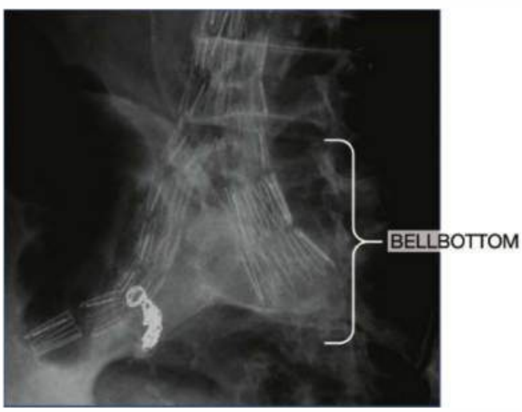

FIG 7 ● In this instance, the patient had bilateral common iliac aneurysms. The right side was large and left was smaller. The right internal iliac artery was occluded and the iliac limb extended to the external iliac artery. The bell-bottom technique was able to be used for the smaller left common iliac aneurysm because it was only 24 mm.

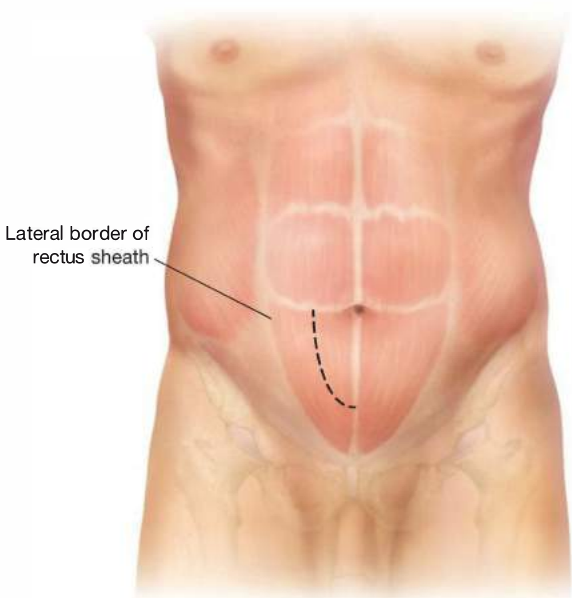

FIG 8 ● In some patients, the distance between the umbilicus and the symphysis pubis may be quite short. If so, the longitudinal segment of the incision is extended more inferiorly than depicted in this diagram. The most important technical point of this exposure is to place the incision sufficiently medially as the lateral border of the rectus sheath is not palpable and there are no obvious surface landmarks.

preserved and gently swept inferiorly. In women without prior hysterectomy, the round ligament of the uterus is often encountered as a fibrous cord during this exposure and is divided between ties. The peritoneal sac is swept bluntly medially until the external iliac artery and the distal half of the common iliac aneurysm are exposed. The ureter is visualized crossing the iliac artery and should be left undisturbed. Self-retaining retractors (e.g., Bookwalter®) are placed at this point.

- Choice of retractors and proper placement are essential for procedural success. The retractor post is placed on the opposite side about the level of the costal margin, and a small round ring is fixed and centered directly over the incision. A Balfour® blade is placed over the inguinal ligament, and a medium Kelly® blade oriented toward the opposite shoulder. A narrow malleable blade is oriented medially to retract the bladder. Following retractor placement, if the incision was sited properly, the iliac bifurcation should be positioned directly in the center of the surgical field.
- The midsegment of the external iliac artery is exposed and controlled. The internal iliac artery is next isolated from the surrounding tissue, from its origin to the bifurcation of the anterior and posterior divisions, which are individually controlled. No attempt should be made to expose anything more than a small anterior aspect of the distal common iliac aneurysm during this maneuver.
- The internal iliac artery origin is ligated with 0-polypropylene suture, and the anterior and posterior divisions of the internal iliac artery are controlled independently. Additional small branches arising from the main trunk are clipped for hemostasis. The internal iliac artery is divided as proximally as possible, and the stump closure is reinforced and imbricated with a 5-0 polypropylene suture (**FIG 9**). The distal internal iliac artery is then mobilized from the subjacent internal iliac vein.
- The patient is systemically anticoagulated at this point. An 8-mm × 10-cm graft knitted, collagen-impregnated polyester graft is anastomosed to the distal stump of the internal iliac artery in an end-to-end manner. The graft is occluded at its open end and distal control released to test anastomotic leaks. The graft is then recontrolled just proximal to the distal anastomosis.

FIG 9 ● When the incision is properly positioned, the iliac bifurcation should be located directly in the center of the wound. The common iliac aneurysm is minimally exposed to allow the stump of the divided internal iliac artery to be safely oversewn.

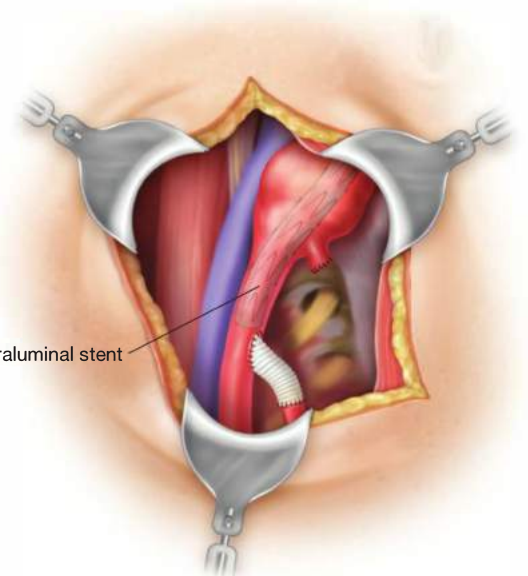

FIG 10 ● An 8-mm graft is anastomosed to the distal end of the internal iliac artery first. Due to the deep nature of this artery, this anastomosis can be difficult. An open ("parachute") anastomotic technique can be helpful in visualizing the suture line throughout placement. The distal anastomosis is tested for hemostasis and any leaks completely repaired before the proximal anastomosis is performed, as the former may be difficult to see once the latter is completed. The external iliac anastomosis is performed at least 5 cm distal to its origin along its posteromedial aspect.

- A segment of the ipsilateral, adjacent external iliac artery, at least 5 cm distal to its origin, is next mobilized and controlled. Following creation of a posteromedial arteriotomy, the graft is trimmed and beveled to length and anastomosed to the external iliac artery in an end-to-side manner. The graft is flushed routinely and flow restored to the internal and external iliac arteries (**FIG 10**).[3]
- A large clip is sewn transversely at the heel of the external iliac artery anastomosis to establish a fiducial point for the internal iliac bypass. After hemostasis is confirmed, the retractor system is removed and retroperitoneal contents allowed to collapse back into the wound. The endovascular portion of the procedure completed through femoral artery access sites in a standard fashion.
- After endograft deployment and satisfactory completion aortography, the retroperitoneum is reinspected for hemostasis following reversal of anticoagulation. The anterior rectus sheath is closed with a running 1-0 PDS suture, followed by closure of Scarpa's layer and skin.
- [Alternate technique] Occasionally, the common trunk of the internal iliac artery is long and runs parallel to the course of the external iliac artery for some distance. If sufficient length is present, the internal iliac artery may

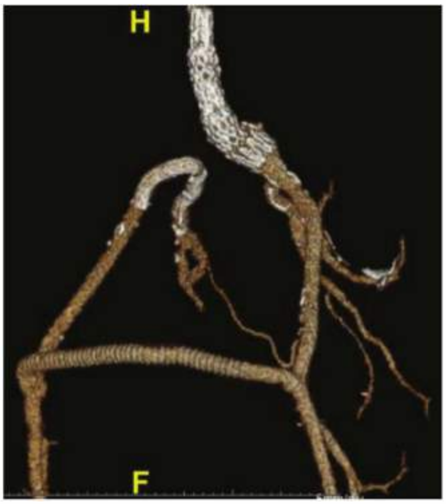

FIG 11 ● Note that an endovascular external-to-internal iliac bypass has been created on the right side which also excludes the common iliac aneurysm. The durability of this bypass is compromised given its reliance on retrograde perfusion through the femoral–femoral bypass graft, the angulated nature of the graft position, and the propensity for one or both ends to "back out" of the origin and target arteries, given sufficient time, pressure, and movement.

be transposed to the external iliac artery, as long as the anastomosis is tension-free.

- [Alternate technique] Another hybrid approach is available to preserve internal iliac flow. In this method, a covered self-expanding stent (e.g., Viabahn®, W. L. Gore, Flagstaff, AZ) is deployed to provide retrograde flow from the external to internal iliac artery, ipsilateral to the common iliac aneurysm to be excluded. An aortouniiliac endograft is then deployed from the contralateral side, and the procedure completed with a femoral–femoral bypass graft (**FIG 11**). Several circumstances limit the general applicability of this technique, including an acute external–internal iliac bifurcation angle and significant diameter discrepancy (>2 mm) between the two arteries. Also, the durability of this technique is not well established and may be limited by the propensity of the covered stent to back out of either the origin or destination artery or kink. This technique also requires advanced catheter and guidewire skills and a large device inventory to reliably complete the procedure.
- [Alternate technique] More recently, a variation of the chimney (parallel) stenting technique has been described for complete endovascular repair of common iliac aneurysms.[4] In this technique, the proximal brachial artery is exposed through an axillary incision to allow safe introduction of a long (90 cm) braided 9-Fr sheath. Briefly, after the bifurcated main body endograft is deployed, the long 9-Fr sheath is advanced from the left brachial artery, through the main body, and positioned into the ipsilateral common iliac artery. The internal iliac artery is catheterized, followed by wire exchange for a stiff wire. A covered self-expanding stent graft (e.g., Viabahn®), sized for the target internal iliac artery diameter, is deployed from the ipsilateral iliac gate to the internal iliac artery landing zone. A second covered self-expanding stent graft is advanced from the ipsilateral femoral artery access retrograde into the aneurysm and proximal external iliac artery and deployed at the same level as prior internal iliac artery stent graft. Both stent grafts are expanded within the ipsilateral iliac limb of the aortic endograft using a kissing-balloon technique. This procedure can be repeated for the contralateral side in cases of bilateral common iliac aneurysms (**FIG 12**). Care should be taken during this maneuver to deploy each stent graft sequentially, rather than simultaneously, in order to position the covered stents accurately relative to each other.
- [Alternate technique] Although only available under an investigational device exemption (IDE), U.S. Food and Drug Administration (FDA)–approved clinical trial at the current time, an iliac branch device (IBD) is under

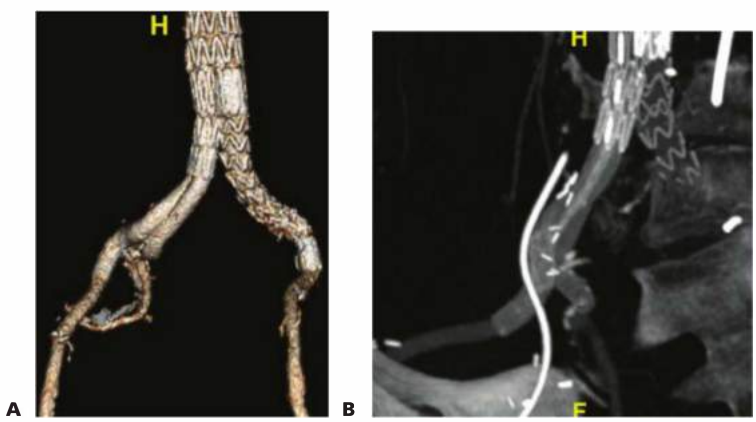

FIG 12 ● Like all "chimney" techniques, the proximal seal is dependent on the length of the parallel segment. In this instance, it should be more than 5 cm to promote thrombosis of the "gutters" between the parallel stents. It is not uncommon for a small type III endoleak to be seen on the completion angiogram with the patient anticoagulated.

TECHNIQUES

development for total endovascular repair of common iliac aneurysms (**FIG 13**). Briefly, this bifurcated device is inserted ipsilateral to the common iliac aneurysm prior to main body deployment. It is designed to be used in conjunction with a standard bifurcated aortic endograft. The partially constrained branch in the investigational device and adjacent internal iliac artery are catheterized from the contralateral side employing a preloaded catheter in the delivery system and cross-femoral guidewire access. A bridging covered stent is advanced from the branch to the internal iliac artery. Following this, a standard bifurcated endovascular aneurysm repair is completed in the usual manner.[5]

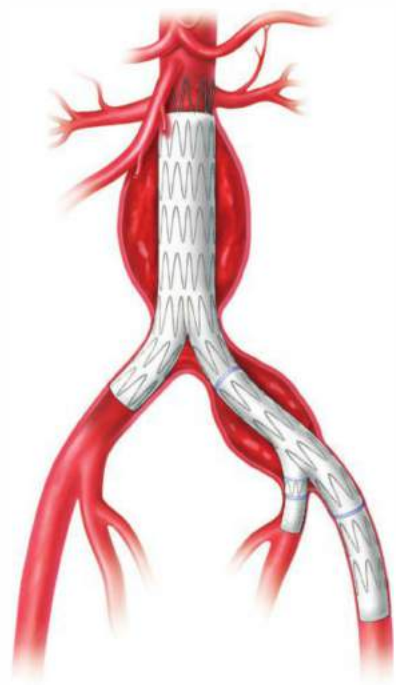

FIG 13 ● This figure depicts the IBD used in the repair of a left common iliac aneurysm. A covered stent is required to bridge the iliac branch to the native internal iliac artery. Although this bridging stent is typically delivered from the contralateral side, it may also be introduced through the left brachial artery.

PEARLS AND PITFALLS

Choose the right procedure for the right patient.	▪ Although perfusion is optimally maintained to at least one internal iliac artery, preservation should be attempted selectively, weighing the risks and benefits of potential ischemic complications associated with intentional occlusion vs. the additional complexity and long-term durability issues associated with preservation techniques.
External-to-internal iliac bypass exposure	▪ Make sure the longitudinal segment of the skin incision is sufficiently medial to the lateral edge of the rectus to accommodate a single layer fascial closure. The preserved rectus muscle provides a natural barrier against postoperative abdominal wall hernia formation.
Use a cross-over introducer sheath for internal iliac embolization.	▪ The cross-over sheath allows for intermittent contrast injection and stabilization of the embolization catheter. Internal iliac sheath access also minimizes the probability that deployed coils may reflux retrograde into the axial iliac circulation, requiring often prolonged and frustrating attempts at retrieval.
Pelvic bleeding	▪ The internal iliac vein is posterior and adherent to the artery and may be the source significant, unanticipated hemorrhage if injured during circumferential arterial dissection.
Inflow to the internal iliac bypass	▪ Choose a site on the external iliac artery sufficiently distal to its origin so that the stent graft can land in a segment free from kinking and prevent subsequent development of an ipsilateral type Ib endoleak.

POSTOPERATIVE CARE

- Postoperative care is similar to a standard endovascular aneurysm repair. A complete blood count and a basic metabolic panel are checked the following morning.
- If the procedure was performed entirely using endovascular techniques, oral intake is started immediately, Foley catheter is removed, and patient is encouraged to ambulate and discharged on following postoperative day.
- If the procedure involved a surgical internal iliac revascularization, the patient is started on clear liquids and advanced as tolerated. The retroperitoneal approach is not typically associated with a clinically significant ileus, and the muscle-sparing exposure is well tolerated. Patients may be discharged typically on the second postoperative day.

OUTCOMES

- Ipsilateral hip and buttock claudication develops in as many as 40% of patients following acute internal iliac artery occlusion. Fortunately, more severe forms of postprocedural pelvic ischemia, although potentially lethal, occur extremely rarely. Although claudication symptoms, when present, are reported to improve within 6 months following the procedure, this improvement may be attributable to lifestyle alteration (e.g., walking less) rather than collateral vessel formation. It is generally agreed, however, that complete symptom resolution rarely occurs.

- Internal iliac bypass grafting (surgical or endovascular) effectively maintains pelvic perfusion, with excellent long-term patency. Most patients enjoy a symptom-free postoperative course in perpetuity. Thus, in active individuals, as a general recommendation, internal iliac circulation should be preserved whenever possible.

COMPLICATIONS

- Complications for management of common iliac aneurysms can be a result of internal iliac revascularization or occlusion techniques.
- The main complication associated with revascularization is bleeding. This can occur intraoperatively from venous injury and/or postoperative anastomotic or other arterial sources. Other less common complications include ureteral injury, bowel injury, ipsilateral leg ischemia, and early graft thrombosis.
- Complications associated with acute occlusion of internal iliac artery include the spectrum of ischemic symptoms ranging from hip and buttock claudication to more severe forms such as perineal necrosis, ischemic sacral plexopathy, and vasculogenic impotence.
- The internal iliac artery serves as an important outflow branch in maintaining patency of the iliac limb after endovascular aneurysm repair. Iliac limbs whose distal landing zone is placed in the external iliac artery may have an increased risk of thrombosis. However, this is not an indication for any additional antiplatelet or anticoagulation treatments beyond what is customary.

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Chapter 25

Occlusive Disease Management: Isolated Femoral Reconstruction, Aortofemoral Open Reconstruction, and Aortoiliac Reconstruction with Femoral Crossover for Limb Salvage

Nathan Itoga E. John Harris, Jr.

DEFINITION

- Aortoiliac occlusive disease falls under the umbrella of peripheral artery disease where atherosclerosis and chronic plaque accumulation leads to diminished blood supply to distal arterial beds.
- The aortic bifurcation near the level of the L4 disc space is one of many areas of decreased shear stress and is an area of early atherosclerosis.
- Peripheral arterial disease (PAD) is usually classified into inflow and outflow disease.
- The infrarenal aorta and iliac vessels are of larger caliber and are classified as inflow vessels.
- The infrainguinal outflow from the common femoral artery is via the profunda femoral and superficial femoral arteries.
- The patterns of arterial stenosis and occlusion can be broken up into five types (Table 1). When a combination of both inflow and outflow disease exists, treatment is focused on the aortoiliac system first or femoral artery occlusive disease. Outflow occlusive disease is addressed in Part 6, Chapters 26–28, 31–33.

Table 1: Type of Lower Extremity Disease Patterns

	Distribution	Notes
Type 1	Confined to the distal infrarenal aorta and common iliac arteries	10% of disease patterns—found in younger female patients. Long-term patency after bypass is lower when done in patients <50 years of age.
Type 2	Found within infrarenal aorta, common and external iliacs	Most common presentation of aortoiliac disease
Type 3	Occlusive disease in the aortoiliac segment is combined with femoropopliteal or tibial disease.	Found commonly in critical limb ischemia
Type 4	Isolated superficial femoral and popliteal artery	
Type 5	Diffuse disease in the femoral popliteal and tibial vessels	

DIFFERENTIAL DIAGNOSIS

- Neurogenic claudication is frequently confused for arterial claudication. Neurogenic claudication is variable—some good days, some bad—whereas arterial claudication is very consistent. Neurogenic claudication can be relieved by the use of spinal support while walking, such as a shopping cart, or wheeled walker. These aids do not influence arterial claudication symptoms.
- Osteoarthritis of the hips can be frequently confused with arterial claudication. Like arterial claudication, pain is brought on by activity and relieved by rest and is more common with increasing age.
- Venous claudication from chronic venous outflow obstruction is described as a bursting type pain, comes on at longer distances, requires a longer rest period that requires leg elevation, and is frequently associated with leg swelling and discoloration.

PATIENT HISTORY AND PHYSICAL FINDINGS

- The diagnosis of aortoiliac occlusive disease can readily be made from a patient's clinical history and physical examination.
- Patient's with aortoiliac disease have up to a 50% risk of concomitant coronary artery disease with the same risk factors of smoking, hypertension, lipid abnormalities, diabetes mellitus, male gender, increased age, and family history.
- The disease burden in the internal and external iliac blood supply leads to a variety of clinical presentations which is most notable for Leriche syndrome which comprises the symptoms of buttock claudication, impotence in men, muscle atrophy, and absent or diminished femoral pulses.
  - Claudication is the most common presenting symptom and is not limited to the buttocks but can occur in the hip, thigh, and, rarely, in the calf muscles.
  - Impotence as an isolated symptom in men should be evaluated for other possible causes. Impotence is only seen in 30% of men with decreased hypogastric perfusion as there are abundant collaterals from the mesenteric, profunda, and lumbar arteries.
  - Ankle–brachial indices (ABI) are usually diminished but rarely lower than 0.5 in isolated aortoiliac occlusive disease for the same reason cited earlier. It is rare to see critical limb ischemia, which encompasses rest pain and/or

tissue loss, in the setting of isolated aortoiliac disease as there are multiple collaterals through the ilioprofunda system.
- Severe common femoral disease, with both superficial femoral and profunda femoral artery high-grade stenosis or occlusion, can mimic aortoiliac occlusive disease.

IMAGING AND OTHER DIAGNOSTIC STUDIES

- Ultrasound studies available in noninvasive vascular laboratories can help aid in diagnosis and assess the degree of PAD.
- ABI measurements can be supplemented by exercise, where a decrease in 15% of the ABI is considered significant as a decrease in peripheral resistance during exercise leads to diminished blood flow distal to the point of stenosis or obstruction.
- Duplex ultrasound for the aortoiliac system is difficult and is limited by body habitus and bowel gas. With an experienced technician, arterial disease of the intraabdominal vessels can be detected with greater sensitivity.
- For vascular surgeons, computed tomography angiography (CTA) is the noninvasive imaging study of choice for preoperative planning. Considerations for kidney disease and contrast dye allergies need to be taken into account. The evaluation usually involves the abdomen pelvis and runoff to the feet. It is difficult, especially in tall patients, to evaluate the thoracic aorta during one contrast bolus due to timing of the contrast injection. A CTA study provides accurate estimation of luminal flow and with good visualization of degree of calcification.
- Magnetic resonance (MR) angiography is also useful but is found to, at times, overestimate the degree of stenosis, and motion artifacts may limit the quality of the study.
- Direct arteriography under fluoroscopy is considered the gold standard, but improvements in CTA approach this accuracy in evaluating PAD.
- Arteriography may be difficult in the setting of an iliac occlusion and may need to be performed through the descending thoracic artery using a radial or brachial artery approach.
- Some surgeons may forego computed tomography (CT) studies and proceed with a contrast digital subtraction angiogram in the setting of a reliable history and physical and/or noninvasive ultrasound testing. This may limit the amount of contrast dye the patient is exposed to by proceeding directly with endovascular intervention. Like CTA, catheter-based arteriographic studies should include infrainguinal outflow of the femoral, popliteal, and tibial vessels, in addition to the abdominal and pelvic views.
- Although rarely used, pressure catheters can also be used during arteriography to identify significant lesions with a mean arterial pressure drop of 5 to 10 mm Hg across the stenosis considered significant.
- Preoperative imaging is essential in preoperative planning. The degree of aortoiliac disease in combination with infrainguinal and tibial occlusive disease needs to be considered in choosing the appropriate intervention for the patient.
- Graft selection, location of cross-clamping, and enlarged collaterals need to be accounted for prior to surgery.
- Identifying the degree and extent of arterial occlusive disease also enlightens the decision between an open or endovascular approach.
- The Trans-Atlantic Inter-Society Consensus (TASC) Classification (**FIG 1**) is a multispecialty consensus approach to managing aortoiliac occlusive disease. Routinely, TASC A and B lesions are treated with endovascular approaches with balloon angioplasty and/or stenting. TASC C and D lesions have a better outcome with an open approach.

SURGICAL MANAGEMENT

- Before surgical management is pursued, medical management should be initiated due to the high incidence of coronary artery disease with peripheral artery disease.
- Patients should be advised to quit smoking; placed on a regular walking program, ideally supervised; and started on statin therapy and aspirin when appropriate and tolerated.
- Preoperative anesthesia visits should include inquiries into cardiac, lung, and renal systems to evaluate overall operative risk.
- Age and comorbidities should be factored into decisions regarding an open versus endovascular approach, as should procedural durability and invasiveness of the intervention.
- The aims of therapy in aortoiliac occlusive disease are to relieve symptoms and, in cases of critical limb ischemia, prevent limb loss. Revascularization of the aortoiliac system can be done in a variety of endovascular and open approaches. The choice of procedure depends on the disease pattern, patient risk factors, available resources, and surgeon experience.
- We describe three common operative interventions for inflow disease: aortobifemoral bypass, femoral–femoral bypass, and femoral endarterectomy.

TYPE A Lesions

- Unilateral or bilateral stenosis of CIA
- Unilateral or bilateral single short (<3 cm) stenosis of EIA

TYPE B Lesions

- Short (<3 cm) stenosis of infrarenal aorta
- Unilateral CIA occlusion
- Single or multiple stenoses totaling 3-10cm involving the EIA not extending into the CFA
- Unilateral EIA occlusion not involving the origins of internal iliac of CFA

TYPE C Lesions

- Bilateral CIA occlusions
- Bilateral EIA stenoses 3-10cm long not extending into the CFA
- Unilateral EIA stenosis extending into the CFA
- Unilateral EIA occlusion that involves the origins of internal iliac and/or CFA
- Heavily calcified unilateral EIA occlustion with or without involvement of origins of internal iliac and/or CFA

TYPE D Lesions

- Infrarenal aortoiliac occlusion
- Diffuse disease involving the aorta and both iliac arteries requiring treatment
- Diffuse multiple stenoses involving the unilateral CIA, EIA, and CFA
- Unilateral occlusions of both CIA and EIA
- Bilateral occlusions of EIA
- Iliac stenoses in patients with AAA requiring treatment and not amenable to endograft placement or other lesions requiring open aortic or iliac surgery

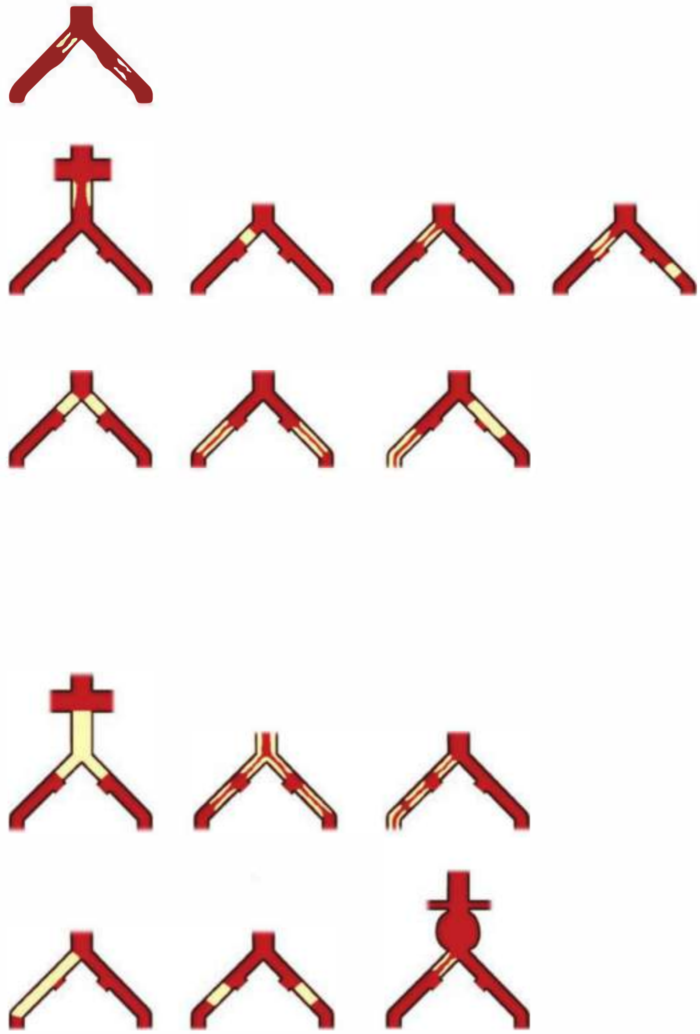

FIG 1 ● TASC II Classification scheme for iliac disease. (Adapted from Norgren L, Hiatt WR, Dormandy JA, et al. Inter-Society Consensus for the Management of Peripheral Arterial Disease [TASC II]. *J Vasc Surg*. 2007;45[suppl S]:S5–S67.)

ISOLATED FEMORAL RECONSTRUCTION FOR LIMB SALVAGE WITH POSSIBLE ENDOVASCULAR INTERVENTION

First Step—Landmarks

- The patient is placed prone on the operating table, with a soft bump under the knee and the leg slightly abducted and externally rotated. The inguinal ligament marks the transition point from the external iliac artery to the common femoral artery and is identified by connecting the anterior superior iliac spine to the pubic symphysis. The common femoral artery is usually located over the medial third of the femoral head but may be difficult to palpate in aortoiliac occlusive disease. Pre- or intraoperative ultrasound can be used to identify the common femoral as well as the bifurcation into the superficial and profunda arteries.

Second Step—Incision and Exposure

- Two types of incisions can be made to expose the common femoral artery. A vertical incision above the common femoral artery and bifurcation allows for greater access to the proximal and distal vessels in extensive disease. An oblique incision is better for cosmesis and is made cephalad to the groin crease and is acceptable in focal isolated lesions and in obese patients.
- After a skin incision is made, the subcutaneous tissue is then dissected with electrocautery with careful attention to ligate superficial crossing vessels to control bleeding and ligating lymphatics to prevent seroma formation.

A self-retaining retractor is used to help expose the tissues and is repositioned as the dissection proceeds deeper. Once the femoral sheath is identified and entered the femoral artery lies lateral to the femoral vein. The distal external iliac artery, the common femoral artery, the proximal profunda femoral and superficial femoral arteries are circumferentially dissected with scissors and tagged with a vessel loop or moist umbilical tape using a right angle. Other arterial side branches may be identified and are controlled with vessel loops or temporary clips but rarely ligated in occlusive disease.

Third Step—Clamping

- Before clamping of the arteries, heparin is given intravenously as a weight-based bolus at 100 units/kg and allowed to circulate for 3 minutes. Heparin has a half-life of approximately 90 minutes and is checked periodically with activated clotting time (ACT) measurements. A range of 250 to 350 is desirable and 1,000 to 3,000 units boluses can be given periodically to maintain this level of anticoagulation. Gaining proximal and distal control of the femoral arteries can be done with a variety of clamps. An angled Novare clamp or femoral C-clamp can be used at the proximal common femoral artery. Next, a profunda clamp is used to clamp the profunda femoral artery and the superficial femoral artery. Clamps are placed on soft areas of the artery past the area of the high plaque burden. Side branches can be controlled with vessel loops pulled tightly around the artery and clamped with a hemostat or temporarily clamped with a medium or large clip.

Fourth Step—Endarterectomy, Tacking sutures

- A longitudinal incision is made along the exposed common femoral artery using a no. 11 blade scalpel followed by Potts scissors. The adventitia is grasped with vascular forceps and a freer elevator is used to dissect the plaque away from the adventitia. The plaque is removed with blunt dissection unless sharp dissection is needed to dissect the plaque off the posterior wall. Tacking sutures with 7-0 Prolene are used to secure the remaining plaque to the posterior wall to avoid a dissection plane and emboli (**FIG 2**).

Fifth Step—Patch Angioplasty

- Rarely is the common femoral artery closed primarily after endarterectomy as this decreases the artery diameter. Patch angioplasty with bovine pericardium, polyester (Dacron), or saphenous vein is used. A patch is cut out to match the length of the endarterectomy incision with tapering at the proximal and distal edges to facilitate a curved end of the ellipse. The patch is secured with 6-0 Prolene suture. A parachute technique or three knots is used to anchor the patch at the proximal or distal end. The patch is then sewn with a running suture line. Before the patch is completely sewn in, back-bleeding is performed from the profunda artery, superficial femoral artery, and common femoral artery. Repair sutures with 6-0 or 7-0 sutures can be made in the case of suture line bleeding. Once the patch is in place, a micropuncture kit can be used to access the common femoral artery if endovascular therapies in a retrograde fashion are planned for the iliac arteries (**FIG 3**). In the case of extensive profunda femoral arterial occlusive disease, this artery should be exposed beyond the extent of any palpable plaque, and a separate arteriotomy, endarterectomy, and patch angioplasty of the superficial femoral and the profunda femoral arteries are performed (**FIG 4**). In the situation where extensive endarterectomy yields an adventitia that is too thin, the femoral bifurcation can be reconstructed with prosthetic graft material (**FIG 5**).

Sixth Step—Closure

- If an endovascular technique is performed in the same operation, simple Prolene stitches can be used to close the sheath access site. Careful attention is then made to ensure hemostasis. The femoral sheath may or may not be closed over the vessels, but careful attention must

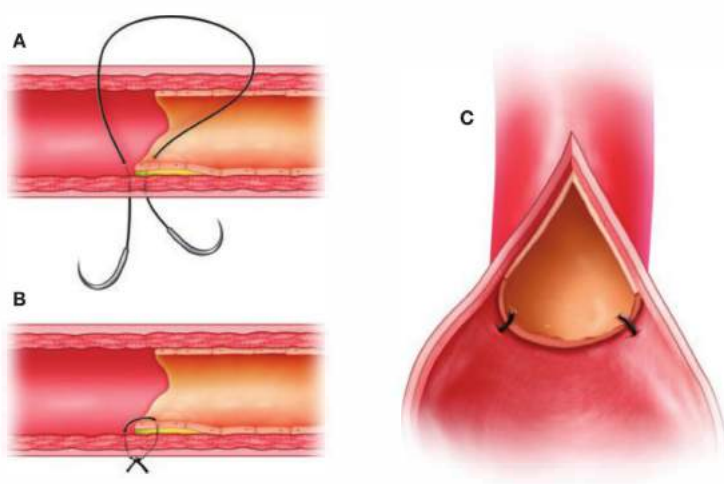

FIG 2 ● A single 7-0 Prolene U-stitch is applied through the endarterectomy/intima interface **(A)**, then ligated **(B)**, with the sutures typically placed at 4 o'clock and 8 o'clock positions **(C)**.

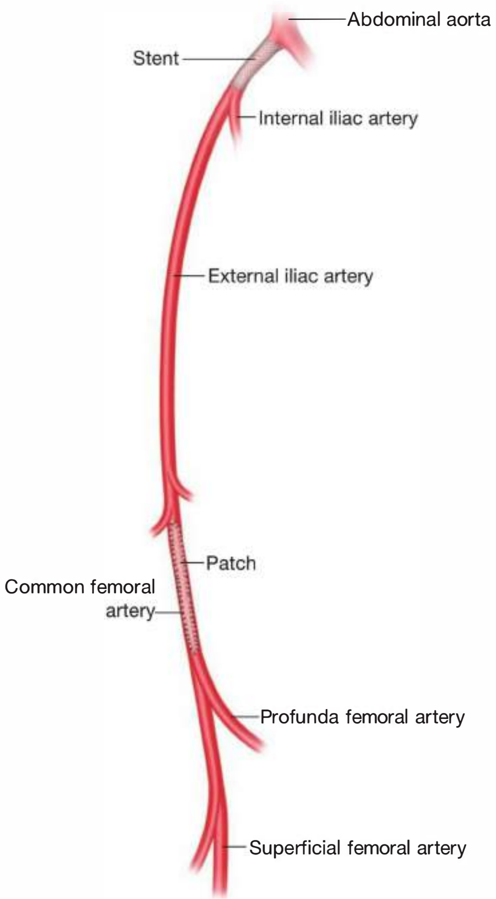

FIG 3 ● A common femoral patch angioplasty extending from the iliofemoral junction onto the origin of the superficial femoral artery (SFA), below a common iliac artery (CIA) stent.

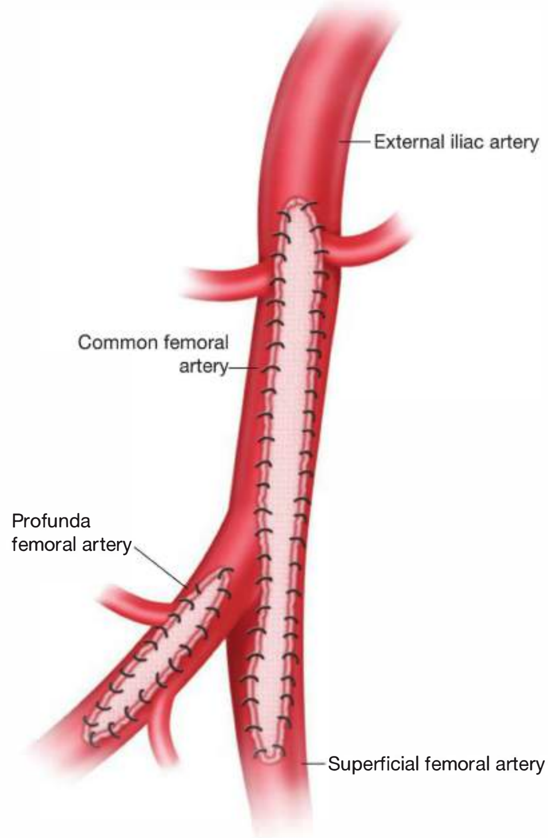

FIG 4 ● An extended femoral endarterectomy. The patch extends form the external iliac artery (EIA), across the entire common femoral artery (CFA) onto the proximal superficial femoral artery (SFA). A separate endarterectomy and patch angioplasty of the profunda femoral artery (PFA) is also depicted.

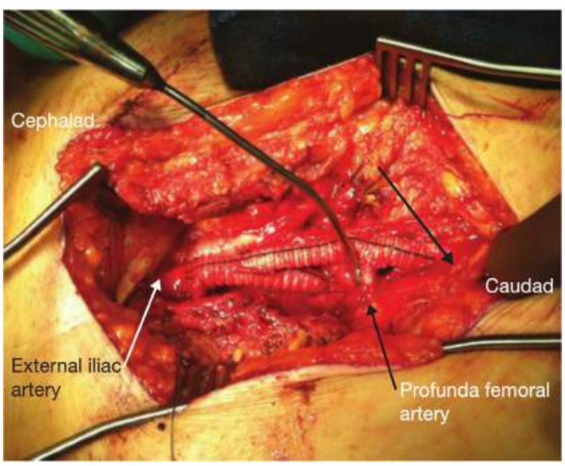

FIG 5 ● Femoral artery reconstruction with external iliac to deep femoral bypass with 8-mm Dacron and femoral to superficial femoral bypass with 6-mm Dacron. The inguinal ligament is mobilized cephalad for exposure.

be made to approximate tissues to close dead space to prevent seroma formation. Usually, a three-layer closure is used. At the end of the operation, femoral and distal flow should be checked with pulse palpation and continuous wave Doppler insonation. We do not routinely employ completion angiography or duplex ultrasonography. Protamine may be given, depending on the time of last heparin bolus or according to the intraoperative ACT reading. Approximately 10 mg is given for every 1,000 units of heparin given, adjusted for time decay and the heparin half-life or can be estimated off the last ACT measurement.

AORTOFEMORAL OPEN RECONSTRUCTION

Positioning

- The patient is supine, with a soft bump under the left hip for a retroperitoneal exposure and the table slightly flexed, or straight supine on a flat table for a transabdominal approach. The entire abdomen; the perineum, blocked with a sterile drape; and the groins and both legs are circumferentially prepped and draped into the sterile field.

First Step—Exposure of Femoral Vessels

- The femoral vessels are typically exposed first through bilateral longitudinal or oblique incisions to minimize the time which the abdomen is open. The crossing vein off the femoral vein beneath the inguinal ligament must be ligated or carefully avoided as this may be injured when the graft is tunneled from the abdomen later in the operation. After a soft spot is identified for anastomosis in the common femoral artery, or the profunda femoral artery when the superficial femoral artery is occluded, and adequate circumferential exposure is achieved, the common femoral artery along with superficial femoral and profunda artery are tagged with vessel loops or moist umbilical tape. The groin incision is then packed with an antibacterial saline-soaked gauze to avoid desiccation.

Second Step—Exposure of the Aorta

- A transperitoneal approach is routinely used to expose the infrarenal aorta, although a retroperitoneal approach may also be used. A longitudinal midline incision is made from just below the xiphoid process to a few centimeters below the umbilicus or down to the symphysis pubis when iliac arterial exposure will be required. Subcutaneous tissue is dissected and the abdomen is entered between the rectus muscles. With routine CTA preoperatively, a thorough abdominal exploration is discouraged, which will minimize postoperative ileus. The transverse colon is retracted cephalad, and the small bowel is shifted to the patient's right side and packed in soft, moist lap sponges to the right. The ligament of Treitz is taken down and the duodenum is mobilized to the right. A self-retaining retractor is then placed to sweep the bowel to the right with a moist laparotomy pad. The retroperitoneal tissue overlying the aorta is dissected, and the aorta is exposed superiorly to the level of the left renal vein. Extra retractors are used as needed for exposure. Distal control of the infrarenal aorta will be necessary if an end-to-side aortic anastomosis is planned. Preoperative imaging and manual palpation of the aorta identify a soft spot for the proximal anastomosis. Accessory renal arteries and the inferior mesenteric artery should be identified and be evaluated if reimplantation is necessary. Endarterectomy of the origin of the reimplanted visceral vessels is recommended, and extra aortic tissue is used as a Carrel patch. Lumbar arteries should also be identified and controlled with suture ligation or a vessel loop with care to avoid excessive bleeding. Depending on the type of aortic occlusive disease, an end-to-side or an end-to-end anastomosis will be fashioned and the dissection necessary is dictated by this decision. In general, an end-to-end anastomosis is more favorable hemodynamically, yet with preserved inferior mesenteric or iliac arteries, an end-to-side anastomosis may be more feasible.

Third Step—Tunneling

- After adequate exposure of the aorta is achieved, focus turns to making tunnels for the femoral limbs of the bypass. Tunnels should track directly along the anterior aspect of the external iliac artery and by elevating soft tissues and ensuring ureters remain anterior. Moist umbilical tapes or Penrose drains are passed with a smooth aortic clamp to mark the tunnels.
- Graft selection can also be made at this time with an 18 × 9-mm or a 16 × 8-mm graft used for males and a 14 × 7-mm or 12 × 6-mm graft typically used for females. Typically, a polyester (Dacron) graft is used, although others prefer polytetrafluoroethylene (PTFE). Prior to aortic clamping, heparin is given intravenously, as explained earlier with a target ACT range of 250 to 350.

Fourth Step—Clamp Placement

- The choice of clamp depends on the approach if end-to-side anastomosis or an end-to-end is chosen. The patency is similar for both approaches and, in most cases, is made by surgeon preference. For an end-to-end anastomosis, the proximal clamp is placed just below the renal arteries if the disease pattern does not obligate suprarenal clamping, with as little dissection of the renal artery origins as possible. The distal infrarenal aorta is then divided and oversewn in two layers with 4-0 Prolene suture. The proximal aortic cuff may require endarterectomy, which is performed up to the proximal clamp. For an end-to-side anastomosis, two aortic clamps are used or a side-biting Satinsky clamp is used to obtain proximal and distal control. With flush occlusion of the aorta at the

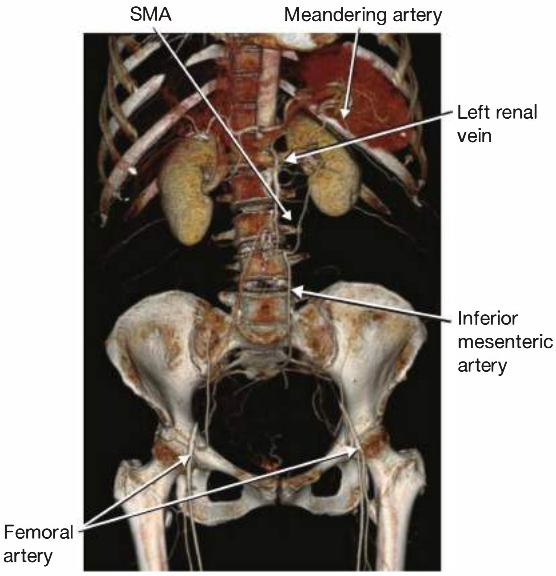

FIG 6 ● CTA identifying flush aortic occlusion at the level of the renal arteries, just deep to the left renal vein, with reconstitution of both common femoral arteries. Note the collateral network from the superior mesenteric artery (SMA), through the meandering artery to the inferior mesenteric artery (IMA), and into the pelvis, which has no hypogastric arterial flow.

level of the renal arteries (**FIG 6**), suprarenal dissection is required, with mobilization and control of the origins of the renal arteries, which are controlled with doubly passed silastic loops so that they may be occluded during endarterectomy to prevent atheroma embolization. A suprarenal clamp is placed to allow thromboendarterectomy of the infrarenal aortic cuff, then the clamp is moved caudally prior to graft anastomosis.

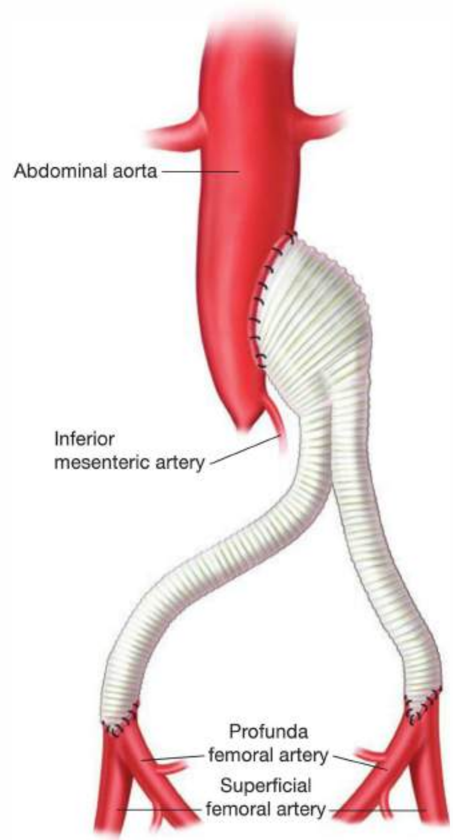

FIG 7 ● With a patent infrarenal aorta and inferior mesenteric artery (IMA), an end-to-side aortic anastomosis is depicted, positioned laterally as mentioned. With iliac occlusions, an end-to-end femoral anastomosis is depicted bilaterally.

Fifth Step—Proximal Anastomosis

- In the case of the end-to-end anastomosis, the technique is straight forward and the graft diameter should match the remaining aortic diameter. In the side-to-side anastomosis, the graft is cut at a bevel to maximize the amount of blood flow and the arteriotomy is laterally placed to allow the graft to enjoy a more retroperitoneal position to minimize the chance for development of an aortoenteric fistula (**FIG 7**). The graft is sewn in place with running 3-0 or 4-0 Prolene sutures using a parachute technique or securing the suture with three knots, starting from the posterior wall to visualize the placement of each stitch. The graft limbs are then clamped and the proximal clamp is then released to check for suture line bleeding. Repair sutures can be used for any suture line bleeding with 4-0 or 5-0 sutures on a pledget as needed. The abdomen is then packed and attention is then turned to the femoral anastomoses. In some instances, where a single internal iliac artery is patent, but the distal aorta or proximal common iliac artery is diseased, we will directly revascularize the internal iliac artery with the bifurcated graft limb and then jump graft down to the femoral position (**FIG 8**).

Sixth Step—Graft Tunneling

- Using the umbilical tape or Penrose drain as a guide, a smooth aortic clamp is then used to tunnel each graft limb from the abdomen into the femoral incision. The graft is then pulled gently through the tunnel above the external iliac vessels and below the ureter. Care must be taken to minimize kinking and redundancy in the graft tunnels. Once tunneled the graft limbs are flushed to confirm adequate inflow, reclamped in the abdomen and flush with heparinized saline solution.

Seventh Step—Distal Anastomosis

- Clamping of the femoral artery is then performed as described earlier so that the common femoral artery, superficial femoral artery, and profunda femoral artery are controlled. A longitudinal incision is then made with a no. 11 blade followed by Potts scissors to approximate the graft limb. The graft is then cut on a taper to allow a natural reimplantation angle into the common femoral artery with minimal tension. The anastomosis is then completed as an end-to-side fashion with 5-0 or 6-0 Prolene suture in a running fashion. In some situations, where retrograde external iliac flow is not possible, an end-to-end femoral anastomosis is preferred to either the common femoral or the profunda femoral artery (**FIG 8**). The same procedure is completed for the contralateral limb.

Eight Step—Closure

- After hemostasis is achieved, careful attention is made to ensure the anastomoses are securely done and dead space is closed to prevent seroma formation and minimize groin infections. Protamine may be given as described earlier.

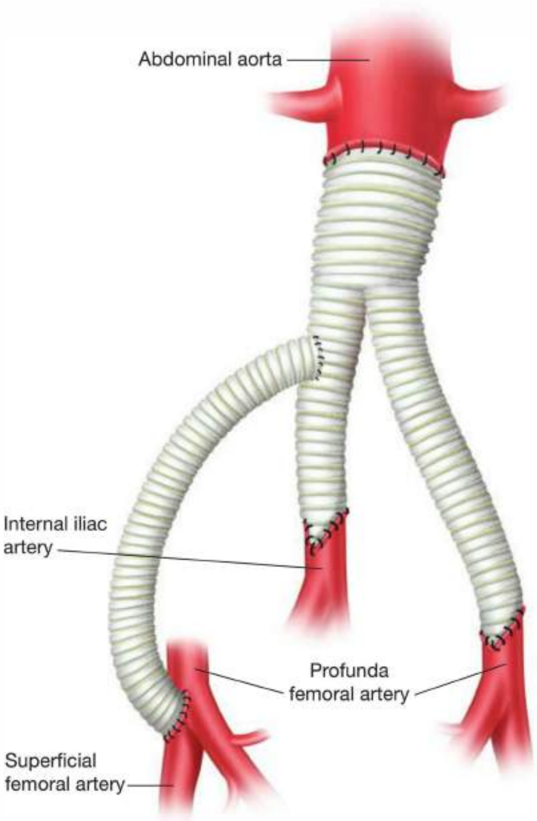

FIG 8 ● An end-to-end aortic anastomosis is depicted. In this case, an isolated internal iliac artery (IIA) was present and preserved with end-to-end anastomosis from the right limb of the bifurcated graft. A jump graft is then brought off this limb to the right common femoral artery (CFA). With occlusion of the left superficial femoral artery (SFA), the left limb is performed in end-to-end fashion to the profunda femoral artery (PFA).

AORTOILIAC RECONSTRUCTION WITH FEMORAL CROSSOVER

- This technique can be used to restore blood flow to a lower limb when one of the iliac arteries is obstructed and the contralateral iliac arteries are patent. The surgical procedure can also be used in conjunction with an endovascular procedure, for example, angioplasty and/or stenting of the nonoccluded iliac vessels. Groin incisions are made in an oblique or longitudinal fashion. Control of the common, superficial femoral, and profunda femoral arteries are performed as previously described. Endarterectomy of the common femoral artery is performed as necessary if there is significant plaque burden. The suprapubic tunnel is made with blunt dissection using a blunt-ended hemostat or one's fingers. The key is to create the tunnel just anterior to the abdominal fascia. Either a blunt tunneling device or a long aortic clamp can be used to pass the graft from one side to the other in the subcutaneous tissue, avoiding entry into the peritoneal cavity. The anastomosis is performed so the graft sits in a curved configuration over the suprapubic tissue (**FIG 9**). Meticulous attention is given to closure to avoid kinking or compression of the graft and to avoid dead space that can lead to problematic seromas and the possibility of soft tissue infection, with subsequent graft infection.

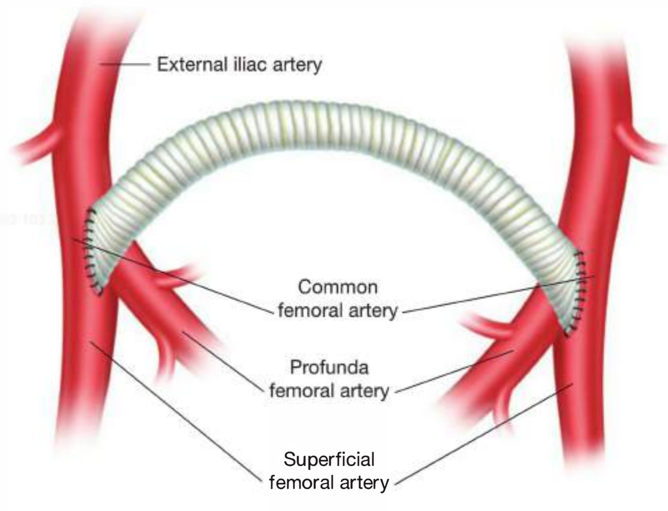

FIG 9 ● A right to left common femoral artery to common femoral artery (CFA) is depicted. Ideally, the graft extends over the origin of the profunda femoral artery (PFA) onto the origin of the superficial femoral artery (SFA).

PEARLS AND PITFALLS

Isolated femoral reconstruction	■ Care must be taken to be certain that proximal and distal atherosclerotic plaque is not causing residual stenosis. ■ Patch angioplasty is critical to the success of this procedure. ■ Distal tacking sutures should be employed generously.
Aortofemoral reconstruction	■ Adequate exposure is critical to success. ■ Localized endarterectomy at both proximal and distal anastomotic sites is generally required. ■ Tunneling errors can lead to late complications and early graft failure.
Femoral–femoral crossover	■ Adequate inflow and outflow must be assured for success. ■ Concomitant femoral endarterectomy should be used freely. ■ Tunneling and closure errors frequently cause early graft failure.

POSTOPERATIVE CARE

- Patients are admitted to a cardiac monitored floor postoperatively as patients are at high risk for or have documented coronary artery disease. Immediately, postoperative vascular checks are performed with high frequency to assess early graft thrombosis requiring reintervention or initiation of anticoagulation. Patients are encouraged to ambulate 4 to 6 hours after the operation, with adequate pain control a point of focus. When the abdomen is entered, in the case of aortobifemoral grafting, patients are kept from an oral diet until bowel function returns. While anticoagulation is not routinely used for graft patency, aspirin is standard, and subcutaneous heparin is given for secondary prevention of deep vein thrombosis (DVT).

OUTCOMES

- See Table 2.

Table 2: Long-term Outcomes for Aortoiliac Disease

Type of Operation	Patency Rates
Femoral endarterectomy with iliac stenting	5-year patency—iliac stenting without femoral endarterectomy—66%; iliac stenting without femoral endarterectomy—88%
Aortobifemoral bypass	5-year primary patency, 90%–93%; 5-year secondary patency, 87%–97%; 10-year patency, 72%–94%; 15-year patency, 63%–82%
Femoral–femoral bypass	5-year patency rate, 42% to 88%; weighted average, 66%

COMPLICATIONS

- Early
  - Hemorrhage
  - Early thrombosis

  - Infections
  - Colon ischemia
  - Femoral nerve injury
- Late
  - Aortoenteric fistula
  - Restenosis, thrombosis of graft
  - Anastomotic pseudoaneurysm
  - Sexual dysfunction
  - Spinal cord ischemia
  - Graft infection

SUGGESTED READINGS

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Chapter **26**

Occlusive Disease Management: Iliac Angioplasty and Femoral Endarterectomy

Venita Chandra

DEFINITION

- Multilevel atherosclerotic occlusive disease involving the distal aorta, iliac vessels, and common femoral arteries is a common occurring pathology seen often by vascular surgeons. Traditional approaches to this disease process involved open surgical reconstruction with an aortobifemoral bypass or iliofemoral bypass. Recently, however, there has been a paradigm shift toward endovascular and hybrid approaches. Combining femoral endarterectomy with endovascular iliac stenting is an increasingly common minimally invasive approach to this problem, providing an effective alternative to open strategies with the potential of shorter hospitalizations and decreased morbidity. Compared to iliac stenting alone, proper evaluation of femoral disease and, if indicated, a hybrid approach with concomitant femoral endarterectomy have been associated with increased durability of endovascular aortoiliac interventions.[1]

PATIENT HISTORY AND PHYSICAL FINDINGS

- Aortoiliac and femoral occlusive disease can present, as with all peripheral arterial diseases (PADs), in a variety of ways.
- The typical presentation of aortoiliac occlusive disease includes claudication of the buttock and upper thigh and erectile dysfunction. When multilevel vascular disease occurs, as in the case of combined aortoiliac and femoral occlusive disease, distal lower extremity symptoms such as calf claudication, rest pain, and tissue loss may ensue.
- Typical physical exam includes the absence or diminution of femoral pulses. Other than the peripheral pulse assessment, the physical exam can demonstrate other signs of PAD such as cool digits and active wounds.

IMAGING AND OTHER DIAGNOSTIC STUDIES

- The initial evaluation of a patient with PAD should involve noninvasive evaluation of peripheral blood flow with arterial waveforms and ankle–brachial indices (ABIs) (**FIG 1**). These studies provide objective data regarding the extent of occlusive disease; however, they do not provide adequate anatomic data for preoperative planning.
- Once the degree and physiologic impact of the disease are determined by noninvasive testing, high-resolution anatomic imaging via either computed tomographic angiography (CTA) or magnetic resonance angiography (MRA) should be obtained for surgical planning.
- CTAs are currently the gold standard for preoperative planning. They have the advantage of providing information regarding the degree and location of stenosis as well as the anatomy of the arterial wall (including degree of calcification and presence of aneurysms). Three-dimensional reformatting can provide additional valuable information (**FIG 2**). CTAs, however, are limited by the fact that they involve the use of contrast as well as radiation exposure. MRAs avoid radiation exposure and contrast often, however, at the risk of reduced anatomic precision. Gadolinium magnetic resonance (MR) contrast also entails risk of long-term renal dysfunction.

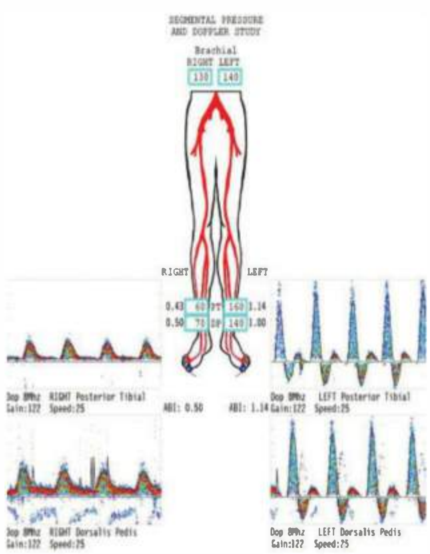

FIG 1 • Arterial waveforms and ABIs for a patient with aortoiliac disease. Note the monophasic waveforms on the right.

FIG 2 • CTA with 3-D reconstruction demonstrating diffuse aortoiliac as well as femoral occlusive disease.

- Catheter-based diagnostic aortography also provides anatomic data; however, this study has a number of limitations including the fact that it is an invasive procedure with potential complications. In addition, arteriograms only provide an understanding of the luminal anatomy, occasionally obscuring features such as aneurysms, inclusion cysts, or periarterial inflammation. Particularly for aorto-iliac-femoral disease, preprocedural CTA has the ability to identify significant common femoral disease that may benefit from concomitant open endarterectomy at the time of catheter-based intervention. Alternatively, relying on catheter-based arteriography as the primary diagnostic modality may reduce overall contrast burden, radiation exposure, and need for additional procedures if common femoral level intervention is not required. In general, careful preprocedural physical examination and duplex imaging may suffice to help determine whether the additional cost, risk, and inconvenience of CTA are justified prior to catheter-based intervention for aortoiliac arterial occlusive disease.

SURGICAL MANAGEMENT

- As with all patients with PAD, initial treatment approach should include comprehensive assessment and management of concomitant cardiovascular disease risk factors. Details regarding maximal medical management of PAD are beyond the scope or purpose of this chapter; at a minimum, however, consideration should be given to beginning statin and antiplatelet therapy prior to intervention, along with consideration of beta blockade and angiotensin receptor blocker or converting enzyme inhibitor therapy in selected patients.
- Regardless of medical or anesthetic risk, however, all patients with critical limb ischemia should be considered candidates for revascularization when limb loss is a distinct possibility. Despite platitudes to the contrary, major limb amputation above or below the knee is not necessarily a "safer" surgical alternative to multilevel hybrid revascularization. Indications for intervention for intermittent claudication are somewhat more complicated, however. The risks of a procedure are weighed against the potential gain; typically, only patients with severe lifestyle-limiting claudication who have failed nonoperative strategies are offered surgical revascularization.

Preoperative Planning

- Determining the anatomic distribution of disease is essential to obtaining optimal results. The imperative for precision imaging cannot be emphasized enough—if you cannot appreciate the full extent of disease, you cannot expect to comprehensively address it. As in all aspects of vascular surgery, the biggest disappointments, both during and after the procedure, usually arise from underestimating the extent of underlying disease.
- The Trans-Atlantic Inter-Society Consensus (TASC) II guidelines provide a classification scheme based on anatomic patterns of disease (**FIG 3**).[2] The recommendations of the TASC II guidelines is an endovascular management for TASC A and B iliac lesions, whereas open surgical reconstruction is recommended for TASC C and D lesions in good-risk patients. Frequently, however, patients with multilevel disease as seen in TASC C and D lesions have more virulent atherosclerotic processes that often make them poorer surgical candidates. In addition, the development of an increasingly sophisticated armamentarium of endovascular tools and strategies are leading more and more vascular surgeons to attempt endovascular revascularization, even for patients with TASC C or D lesions. Further updates of the TASC classification guidelines are under review and will likely be published in the near future, highlighting the dynamic nature of surgical management of this challenging condition.
- Targeted perioperative risk assessment should be undertaken in appropriate patients, particularly those with reduced exercise tolerance, known or suspected congestive heart failure, clinically significant pulmonary disease, exercise-induced angina, arrhythmias, or those with recent history of myocardial infarction. The presence of additional relevant comorbidities, including diabetes, reduced glomerular filtration rate, iodinated contrast allergies, thrombophilia or coagulopathic disorders, concomitant bacterial infection, or liver disease should also be identified and, when present, evaluated.

Positioning

- Patients are generally placed in the supine position, either in a hybrid operating suite with fixed imaging capabilities or on a radiolucent table with a mobile imaging unit (C-arm) in a traditional operating room environment.
- Positioning should be arranged in such as way as to ensure adequate exposure of the entire aortoiliac and femoral vasculature, with room on either side of the patient to rotate the imaging unit to various angles in order to obtain appropriate oblique images. In angiographic parlance, in many important circumstances (such as identifying and protecting the origin of the ipsilateral internal iliac artery), "one view is no view."

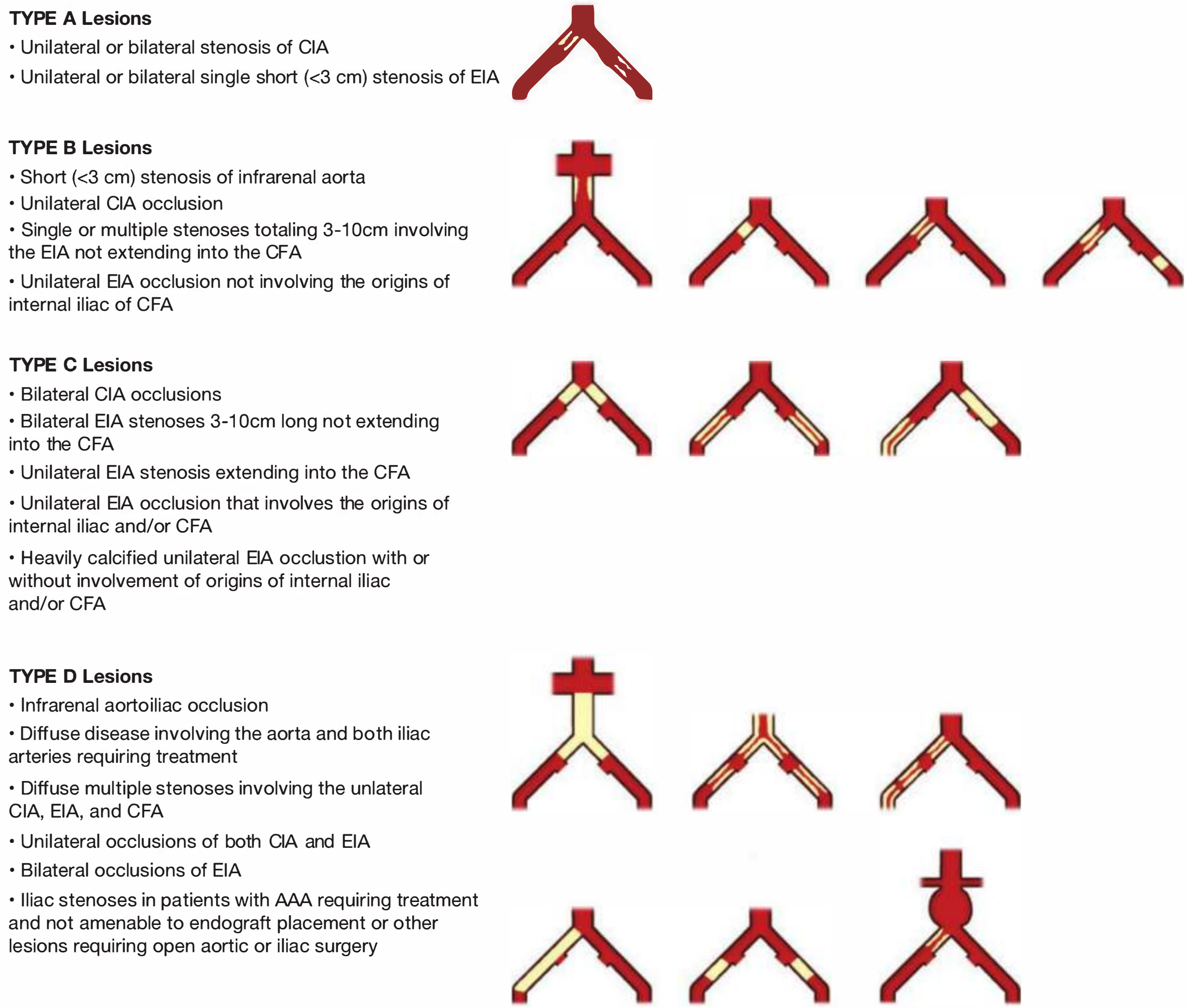

FIG 3 ● TASC II Classification scheme for iliac disease. (Adapted from Norgren L, Hiatt WR, Dormandy JA, et al. Inter-Society Consensus for the Management of Peripheral Arterial Disease [TASC II]. *J Vasc Surg*. 2007;45[suppl S]:S5–S67.)

FEMORAL ENDARTERECTOMY

First Step

- For extended femoral endarterectomy (often requiring exposure of the proximal deep femoral artery as well as the entire length of common femoral artery), optimal exposure is obtained via a longitudinal incision placed directly over the femoral artery (**FIG 4**). The inguinal ligament should be identified by palpation of the pubic tubercle and anterior superior iliac spine (an oblique line between these two structures is the typical course of the inguinal ligament) and used as a guide for femoral localization. Typically, the femoral artery is located approximately one-third the distance from the pubic tubercle to anterior superior iliac crest. Even when no pulse is palpable, a firm calcified linear mass can usually be palpated in this area. Alternatively, duplex ultrasound or fluoroscopic imaging may be used to ensure accurate placement of the incision. Failure to incise directly over the common femoral artery may increase risk for chronic lymphatic drainage, delayed or complicated wound healing, and femoral nerve or venous injury. Although oblique femoral incisions have gained in popularity, especially when used to obtain femoral access for proximal aneurysm repair, these often do not provide exposure sufficient for comprehensive endarterectomy as previously detailed.
- The subcutaneous tissues are divided, ligating any lymphatic channels that are encountered. The inferior edge of the inguinal ligament is identified and the common femoral artery is exposed through the femoral sheath as it exits underneath the inguinal ligament.

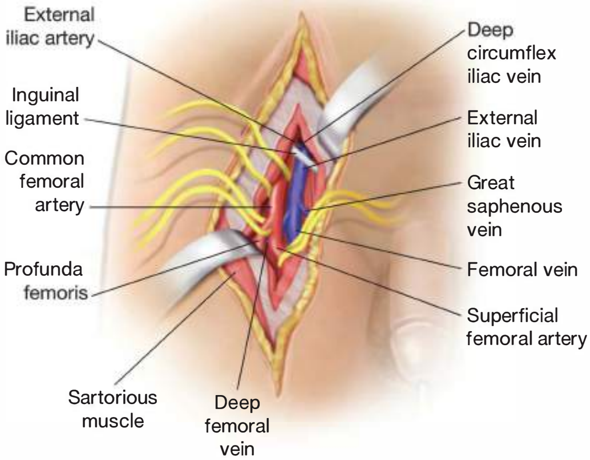

FIG 4 ● Typical longitudinal femoral artery exposure and anatomy. CFA, common femoral artery; EIA, external iliac artery; EIV, external iliac vein; GSV, greater saphenous vein; DCIV, deep circumflex iliac vein; SFA, superficial femoral artery.

Second Step

- Full circumferential dissection of the distal external iliac artery (under the inguinal ligament), the common femoral artery, the superficial femoral artery, and the origin of the deep femoral artery and its initial branches are obtained sequentially (**FIG 4**).
- The individual arteries should be assessed for areas of calcification and extensive plaque burden. Soft sections with minimal calcification, or plaque limited to the posterior arterial wall, should be identified for consideration of clamp placement as appropriate for the planned procedure.
- The inguinal ligament may be divided for adequate exposure of the distal external iliac artery when necessary to ensure adequate endarterectomy When considering the relative margin of distal endarterectomy versus proximal stent placement, it is important to avoid stent placement across the inguinal ligament, as this may greatly reduce long-term patency of the procedure as well as complicate stent delivery through an ipsilateral retrograde sheath. In general, operators should err of the side of more extensive proximal endarterectomies as opposed to distal extension of external iliac stents.
- Careful ligation of the circumflex iliac vein as it crosses over the external iliac artery under the inguinal ligament should be considered to prevent accidental tearing of the vessel during clamping.
- External iliac collaterals, like the epigastric artery or circumflex iliac artery, should be preserved during dissection and endarterectomy whenever possible to ensure optimal long-term outcome.

Third Step

- Once exposure is complete, the common femoral artery can be punctured under direct vision with advancement of a wire under fluoroscopic guidance across the iliac lesion (**FIG 5**).
- This eliminates the possibility of creating a retrograde dissection when a wire is passed after the endarterectomy is performed, as well as the need to puncture the endarterectomy patch to gain access.
- If the disease burden is confined to the common iliac artery or only the proximal external iliac artery, then iliac stenting can proceed at this point, prior to proceeding with the endarterectomy. Occasionally, however, the amount of femoral disease burden is so great that the sheath will be occlusive or otherwise impair runoff, which may limit the ability to obtain digital subtraction angiography (DSA) images during or after stent placement. So consideration should be given to initial

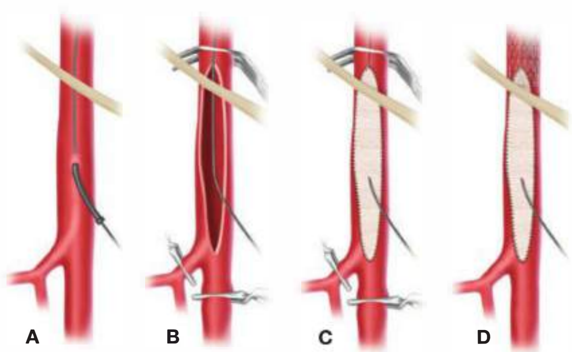

FIG 5 ● Technique for concurrent femoral endarterectomy and iliac stenting. **A.** Direct puncture of common femoral artery and advancement of wire under fluoroscopic guidance. **B.** With wire across iliac lesion, clamp proximal and distal and proceed with arteriotomy. **C.** After endarterectomy, patch is sewn in. Prior to completion of patch center, the distal portion of the patch is punctured with an 18-gauge needle and the wire is passed through the patch. **D.** After completion of the patch, flow is restored and a sheath can be advanced over the wire and iliac stenting can proceed. For patients with distal external iliac disease, the iliac stents can be carried down into the proximal portion of the endarterectomy and patch.

endarterectomy depending on individual anatomic circumstances.

- When retrograde wire passage is not possible due to extensive proximal plaque burden, tortuosity, or other anatomic considerations, antegrade passage from the contralateral iliofemoral system (obtained via either percutaneous or open femoral access) or left axillary or brachial access may be attempted. Obviously, longer sheath/catheter/guidewire combinations will be needed for these procedures and positioning considerations will be affected as well (e.g., arm will need to be exposed and prepped on a radiolucent surface). Once antegrade wire is accomplished, this may be used to deliver treatment devices directly or snared and externalized through the ipsilateral femoral access for retrograde intervention as originally planned.

Fourth Step

- Leaving the wire in place, systemic anticoagulation is accomplished with sufficient doses of unfractionated intravenous heparin administration and proximal and distal femoral control is obtained with vascular clamps. Especially proximally, a padded clamp should be chosen to allow the external iliac artery to be clamped over the existing wire to prevent or minimize wire-related injury.
- A longitudinal common femoral arteriotomy is performed to expose the full extent of femoral disease that needs to be addressed to ensure adequate runoff from the iliac intervention. This can almost always be accomplished within the femoral incision itself without need for additional distal femoral bypass procedures, unless extensive forefoot gangrene is present as a consequence of multilevel arterial occlusive disease. Extended deep femoral endarterectomy is highly effective in achieving suitable runoff when few other revascularization options may be available (**FIG 4**).
- The arteriotomy can extend onto either the superficial or deep femoral artery. Occasionally, an eversion endarterectomy of the deep femoral artery can be performed when the arteriotomy extends onto the superficial femoral artery. Alternatively, the arteriotomy may be extended down the deep femoral artery when the superficial femoral artery is chronically occluded. Selection of the reconstruction technique is influenced by the occlusive pathology, level of debility, indications for revascularization, and optimal revascularization strategy (**FIG 6**).

Fifth Step

- Carefully, an endarterectomy plane is developed between the plaque and remaining mural media or adventitia using a Penfield dissector or Beaver blade. The plane most typically is developed within or exterior to the media, leaving the adventitia intact. Failure to appreciate the appropriate endarterectomy plane may weaken the adventitia, leading to bleeding or postoperative hematoma or pseudoaneurysm formation. Care should be taken to dissect the plaque away from the remaining arterial wall, not vice versa. The endarterectomy plane is developed on each side of the vessel and advanced posteriorly until the planes meet in the midline. Following this maneuver, the plaque is transected flush with the arterial wall. Care should be taken to achieve good

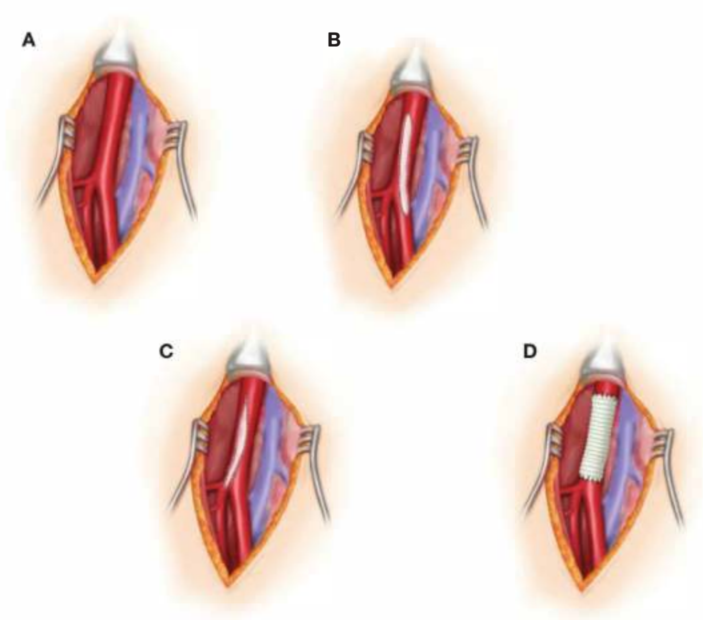

FIG 6 ● Various femoral endarterectomy closure strategies. **A.** Typical anatomy; occasionally, primary repair can be considered if common femoral artery is of adequate size. **B.** Arteriotomy and patch extended onto superficial femoral artery; deep femoral artery endarterectomy can be performed using an eversion technique. **C.** Arteriotomy and patch extended onto deep femoral artery. Particularly useful in chronically occluded superficial femoral artery (SFA). **D.** Interposition repair of common femoral artery; can syndactylize deep femoral artery and SFA if needed.

quality and minimally diseased endpoints in both the superficial and deep femoral arteries as necessary (**FIG 7**). Tacking sutures, as commonly employed during carotid endarterectomy, may also be necessary in the femoral artery to ensure adequate endpoints. Particularly in the case of the deep femoral artery, care should be taken to extend the endarterectomy well past the mass of common femoral artery–related plaque. This may require exposing the deep femoral artery well beyond its initial branches, dividing crossing branches of the deep femoral vein, and avoiding excessively deep placement of self-retaining retractors to limit the possibility of traction injury to femoral nerve branches.

- Often, significant posterior plaque extends proximally well into the external iliac arteries. As previously discussed, care should be taken in deciding at which point the endarterectomy should end versus distal extension of iliac stents (**FIG 5**).

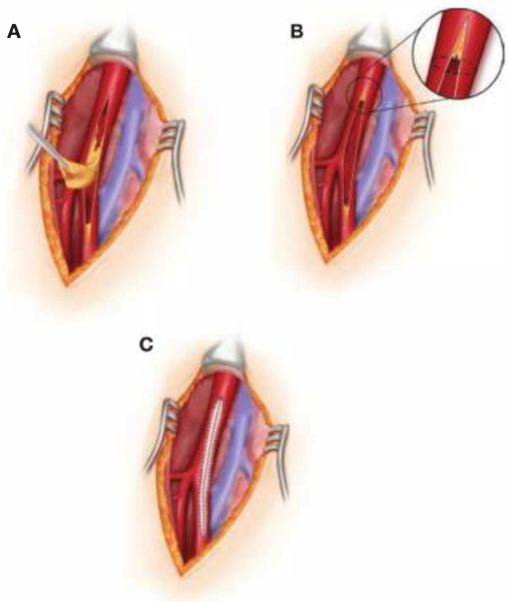

FIG 7 ● Femoral endarterectomy technique. **A.** Longitudinal arteriotomy and development of endarterectomy plane. **B.** Ensure adequate endpoints on either end. **C.** Patch closure.

Sixth Step

- Once the full extent of plaque has been removed and suitable irrigation performed to identify and eliminate remaining mobile fragments of residual media, patch angioplasty should be performed typically using running 5-0 polypropylene suture initiated at both the proximal and distal endpoints and tied in the middle. Bovine pericardium, extruded polytetrafluoroethylene (ePTFE), and polyester or autogenous vein segments all may represent reasonable patch options, depending on individual circumstances. In general, autogenous vein is more resistant to infection, whereas prosthetic patch options are available off the shelf in a variety of configurations. ePTFE patches tend to bleed more through their suture holes following placement, although this tendency may be tempered by use of ePTFE patches. Currently, our preference is to use bovine pericardial patch as the default choice in the absence of infection or other contraindication (e.g., patient objection due to religious reasons) (**FIG 6**).
- Rarely, when arterial wall integrity appears compromised following endarterectomy, femoral interposition grafting may be performed in lieu of patch angioplasty. Interposition grafting may also be a good choice when the femoral plaque burden is so great that endarterectomy is impractical; in this case, an interposition graft (ePTFE or knitted polyester) can be placed instead of a patch. This can be configured in any number of ways:
  - Distal anastomosis to distal common femoral artery
  - Distal anastomosis to syndactylized superficial and deep femoral arteries (**FIG 6**)
  - Distal anastomosis to superficial femoral artery with reimplantation of the deep femoral artery
  - Distal anastomosis to the deep femoral artery with reimplantation of superficial femoral artery
  - Distal anastomosis to the deep femoral artery only, when the superficial femoral artery is already occluded

Seventh Step

- Before completion of patch closure, the middle or distal portion of the patch is punctured with an 18-gauge needle and the back of the previously placed wire is routed through the needle. Patch closure is then completed and the clamps removed; at this point, an appropriately sized sheath can be advanced over the wire, through the patch, in preparation for iliac stenting.

COMMON ILIAC STENTING

First Step

- Typically, a 6- or 7-Fr sheath is adequate for iliac stenting. Once the sheath is placed after completion of the patch, appropriate arteriogram images are obtained.
- For distal aorta and proximal common iliac disease, often the best approach is passage of a flush catheter into the aorta and a power-injected aortogram.
- For primarily iliac disease, retrograde arteriography through the femoral sheath is usually sufficient to obtain adequate iliac opacification.
- Contralateral anterior oblique (15- to 30-degree) projections are typically chosen for visualization of the respective iliac systems to ensure identification of the origin of the ipsilateral internal iliac arteries. Also, the full extent of disease burden may be most adequately addressed by multiple obliquities in any circumstance.

- A marking catheter may be used to assist in length measurements and "buddy" wires may also be placed from contralateral femoral access. Every effort should be made to maintain perfusion to the hypogastric arteries.

Second Step

- Selection of the appropriate balloon and stent diameter is of great importance. Slight oversizing of 5% to 10% is recommended, except in the case of heavily calcified lesions, where oversizing may predispose to arterial rupture.
- Optimal target vessel diameter may be estimated preoperatively by measurements from the CTA, particularly looking at the diameter of adjacent or contralateral normal arterial segments. Similarly, diameter and length measurements may also be obtained during the hybrid procedure itself. Generally speaking, common iliac artery target diameters may range from 7 to 10 mm, depending on gender, body habitus, and burden of disease. External iliac artery diameters range from 5 to 8 mm under similar qualifications.
- Balloon "predilation" may facilitate stent placement and assist with stent sizing.
- Mild pain during dilation is to be anticipated and indicates stretching of the adventitia; excessive or persistent pain, however, may indicate arterial compromise or rupture. In the latter circumstance, consideration should be given to additional placement of a covered stent when contrast extravasation is present on arteriography and not immediately controlled with extended balloon deployment. In the retroperitoneum, unlike the lower extremities, tamponade will not likely limit further bleeding and extended balloon deployment may not be advisable as definitive treatment. When general anesthesia is required for the concomitant endarterectomy, this warning sign may not be present and completion arteriography should be carefully scrutinized for indications of iliac artery compromise or contrast extravasation.
- There are numerous commercially available stents to choose from, many of which are specifically indicated for iliac arterial intervention (e.g., "on label"). Appropriate diameter and length stents generally fall into two categories, balloon-expandable or self-expanding and can be covered or uncovered (e.g., with adherent graft material).
- The length of the balloon or stent should cover the entire length of the diseased area.
- Balloon-expandable stents have the advantage of higher precision of placement and greater radial strength; however, they are less flexible than self-expanding stents. As a general rule of thumb, balloon-expandable stents are best suited for common iliac artery lesions where "kissing" stents in the contralateral iliac artery may be needed to deal with excessive plaque burden or calcification or the aortic bifurcation may need to be "advanced" into the distal aorta to completely ensure adequate luminal recanalization. Alternatively, external iliac lesions are often best treated with self-expanding stents, which by their nature are more flexible and compliant with the radius of curvature present in this artery. Exceptions exist for both indications, however, and device placement should be individualized to specific anatomic and clinical requirements.

Third Step

- In the setting of bilateral or even unilateral proximal common iliac artery disease or distal aortic disease, bilateral aortic bifurcation balloon dilation and stenting should be completed simultaneously to protect the contralateral common iliac artery from dissection, plaque dislodgement, or subsequent embolization. This is generally referred to as "kissing" stents.
- Balloon-expandable stents are typically used for these proximal common iliac lesions and they may be deployed well into the distal aorta, essentially "advancing the aortic bifurcation."

Fourth Step

- For common iliac lesions immediately adjacent to the aortic bifurcation, after precise arteriographic localization of the aortic and iliac bifurcations and extent of plaque burden, appropriately sized stents are selected. Uni- or bilateral sheaths of sufficient diameter for the selected stents are advanced into the distal aorta. When common iliac lesions are not strictly "orificial," concomitant contralateral stenting is generally not required. Again, careful angiographic assessment should be made to determine the extent of plaque burden present at the origin of the common iliac arteries to make this determination.
- Appropriately sized balloon-expandable stents are advanced within the sheaths and positioned across the respective lesions. The sheaths are then pulled back to expose the entire stent; this sequence prevents accidental dislodgement of the stent off the balloon, attempting to cross the lesion, and limits the risk of plaque embolization during stent passage.
- Once both stents are positioned appropriately, they are inflated simultaneously to achieve the kissing configuration (**FIG 8**).

Fifth Step

- Completion arteriography, typically through a pressure injection in the distal aorta through "side-hole" or flush catheters, is obtained to confirm stent placement, evaluate degree of residual stenosis, and rule out complications such as dissection or thrombus/embolization.
- When pressure measurement are required, pull-back pressures are obtained with the goal of eliminating pressure gradients across the treated lesion at rest or limiting to less than 15 mmHg following injection of a distal vasodilator such as papaverine.

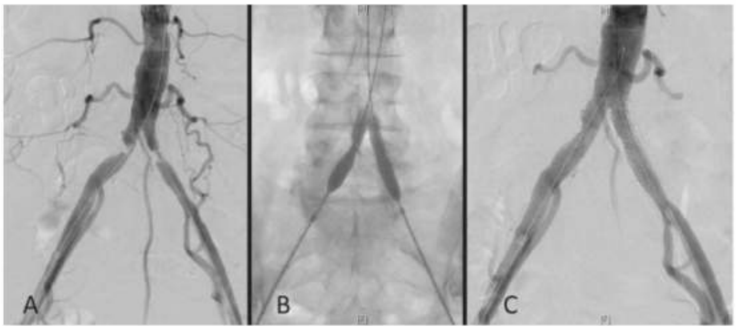

FIG 8 ● Bilateral common iliac artery stenosis treated with kissing stent technique. **A.** Initial aortogram demonstrating high-grade bilateral proximal common iliac stenosis. **B.** Balloon dilation demonstrating waist in balloon at location of stenosis. **C.** Completion aortogram with bilateral kissing iliac stents, raising the aortic bifurcation by a few centimeters.

EXTERNAL ILIAC ARTERY STENTING

First Step

- When the external iliac artery is diseased, particularly the distal segment, self-expanding stents are typically used due to the increased tortuosity of these vessels and the increased flexibility of self-expanding stents as opposed to balloon-expandable stents.
- The same principles exist in terms of sizing, although for self-expanding stents, 10% to 20% oversizing is typically recommended in the respective instructions for use (IFU).

Second Step

- Deployment of self-expanding stents does not require advancement of the introducer sheath past the lesion. The self-expanding stents usually are mounted on a carrier and constrained. The stents should be positioned across the lesion and deployed.
- Close fluoroscopic monitoring should occur during deployment, as self-expanding stents tend to be far less precise in positioning in comparison to balloon-expandable stents and typically may advance across the lesion during deployment.

Third Step

- Predilation and postdilation may be performed as necessary with appropriately sized balloons before and after stent deployment.
- In the setting of very distal external iliac artery disease or incomplete distal external iliac endarterectomy (as described earlier), the distal end of the stent may be carried down to the level of the endarterectomy, again with care to be taken to avoid crossing the inguinal ligament as previously described (**FIG 5**).

Fourth Step

- Just as in common iliac stenting, completion arteriograms should be performed, and pressure gradients may be obtained as necessary to confirm sufficient resolution of the stenosis.

Fifth Step

- Usually, a single-repair stitch can be used to close the patch sheath access site, regardless of the diameter of the sheath used for stent deployment.
- Once hemostasis is achieved, the sheaths removed, and anticoagulation reversed with protamine injection, the femoral exposure should be closed with a multilayer, anatomic closure with absorbable suture.

PEARLS AND PITFALLS

Occluded iliac artery strategies	
Reentry devices	■ When attempting to cross an occluded segment with catheter-guidewire combinations, a subintimal plane may be developed. This subintimal technique is appropriate as long as the true lumen can once again be regained prior to entering the aorta. In some circumstances, this reentry may be challenging. In these situations, reentry devices can be employed. These devices have nitinol cannula that can be advanced through the device and used to puncture into the true lumen; a 0.014-in wire is then advanced. Free passage of the wire indicates true lumen access, which is confirmed by contrast injection. The passage can then be dilated and stented in a conventional manner (**FIG 9**). Care should be taken to attempt reentry before the dissection plane is advanced too far proximally into the distal aorta, as this may compromise the ability to properly deploy balloon-expandable stents and/or compromise inferior mesenteric arterial flow. Similarly, reentry systems should be used with caution in the iliac arterial system to avoid perforation and retroperitoneal bleeding.

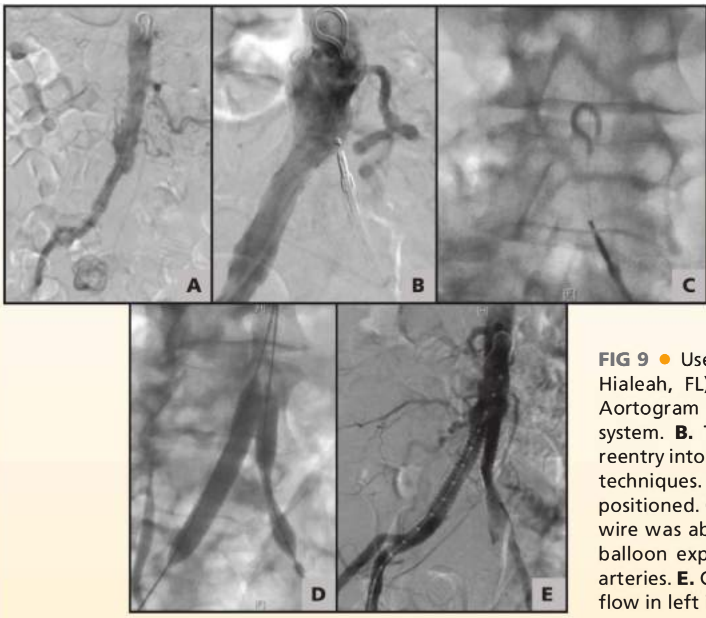

FIG 9 ● Use of an Outback® reentry catheter (Cordis Corporation, Hialeah, FL) in treatment of a chronic total iliac occlusion. **A.** Aortogram showing complete occlusion of the left iliac arterial system. **B.** The majority of the occlusion was crossed; however, reentry into the true aortic lumen was unsuccessful using traditional techniques. The Outback® reentry catheter was advanced and positioned. **C.** After advancement of the reentry needle, a 0.014-in wire was able to be passed into the aorta. **D.** Retrograde kissing balloon expandable stent placement into bilateral common iliac arteries. **E.** Completion aortogram demonstrating reconstitution of flow in left iliac system.

Alternative approach	■ Antegrade approach from either a brachial or contralateral femoral access sometimes provides more "pushability" across recalcitrant lesions and may be more successful at obtaining wire access. This is particularly true when a small invagination is apparent angiographically in the ipsilateral common iliac artery (when totally occluded). Once the occlusion or stenosis is traversed, the wire can be snared from the ipsilateral femoral and an ipsilateral sheath can still be advanced to complete the procedure as previously described from the ipsilateral femoral access. This is generally advisable as compared to attempted stent placement from left brachial access, due to proximity and control issues, as well as the availability of suitably sized stents on long delivery catheters.
Severe calcified disease strategies	■ In patients with significant atherosclerotic burden, care should be taken during the intervention to minimize atheroembolization. Use of covered stent grafts can be considered in these scenarios. Additionally, as an added benefit of the hybrid approach, flushing maneuvers of the patch angioplasty site may be performed to eliminate embolic debris.
Arterial rupture	■ Cover with stent graft. Consider proximal balloon occlusion.
Arterial dissection	■ Extend stent if flow limiting dissection.

POSTOPERATIVE CARE

- Following femoral endarterectomy and iliac stents, patients are usually monitored in the hospital for 1 to 2 days.
- Postoperative antithrombotic management is not well studied in this population; however, most surgeons treat patients with dual antiplatelet therapy such as aspirin and clopidogrel, with a loading dose of clopidogrel followed by a daily dose, for the first 6 weeks following the procedure. Long-term antiplatelet management is usually achieved with acetylsalicylic acid (ASA) alone, except in circumstances of aspirin allergy.
- Routine follow-up with arterial duplex and ABIs is important to monitor for continued patency and potential need for secondary intervention.

OUTCOMES

- Early and long-term results of concomitant common femoral artery endarterectomy and iliac stenting have been excellent. One-year primary patency and primary-assisted patency rates have been reported to be 84% and 97%, respectively.[3] Five-year primary, primary-assisted, and secondary patency rates were 60%, 97%, and 98% in a recent report of 171 patients.[4]
- There is some evidence that covered stent grafts may have improved patency compared to bare metal stents, particularly in TASC C and D lesions.[4,5]
- Iliac artery stenting combined with open femoral endarterectomy also appears to be equally effective as open surgical revascularization. Piazza and colleagues[6] found similar 30-day morbidity and mortality as well as primary patency at 3 years when comparing a 10-year cohort of patients treated in both manners. These similarities were maintained even after stratification for TASC group.

COMPLICATIONS

- Contrast nephropathy
- Wound complications, including infection, dehiscence, seroma formation, and nerve entrapment

- Arterial rupture
- Arterial dissection
- Embolization

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Chapter **27**

Management of the Infected Femoral Graft

Matthew Mell

PATIENT HISTORY AND PHYSICAL FINDINGS

- The symptoms of an infected femoral graft can vary widely, from a chronically draining wound to sepsis and hemodynamic collapse.
- Symptoms may have been present from hours to weeks.
- Physical examination should include inspection of the surgical wounds and graft tunnels for induration, erythema, tenderness, open wounds, aneurysmal degeneration of the graft or anastomosis, or drainage.

IMAGING AND OTHER DIAGNOSTIC STUDIES

- When possible, causative organisms should be identified prior to surgery to aid in choosing appropriate systemic antibiotics and the optimal surgical approach.
- Prior to surgery, detailed imaging with computed tomographic angiography (CTA) can provide critical information for developing a cohesive plan for surgical exploration and graft removal and replacement.
- Computed tomography (CT) can accurately identify anatomic signs of infection, including abscess or anastomotic aneurysm. CT can also provide clues to the extent of infection.
- CTA provides high-resolution imaging of the aorta and runoff vessels, which will aid in determining the options for revascularization, including in situ reconstruction, obturator bypass, or ilioprofunda bypass.
- Radionuclide scans may provide evidence for graft infection when other imaging studies are nondiagnostic.

SURGICAL MANAGEMENT

- Aggressive and wide debridement of devitalized or infected tissue must accompany graft excision and replacement in the setting of infection.
- Partial or complete excision of infected prosthetic grafts is generally required to eliminate the infection.
- Excision of infected autogenous graft infections may be necessary when associated with sepsis caused by *Escherichia coli*, *Pseudomonas*, *Klebsiella*, or *Proteus* spp.
- Graft excision without reconstruction: Infected thrombosed grafts with adequate collateral circulation may require only excision without reconstruction.
- Excision and extraanatomic bypass is preferred with presence of severe sepsis and/or hemorrhage. Examples of extraanatomic bypasses include axillary-to-femoral bypass (**FIG 1**), obturator bypass, or cross-femoral bypass.
- In situ replacement: Low-grade infections without sepsis or invasive infection and those with distal occlusive disease may be best treated with in situ graft replacement.
- Graft replacement material
- Graft material should be considered prior to surgery to ensure availability.
- Potential options for graft material include the following:
  - Autogenous vein (saphenous vein, cephalic vein, basilic vein, superficial femoral vein [SFV])
  - Cryopreserved tissue (aorto-iliac-femoral artery, femoral vein, saphenous vein)
  - Prosthetic graft (rifampin-soaked Dacron™, polytetrafluoroethylene [PTFE])
- Consider the need for wound coverage:
  - Debridement of an infected groin wound may result in a large defect that either cannot be covered or closed. Muscle flaps can provide coverage of healthy well-vascularized tissue to protect the repair.
  - Small to medium defects can be covered with a sartorius muscle flap, which is divided from its attachment to the anterior superior iliac spine and mobilized medially to cover the wound.
  - A pedicled flap from the leg or abdominal wall may be required for larger wounds. These flaps include rectus femoris, rectus abdominis, tensor fasciae latae, or gracilis.

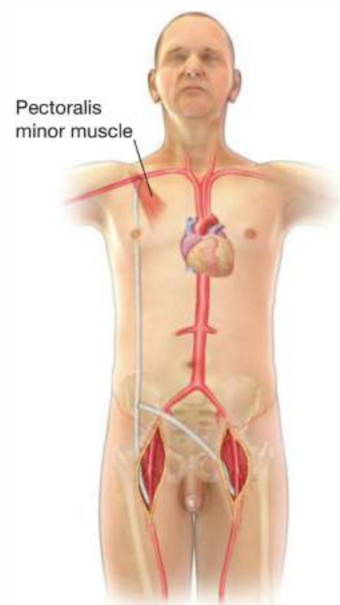

FIG 1 ● Figure 1: Axillo-femoral bypass. Note that the proximal graft is placed behind the pectoralis minor muscle.

GENERAL CONSIDERATIONS

- It is desirable when considering an extraanatomic reconstruction to revascularize before excising the infected graft. This can be accomplished with a bypass and tunnel performed across clean tissue planes. Once the bypass is completed and wounds closed, the groin can be explored and the infected graft removed. With this approach, the continuity between the superficial femoral and deep femoral arteries should be maintained by either oversewing the distal common femoral artery or anastomosing the profunda femoris artery (PFA) to the superficial femoral artery with proximal ligation (**FIG 2**).
- Debridement of the infected site must include removal of infected or necrotic tissue and complete excision of the anastomosis. Dissection may be aided by lack of incorporation of the infected graft but also may prove challenging from extensive scarring in the reoperative field. Sharp dissection techniques are critical to minimizing the risk of inadvertent injury to vessels or adjacent structures.
- It is important to send cultures of the perigraft fluid, tissue, and graft.[1] Instructions should be given to the microbiology lab to perform sonication of the graft to separate biofilm from graft and maximize the bacteriology yield.

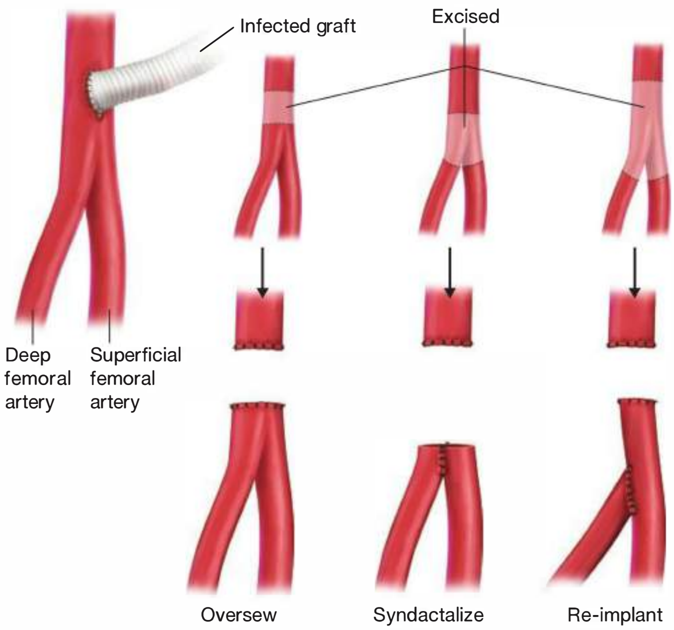

FIG 2 ● Surgical options for maintaining continuity of arterial flow to the profunda femoris artery after obturator bypass and common femoral artery ligation

OBTURATOR BYPASS

- Using the obturator foramen may be a useful approach for bypassing an infected groin through a sterile field.[2] A reinforced PTFE graft is best suited for this technique and can be used if sepsis has been controlled and the bypass can be performed without violating the infected field.
- The proximal anastomosis can be performed to the common iliac artery, external iliac artery (ipsilateral or contralateral), or previous graft if not infected (**FIG 3**). Exposure can be obtained through a standard retroperitoneal incision, by dividing the external and internal oblique and transversus abdominis muscles, identifying the preperitoneal space, and retracting the peritoneum medially with blunt dissection techniques. The obturator foramen is just posterior to the anterior ramus of the pelvis, although it may not be easily palpated due to the overlying obturator membrane.
- Distal anastomosis can be performed to the distal superficial femoral artery, the midportion of the PFA (see the following section, lateral approach to the Lateral Profunda Femoris Artery Exposure), or the popliteal artery. During this dissection, the adductor longus and magnus can be identified with the leg abducted and externally rotated. The tunnel will be placed deep to these muscles, which insert on the external surface of the obturator foramen.

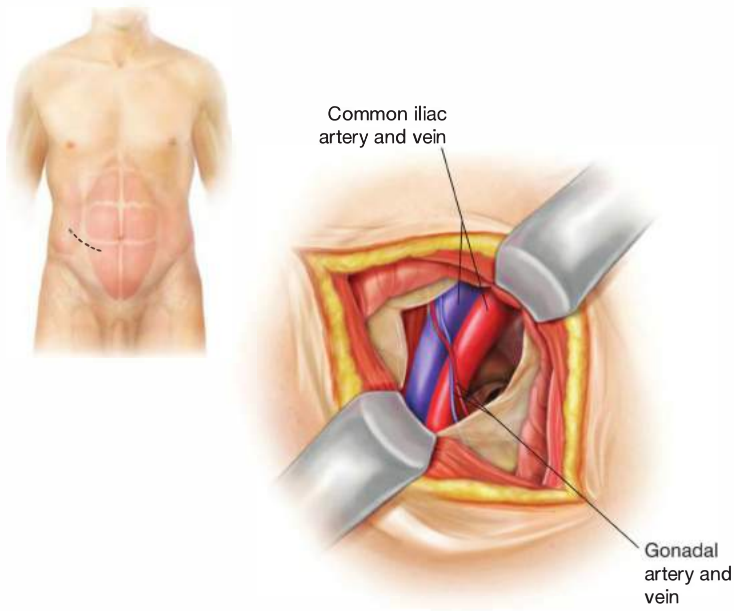

FIG 3 ● Operative incision for retroperitoneal exposure of the iliac artery. Peritoneum and its contents are retracted medially to aid in exposure.

- The tunnel should be performed in a cranial direction with a long aortic clamp or tunneling instrument (**FIG 4**). The instrument is passed deep to the adductor magnus while a hand is placed over the obturator foramen from the retroperitoneal incision. The instrument can be directed through the obturator foramen. The tunnel should be made through the lateral portion of the obturator foramen to avoid the obturator artery and nerve, which traverse anteromedially.
- Once the tunnel is made, the graft can be placed and the bypass performed. Once completed, the incisions should be closed and protected before proceeding with excision of the infected graft.

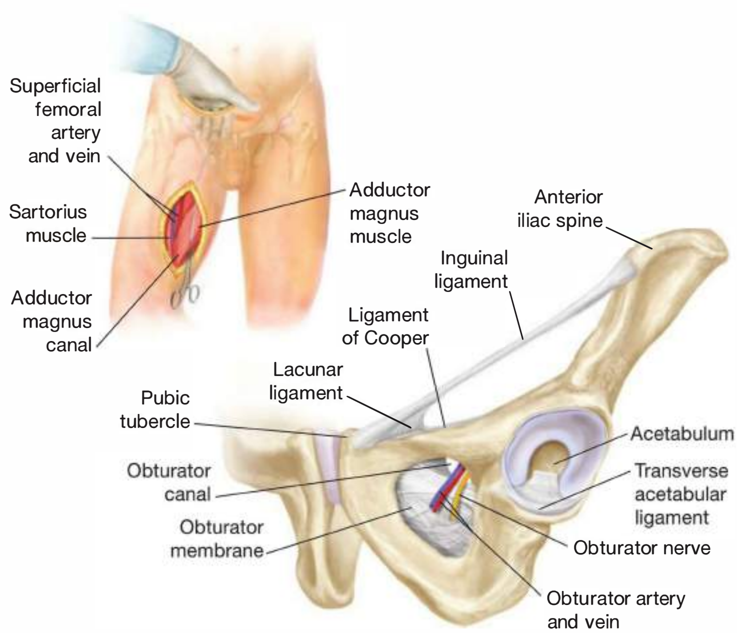

FIG 4 ● Exposure of the superficial femoral artery and tunneling for an obturator bypass. Left: creating the tunnel behind the adductor magnus muscle. Right: placement of the tunnel through the obturator membrane.

LATERAL PROFUNDA FEMORIS ARTERY EXPOSURE

- Another option for remote revascularization is to use the second portion of the PFA, exposed through a lateral incision.[3] This approach may be useful if the superficial femoral artery is occluded and the goal is to establish flow from the axillary artery via a tunnel medial to the anterior iliac spine and lateral to the femoral infection.
- The PFA is exposed through an incision placed along the lateral border of the sartorius muscle 4 to 6 cm below the anterior superior iliac spine (**FIG 5**). The sartorius and superficial femoral vessels can be retracted medially to expose the adductor longus. Its overlying fascia is divided, and with medial retraction, the PFA is exposed.

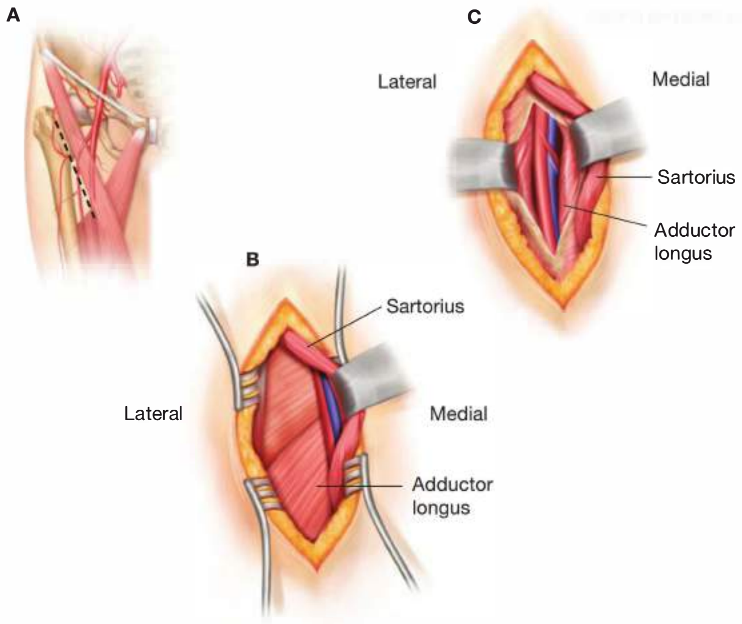

FIG 5 ● Lateral exposure of the profunda femoris artery. **A.** Incision along the lateral border of the sartorius muscle. **B.** Medial retraction of the superficial femoral artery and vein to expose the adductor longus. **C.** Fascial incision and medial retraction of the adductor longus to expose the profunda femoris vessels.

SUPERFICIAL FEMORAL VEIN HARVEST

- SFV can be a suitable graft for reconstruction, with a low incidence of recurrent or uncontrolled infection.[4] Preoperative evaluation should include duplex imaging of the SFV to exclude deep venous thrombosis and to determine the vessel diameter.
- Dissection can be performed through a standard anteromedial leg incision, or placed over the lateral border of the sartorius (**FIG 6**). The vein should be dissected from its confluence with the profunda femoris vein distally to obtain sufficient length for reconstruction. Care should be taken to preserve the profunda femoris vein and the common femoral vein and to stop the dissection at the adductor canal. These limits will preserve important collateral circulation between the profunda femoris and the popliteal vein, which will minimize postoperative leg edema.
- Once harvested, branches of the SFV should be doubly ligated or suture ligated a distance 2 mm from their junction with the SFV to prevent slippage of the ligature once the conduit is pressurized. The SFV can be used in a reversed manner or nonreversed after disrupting the valves.

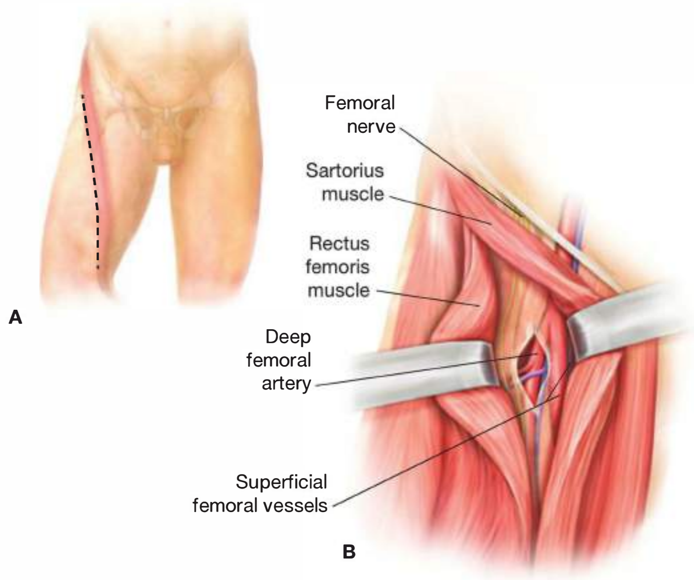

FIG 6 ● Exposure of the superficial femoral vein. **A.** Incision along the sartorius muscle. **B.** medial retraction of the sartorius to expose the superficial femoral vein.

CRYOPRESERVED GRAFTS

- Some studies have shown favorable results for cryopreserved allografts with regard to limb loss, recurrent infection, and survival compared with other in situ replacements.[5]
- When considering an allograft, greater than 24 hours may be required to locate suitable graft material and length if there is no on-site inventory.
- Grafts should be prepared immediately before implantation. The thaw-and-rinse process takes approximately 45 minutes.
- Ligated braches should be tested for hemostasis and suture ligatures placed if necessary. If using an aortoiliac homograft, it is easier to confirm hemostasis if the graft is placed with the lumbar branches facing anterior.
- Graft length should allow for a tension-free anastomosis. When possible, avoid allograft-to-allograft anastomoses.

PEARLS AND PITFALLS

Preoperative considerations	■ When possible, consideration should be made prior to surgery for the best option(s) of graft material, allowing time to obtain it if required. For autogenous vein, preoperative duplex is essential to determine the size and quality of the proposed conduit.
Proximal and distal vessel control	■ When possible, proximal and distal vessel control should be obtained through extension of the original incision or through separate incisions before dissecting the infected vessels. Remote bypass with subsequent removal of infected material may be preferable to in situ repair.
Intraoperative cultures	■ It is important to obtain Gram stain, aerobic, and anaerobic cultures of the perigraft fluid, perigraft tissue, and graft. The yield of the graft will be increased if sonication of the graft is performed in the microbiology lab prior to incubation.
Tunnels	■ Tunnels, when possible, should be placed in sterile fields.
Systemic antibiotic treatment	■ Broad-spectrum antibiotics should be initially considered for patients with severe sepsis. For those without sepsis, blood and wound cultures should be performed prior to starting antibiotics. Initial antibiotics should include coverage for methicillin-resistant *Staphylococcus aureus* (MRSA). After surgery, parenteral antibiotics should be considered for 4–6 weeks, especially for invasive infections or in situ repair.

POSTOPERATIVE CARE

- Antibiotics should be continued for at least 2 to 6 weeks, depending on the type of organism, and should be chosen based on antimicrobial sensitivity when available.
- Patients should be inspected daily for signs of infection, which may include fever, leukocytosis, erythema or drainage from the wound, or wound breakdown. Persistent infection should trigger consideration of wound exploration and re-evaluation of the antibiotic regimen.
- Drains, if placed, should be removed as soon as possible, based on quantity and appearance of fluid. Ongoing purulent drainage or continued fever and leukocytosis may indicate lack of source control, which may require wound exploration and washout.
- Arterial surveillance should be performed prior to discharge to confirm the integrity of the repair and establish a baseline for future surveillance examinations.

COMPLICATIONS

- Bleeding from the wound should raise immediate concerns of arterial disruption from persistent infection leading to tissue destruction. If present, patients should undergo arterial duplex and be considered for reexploration. Under these circumstances, complete evaluation of the arterial reconstruction (even if remote) is advisable as vascular resection and reconstruction may be required. At times, arterial ligation may be the only option for local control of sepsis.
- If not already performed, patients requiring reexploration and debridement for persistent infection will most often benefit from muscle flap coverage of the defect.

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Chapter **28**

Surgical Exposure of the Lower Extremity Arteries

Luke X. Zhan Joseph L. Mills, Sr.

DEFINITION

- Chronic lower extremity ischemia, also known as peripheral artery disease (PAD), is a common condition managed by vascular specialists. The primary etiology is atherosclerosis. Atherosclerotic stenosis or occlusion of the peripheral arterial tree results in arterial insufficiency and end-organ (limb) ischemia. PAD is a major contributor to morbidity, reduced quality of life (QOL), and mortality in an increasing elderly demographic in the Western world.

DIFFERENTIAL DIAGNOSIS

- The challenge for the vascular specialist is to determine whether the nature and severity of presenting symptoms correlate with the degree of chronic arterial insufficiency present or whether alternative etiologies, such as neuropathy, inflammation, infection, lymphatic or venous disease, and repetitive trauma, are more likely responsible. Definitive diagnosis is derived from detailed historic and physical examination findings correlated with appropriately directed noninvasive vascular laboratory and adjunctive imaging studies.

PATIENT HISTORY AND PHYSICAL FINDINGS

- Patients with PAD may present with a spectrum of symptoms ranging in severity from none to varying degrees of claudication to severe or "critical" limb ischemia ("CLI" = ischemic rest pain, ulceration, and gangrene). Pulse palpation is an integral component of the physical examination. Femoral, popliteal, posterior tibial, and dorsal pedal pulses should be noted and graded (0 = absent; 1 = present but diminished; 2 = normal; 3 = enlarged, aneurysmal). Claudication is defined as muscular pain, cramping, aching, or discomfort in the lower limb, reproducibly elicited by exercise and relieved within 10 minutes of cessation. CLI has been traditionally defined as (1) persistent, recurring ischemic rest pain requiring opiate analgesia for more than 2 weeks and (2) ankle systolic pressure less than 50 mmHg or toe systolic pressure less than 30 mmHg (or absent pedal pulse in patients with diabetes).[1] Ischemic rest pain typically is nocturnal, worsens with elevation, and is relieved by dependency. Pedal pulses are absent; dependent rubor, elevation pallor, and calf muscle atrophy are frequent accompaniments. CLI also includes ischemic foot ulceration and gangrene in the setting of ankle systolic pressure less than 50 to 70 mmHg or toe systolic pressure less than 40 mmHg in patients without diabetes (<50 mmHg in diabetics).

SURGICAL MANAGEMENT

Indication

- All patients with PAD require comprehensive medical management and risk factor modification. Revascularization (either open bypass or endovascular intervention) is indicated in patients who remain symptomatic and significantly limited despite adequate risk factor modification, exercise, and medical management. The primary goal of intervention, in patients with lifestyle-limiting claudication, is to improve exercise tolerance and hence QOL. Patients with rest pain, tissue loss, and gangrene are at greater risk for limb loss and cardiovascular mortality (stroke, myocardial infarction) associated with systemic atherosclerosis than those who present with claudication alone. Revascularization in the CLI cohort is focused on wound healing and functional limb salvage as well as symptomatic relief and improvement in QOL.[2,3]

Preoperative Planning: Imaging and Risk Assessment/Mitigation

- The vascular specialist must first determine, given the underlying disease burden, the severity of ischemic and infectious complications as well as the patient's comorbidities, functional status, and anticipated longevity. Once it is decided that revascularization will improve the patient's functional status and QOL, these same variables, in concert with anatomic assessment of the location, extent, and severity of occlusive arterial lesions will determine whether endovascular, open, or hybrid revascularization options are indicated. When bypass is selected as the preferred revascularization option, the goals of preoperative planning involve delineation of diseased arterial segment(s), identification of the most appropriate arterial inflow source, selection of the optimal bypass target for maximal outflow and target bed perfusion, and selection of the best available conduit. In practice, conduit availability is almost always a critical, rate-limiting factor because good quality, autogenous vein conduit is preferred in almost every circumstance.
- Adequate preoperative planning depends on a thorough history and detailed physical examination.
- The delineation of the relevant arterial anatomy on the index limb is facilitated by high quality, noninvasive vascular laboratory studies (ankle–brachial index and toe pressure measurements). These are supplemented by arterial color duplex ultrasound imaging. Arterial duplex is extremely accurate in the assessment of iliofemoral and femoropopliteal arterial occlusive disease but less so for infrageniculate (tibial–peroneal) lesions. Duplex enables differentiation of stenosis from occlusion and determination of lesion length and degree of calcification. Cross-sectional imaging studies such as computed tomography angiography (CTA) or magnetic resonance arteriography (MRA) may add complementary information, but most experienced operators prefer the precision and resolution inherent in catheter-based, intraarterial contrast arteriography for definitive preoperative planning, especially when bypass will be required to distal calf or pedal targets.
- PAD is a coronary artery disease equivalent. Therefore, preoperative risk evaluation for overall cardiovascular-related mortality represents a component of preoperative planning.

In most patients with stable or minimally symptomatic coronary disease, preoperative risk-reduction efforts are best focused on optimizing medical management. Frequently, this includes statin and antiplatelet therapy, β-blockade, and optimization of hypertension management.

- The surgical plan should be tailored to each patient's needs based on extent of disease, conduit availability, and realistic long-term functional potential. Infrainguinal bypass may originate from the common, superficial, or deep femoral artery or the popliteal artery with a bypass target of the popliteal, tibial, or pedal/plantar arteries. The positioning, choice of incisions, and surgical techniques are dictated by type of bypass procedure deemed most appropriate under the circumstances.

- Refer to references 4 through 9 for this section.

FEMORAL VESSEL EXPOSURE

Positioning

- The patient is placed in supine position. A Foley catheter is inserted. Arms may be tucked to facilitate intraoperative prebypass and completion angiography.

Placement of Incision

- The common femoral artery (CFA) is located on a line between the pubic tubercle and anterior iliac spine, two fingerbreadths lateral to pubic tubercle. Palpation of the inguinal ligament and femoral pulse or direct arterial visualization with duplex imaging can localize the CFA bifurcation and guide optimal incision placement. Even when pulseless due to excessive calcification or occlusive disease, the CFA may be localized by reliance on anatomic landmarks and direct palpation, recognized as a firm tubular structure positioned within the femoral sheath.
- The vertical groin incision is most commonly employed to provide optimal access to the entire length of the CFA. This should be created coaxially along the artery itself, continued from the inguinal ligament distally, and aimed at the medial aspect of the knee. The incision can be extended superiorly or inferiorly to increase arterial exposure as necessary to achieve optimal inflow (**FIG 1**, *dashed line A*).
- Alternatively, especially in obese patients with substantial abdominal pannus, a curvilinear incision can be placed 1 cm below and parallel to the inguinal ligament to avoid potential skin maceration and wound complications that may accompany vertical incisions in this situation (**FIG 1**, *dashed line B*). Although the proximal superficial femoral and deep femoral arteries can be exposed via this incision, such a curvilinear or oblique incision limits further distal arterial exposure. It therefore would not be selected if an extensive common and deep femoral artery endarterectomy is anticipated as potentially necessary to optimize inflow.
- The incision is carried sharply through the subcutaneous tissue and superficial fascia.

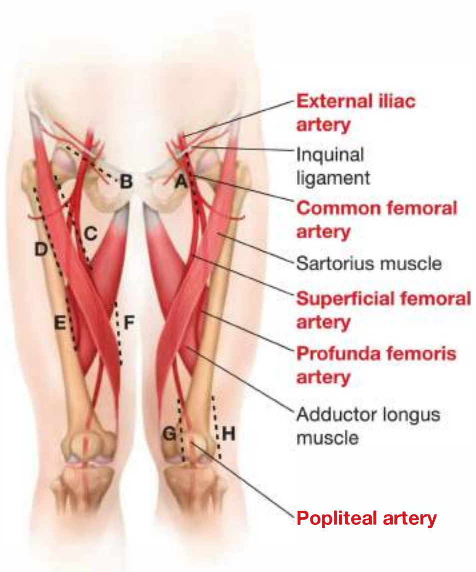


FIG 1 ● Placement of incisions for infrainguinal arterial exposure. Incisions *(A)* and *(B)*: Femoral vessel exposure at proximal thigh. Incisions *(C–F)*: Exposure of mid- and distal superficial and deep femoral arteries. Incisions *(G)* and *(H)*: Lateral and medial exposure of popliteal artery above the knee.

Dissection and Control of the Common, Superficial, and Proximal Deep Femoral Arteries

- Deep to the subcutaneous tissue and superficial fascia, the dissection is extended longitudinally, even when using an oblique incision, to optimize the length of femoral exposure. Depending on the depth of dissection and subcutaneous adiposity, self-retaining Weitlaner or cerebellar retractors are carefully placed to optimize exposure while avoiding traction injury to femoral nerve branches or the common femoral vein. Further dissection through the femoral sheath exposes the anterior surface of the femoral artery.
- The dissection plane should remain centered directly over the femoral artery. Encountering venous structures indicates medial deviation from the optimal plane; exposure of the iliopsoas muscle, femoral nerve fibers, or lymphatic vessels is an indication of lateral deviation. An increasing incidence of femoral incisional complications, including wound edge necrosis and separation, lymphatic leaks, femoral neuropraxia, and venous injuries are associated with incorrectly placed inguinal incisions for femoral exposure.
- Dissect directly along the CFA both proximally and distally. Placement of silastic vessel loops around the

femoral artery and its larger branches aids in retraction, dissection, and mobilization.

- Proximal dissection is continued along the CFA to the inguinal ligament. The inguinal ligament may be divided to aid in exposure or to enable extended endarterectomy. Caution is necessary in this area, as a prominent femoral vein tributary crosses anteriorly over the CFA in this area and is prone to injury if not identified, ligated, and divided early in the dissection. Inadvertent injury to this "vein of pain" produces retraction and troublesome bleeding. The medial and lateral femoral circumflex arteries, important collaterals in iliofemoral arterial occlusive disease, are identified at level of the inguinal ligament and individually controlled with removable clips or silastic vessel loops. Use of the former reduces clutter in the wound during endarterectomy or creation of the proximal anastomosis.
- As the dissection proceeds distally, an abrupt change in caliber marks the femoral bifurcation and the origins of the deep (also known as "profunda femoris" in Latin) and superficial femoral arteries (SFA). The latter continues distally in the same plane; the former usually courses posteriorly and laterally away from the femoral bifurcation. After silastic loops are placed on each vessel, gentle upward traction on the CFA or SFA may help bring the deep femoral artery into view. The lateral circumflex iliac vein may course anteriorly over the origin of the deep femoral artery and should be ligated and divided to optimize exposure and control of the first segment of this vessel (**FIG 2A**).
- Medial and distal dissection provides extended exposure of the proximal SFA (**FIG 1**, *dashed line F*). This vessel only occasionally has small branches in its proximal segment. A sensory branch of the femoral nerve may be present crossing the SFA from lateral to medial. Transection may result in medial thigh discomfort. Even extended femoral bifurcation dissections rarely require division of femoral nerve branches, which should be avoided to minimize postoperative paresthesias and dysesthesias.

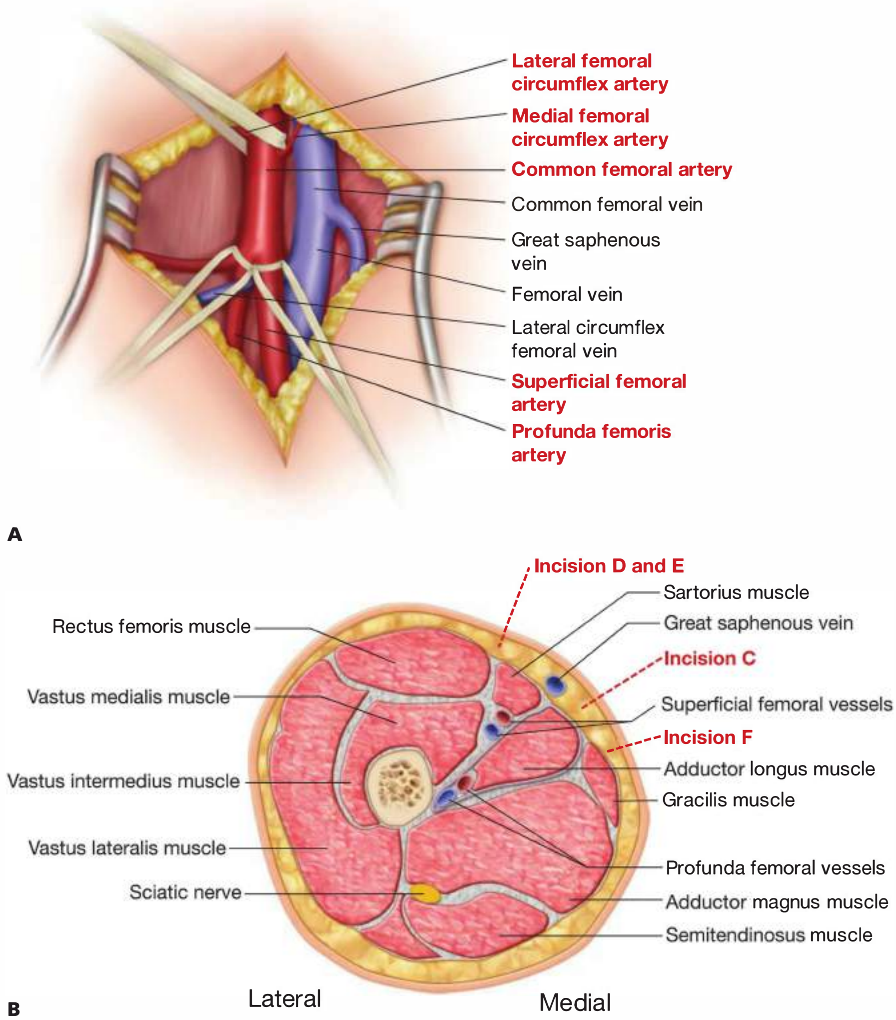


FIG 2 ● **A.** Exposure of femoral vessels at groin. **B.** Anteromedial and posterolateral approaches to expose middle and distal segments of the superficial and deep femoral arteries. Incisions *(C–F)* correspond to **FIG 1**.

Exposure of the Middle and Distal Segments of Deep Femoral Artery

- Exposure of the distal portions of the deep femoral artery often enables use of shorter vein conduit in distal leg bypass or may improve outflow from proximal revascularization procedures (iliac angioplasty and stenting or aortofemoral bypass). These segments are easily exposed from either posteromedial or anteromedial approaches (**FIG 1**, *dashed line C–F*). The approach should be dictated by the indication (inflow sources or outflow target); an additional consideration is the necessity to obtain exposure in a native field, either in the setting of prior dissection or femoral graft infection.
- Incisions are placed along either the medial (anteromedial approach; *dashed line C* and *F* in **FIG 1**) or lateral borders (posterolateral approach) of the sartorius muscle (**FIG 1**, *dashed line D* and *E*). The dissection plane is developed through the subcutaneous tissue and fascia, passing lateral or medial to the sartorius, respectively. Mobilize and retract sartorius muscle laterally or medially, depending on approach.
- The dissection is continued posteriorly, passing lateral to the superficial femoral vessels and accompanying nerve, to the space between the adductor longus muscle (medially) and vastus medialis (laterally) (**FIG 2B**, incisions *C–E*). The deep femoral artery and vein pass directly underneath.
- Dissection between adductor longus and vastus medialis muscle exposes the middle segments of the deep femoral artery. Crossing venous tributaries should be ligated and divided as necessary to provide optimal exposure. The more distal segments of deep femoral artery begin to course posterior to the femur beyond this point and are therefore less useful for bypass origination or destination.
- Alternatively, exposure between the adductor longus (anteriorly) and gracilis muscle (posteromedially) enables medial exposure of the deep femoral artery in the distal thigh (**FIG 1**, *dashed line F*; **FIG 2B**, incision *F*).

POPLITEAL ARTERY EXPOSURE

Medial Exposure of the Above-Knee Popliteal Artery

- Place patient in supine position. Rotate leg laterally, flex the leg, and place a bump underneath the knee joint.
- Place a 10- to 12-cm longitudinal incision along the groove formed between the edges of the vastus medialis (anteriorly) and the sartorius muscles (posteromedially) (*dashed line A* in **FIG 3A**). The incision is carried through the subcutaneous tissue and fascia. Place self-retaining retractor. Take care not to trap and injure the great saphenous vein and the saphenous nerve. The great

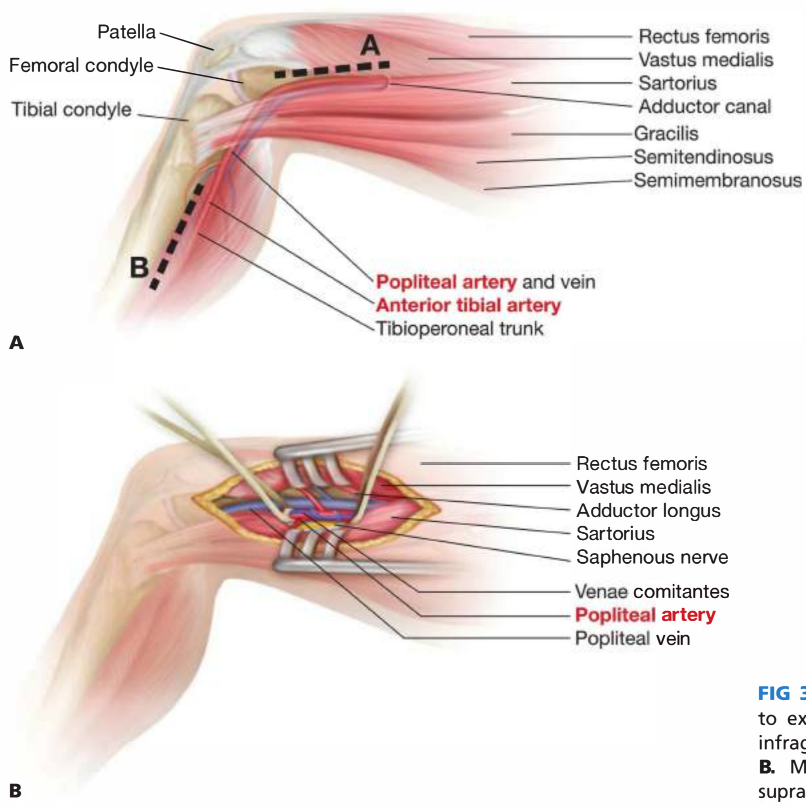
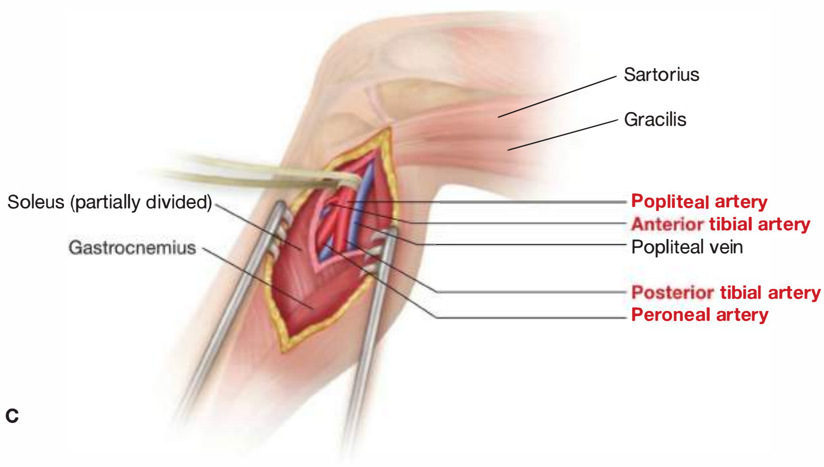


FIG 3 ● **A.** Incisions for medial approaches to exposure of the supra- (incision *A*) and infrageniculate (incision *B*) popliteal artery. **B.** Medial approach for exposure of the suprageniculate popliteal artery. *(continued)*



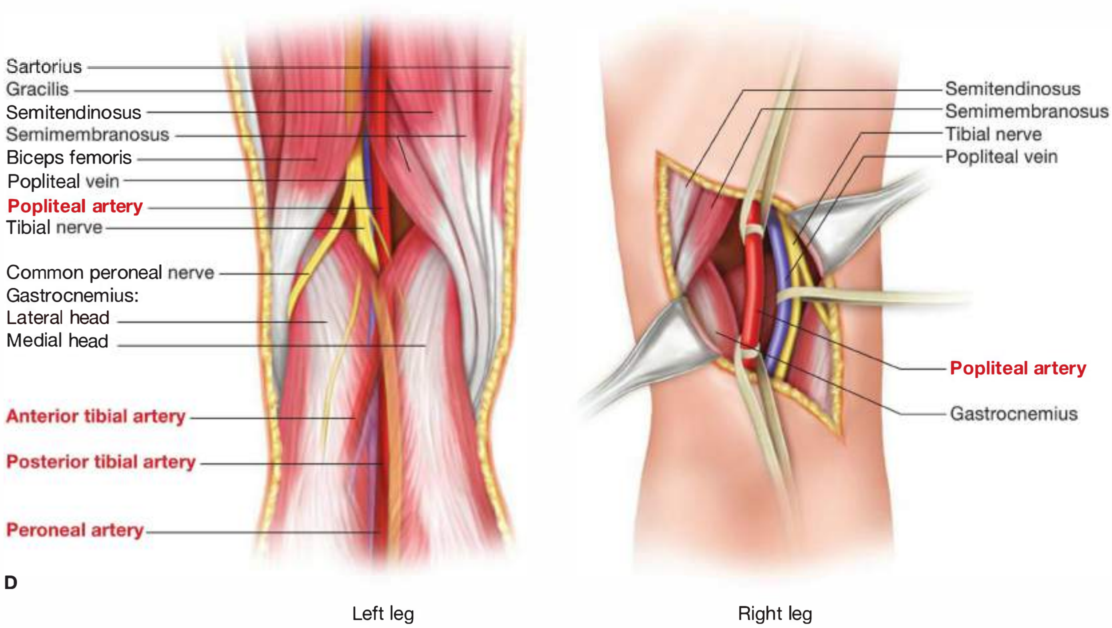


FIG 3 ● *(continued)* **C.** Medial approach for exposure of the infrageniculate popliteal artery and its branches. **D.** Posterior exposure of the popliteal artery.

saphenous vein is likely to be encountered more posteromedially to the incision in the subcutaneous tissue. The saphenous nerve may be encountered at distal end of the incision as it joins the saphenous vein near the medial aspect of the knee.

- Incise the deep fascia longitudinally and above the sartorius muscle to enter the popliteal fossa. The popliteal artery can be palpated up against the posterior surface of the femur (FIG 3B).
- The popliteal artery is often surrounded by multiple venous collaterals, or "venae comitantes" in Latin; the popliteal vein is usually posterolateral to the artery in this location. The popliteal and/or superficial femoral veins may be duplicated throughout the popliteal fossa and distal thigh. Isolation and control of the artery usually requires ligation and division of surrounding collateral veins.

Lateral Exposure of the Above-Knee Popliteal Artery

- Lateral exposure of the above-knee (AK) popliteal artery is useful in a variety of circumstances—for instance, axillopopliteal bypass or when the medial approach has previously been developed or is complicated by infection or injury.
- Place patient in supine position. Rotate leg medially, flex the knee, and place a bump underneath the knee joint.
- Place 10- to 12-cm longitudinal incision between the vastus lateralis and the biceps femoris muscles (*dashed line A* in FIG 4A). The incision is carried through the subcutaneous tissue and fascia.
- Make a generously cruciate incision ("T-ed") at both ends on the fascia lata to prevent bypass graft impingement by its dense fibers.
- Place retractor and enter the popliteal space. Sciatic nerve then popliteal vein will be encountered first before

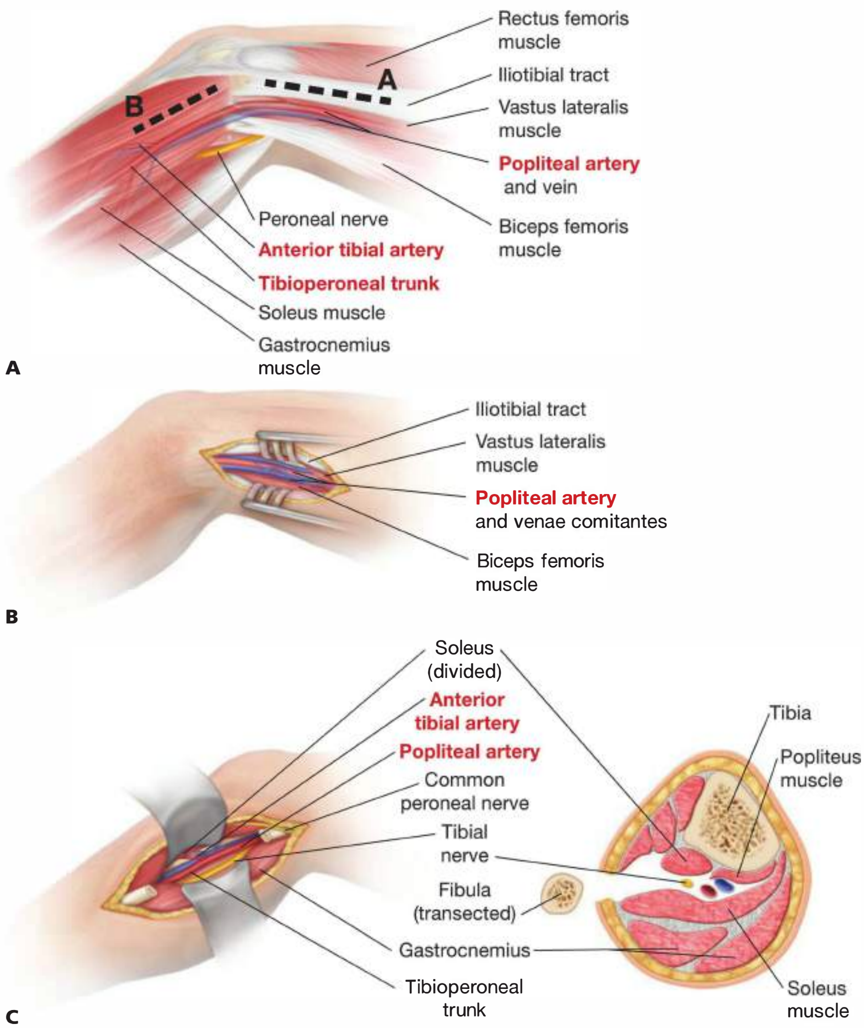


FIG 4 ● **A.** Incisions for lateral exposure of supra- and infrageniculate popliteal artery and its trifurcation. **B.** Lateral exposure of suprageniculate popliteal artery. **C.** Lateral exposure of infrageniculate popliteal artery and its trifurcation.

popliteal artery. Gently retract sciatic nerve downward. Then mobilize and retract popliteal vein to expose and control the popliteal artery.

Posterior Exposure of the Popliteal Vessels

- Posterior exposure may be the preferred approach for management of popliteal artery entrapment, popliteal cyst, focal popliteal artery aneurysm, or arterial injury following traumatic posterior knee dislocation. Although direct and relatively uncomplicated, posterior access is limited by the heads of the gastrocnemius muscle distally and the biceps femoris/"hamstring" muscles proximally; only focal, limited popliteal artery access is achievable through this incision.
- Patient is placed in prone position with pillow to prop up the lower leg and foot.
- The incision is S-shaped, across the posterior crease of the knee joint, with its superior extent beginning medially.
- The incision is carried anteriorly through the subcutaneous tissue and superficial fascia to enter the popliteal fossa. Exposure is maximized by mobilizing the popliteal artery between the two heads of the gastrocnemius muscle inferiorly and between semimembranosus and biceps femoris muscle superiorly.
- The muscles are gently retracted to expose the entire popliteal fossa. The tibial and common peroneal nerves are encountered superficially in this exposure. The popliteal artery is anterior, or deep to the vein, in the depths of the wound.
- It may be necessary to mobilize the popliteal vein with ligation and division of popliteal venous tributaries to fully expose the artery. Once the appropriate segment is exposed, silastic vessel loops are placed proximally and distally.

INFRAGENICULAR EXPOSURE

Medial Exposure of the Infragenicular Popliteal Artery and Its Branches

- The most common approach is a medial one (FIG 3A).
- Place patient in supine position. Rotate leg laterally, flex the leg, and place a bump underneath the knee joint.
- Make a longitudinal incision from below the edge of the tibia along the course of the great saphenous vein (*dashed line B* in FIG 3A).
- Carry the incision through subcutaneous tissue and fascia into the deep posterior compartment. The below-knee (BK) popliteal vessels reside deep in the wound and are partially covered by the origin of the soleus muscle.
- Division of the soleus origin medially (FIG 3C) will facilitate exposure of the tibioperoneal trunk, and origin of the anterior tibial artery, but is not really necessary for exposure of the popliteal artery itself. As was described for the posterior approach, the artery lies in close proximity to the popliteal vein and tibial nerve. Mobilization of the popliteal vein from the adjacent artery is necessary for sufficient exposure of all relevant structures, including the anterior tibial artery, tibioperoneal trunk, and derivative branches (posterior tibial and peroneal arteries). It is usually necessary to ligate and divide the anterior tibial vein at its confluence with the (often paired) popliteal vein to gain sufficient exposure to isolate and mobilize the more distal branches.
- Dissection must proceed deliberately to avoid injury to the neighboring tibial nerve and its distal branches.

Lateral Exposure of the Infragenicular Popliteal Artery and Its Trifurcation

- The lateral approach is rarely required but may be particularly useful to avoid scarring from a previous medial approach.
- Place the incision posterior to the head of the fibula and extend along the course of the fibula. Dissect directly onto fibula (incision is marked as *dashed line B* in FIG 4A). Note the location of the common peroneal nerve, which courses from posterior to anterior around the neck of the upper fibula just below its head, before it branches into the superficial and deep peroneal nerves.
- Circumferentially elevate the periosteum of the fibula and excise the exposed segment of the fibula with a saw. The popliteal vessels and branches are found directly beneath the fibular periosteum, with the artery usually located anterior to the posterior tibial nerve and the popliteal vein.
- Extending the dissection distally allows exposure and control of distal popliteal artery, as well as the origins of the anterior tibial and the tibioperoneal trunk.

Exposure of the Anterior Tibial Artery

- **Proximal segment**
  - The proximal segment of the anterior tibial artery is exposed in a fashion similar to the exposure for the infragenicular popliteal artery and its branches.
- **Middle segment**
  - The middle segment exposure of the anterior tibial artery is useful when there is limited length of autogenous vein.

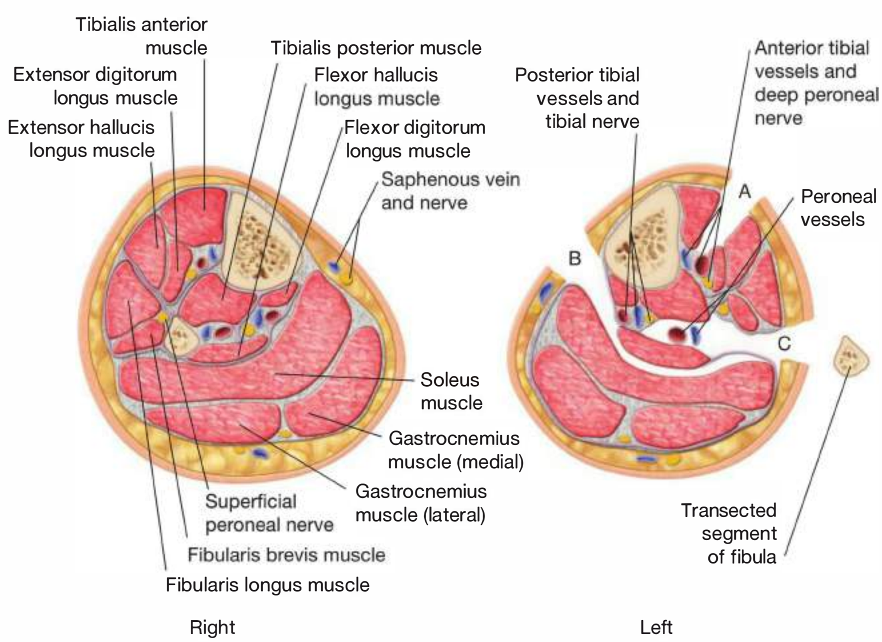


FIG 5 ● Exposure of anterior tibial, posterior tibial, and peroneal arteries at mid-lower leg.

- Place an axial incision in a vertical plane about two fingerbreadths lateral to the anterior edge of the tibia (**FIG 5A**).
- Deepen the incision between the tibialis anterior and the extensor hallucis longus muscles.
- The anterior tibial artery is superficial to the interosseus membrane between the cleft formed by these two muscles.
- Dissecting away the overlying collateral veins allows exposure and control of the middle segment of the anterior tibial artery. Use of a proximal sterile tourniquet during exposure of all the crural arteries may significantly accelerate the dissection while limiting bleeding from the numerous and redundant collateral veins.

Exposure of the Posterior Tibial Artery

- **Proximal segment**
  - The proximal segment of the posterior tibial artery is approached in a similar fashion to the exposure for the infragenicular popliteal artery and its branches and requires taking down the soleus muscle from the tibia.
- **Middle segment**
  - The middle segment exposure of the posterior tibial artery is useful when there is limited length of vein graft to bypass to the posterior tibial artery.
  - Incision is made just anterior to the soleus muscle. Divide the overlying soleus to expose the underlying vessels (**FIG 5B**).
  - The posterior tibial artery lies anterior to soleus muscle with the peroneal artery located laterally, in the same plane, between the soleus and tibialis posterior muscles.
  - Avoid injury to the tibial nerve, which commonly runs between the posterior tibial and peroneal vessels.

Exposure of the Peroneal Artery

- **Proximal and middle segments**
  - Exposure of the proximal segment of the peroneal tibial artery is via distal extension of the infragenicular popliteal artery approach.
- **Middle segment**
  - The middle segment may also be approached anterolaterally. The following description relates to lateral exposure requiring fibulectomy.
  - Place a vertical incision over the fibula at the desired level (**FIG 5C**).
  - Carry down the incision through the overlying muscle down to the fibula. Elevate the periosteum of the fibula circumferentially.
  - Transect the overlying segment of fibula. Incise the inner periosteal membrane. The peroneal vessels are found immediately beneath. The artery usually is anterior to flexor hallucis longus and posterior to the tibialis posterior muscles.
  - The peroneal artery is exposed and controlled after mobilization from circumferential collateral veins and the main peroneal vein.

EXPOSURE OF PEDAL VESSELS

Exposure of the Inframalleolar Posterior Tibial Artery

- Distal posterior tibial exposure enables pedal bypass at or below the ankle, which may be especially useful in patients with advanced diabetes.
- Make a longitudinal incision through skin and fascia at the midpoint between the medial malleolus and the Achilles tendon. If this exposure is used for an in situ bypass procedure, the incision should be sighted slightly more anteriorly to accommodate the anterior course of the great saphenous vein as it crosses the medial malleolus.
- Identify and divide the flexor retinaculum as needed to provide optimal exposure. The posterior tibial vessels are located between the flexor digitorum longus and flexor hallucis longus muscles/tendons.
- Place a small Weitlaner self-retaining retractor. The neurovascular bundle is usually enveloped by fatty tissue below the fascia.
- Dissection proceeds along the neurovascular bundle. The posterior tibial artery is usually anterior to the tibial nerve. There is typically a rich network of venous collaterals present. These may either be mobilized or (more commonly) divided to facilitate distal posterior tibial artery exposure.
- When more distal bypass targets are needed (e.g., prohibitive burden of disease in the posterior tibial artery itself), the dissection may be continued along the posterior tibial artery distally to the bifurcation of the medial and lateral plantar arteries. In all such cases, however, preoperative imaging is paramount to immediate and long-term surgical success, and only in rare circumstances should the operative plan be changed by unexpected findings at the time of surgery. The presence of luminal calcification alone, without substantial compromise to the target lumen diameter, is not a contraindication to bypass construction. When uncertainty is present regarding the optimal bypass target despite adequate preoperative imaging, consideration should be given to on-table, intraoperative arteriography to guide surgical decision making and confirm outcome. To this end, we perform all open bypass procedures in a hybrid operating room environment with high-quality imaging capabilities to ensure the optimal outcome of all procedures, regardless of the initial operative plan.

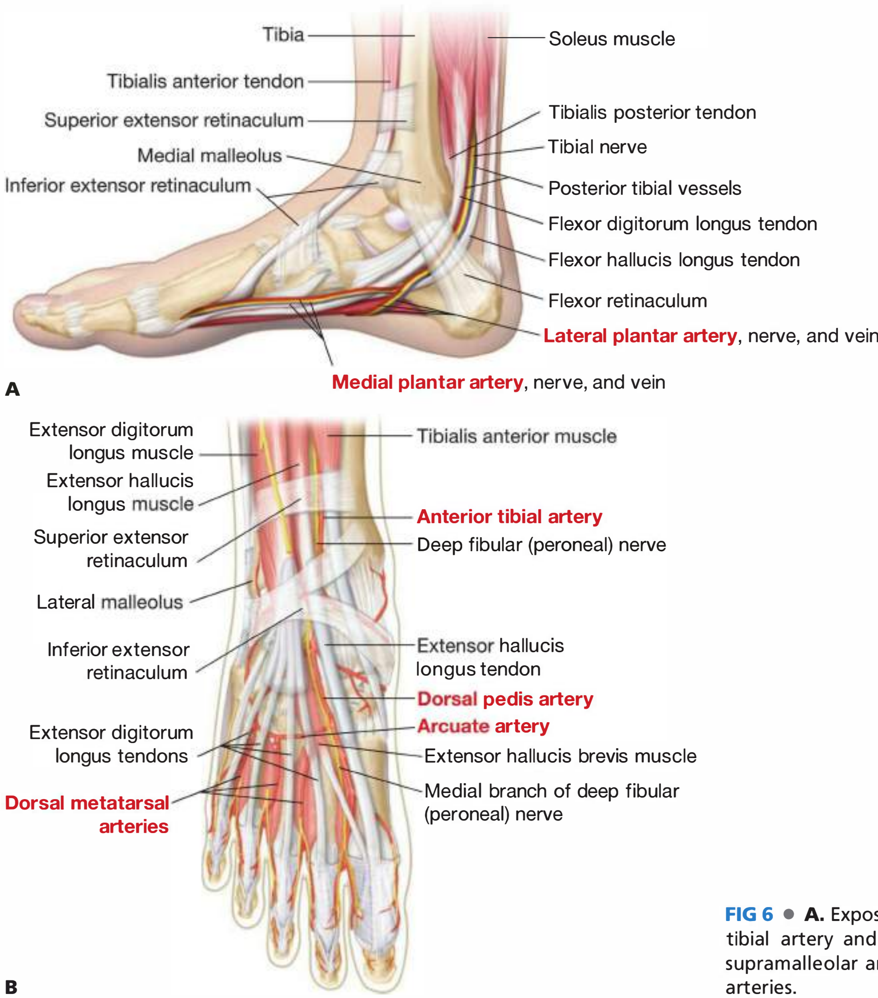


FIG 6 ● **A.** Exposure of inframalleolar posterior tibial artery and its branches. **B.** Exposure of supramalleolar anterior tibial and dorsal pedal arteries.

Exposure of the Supramalleolar Anterior Tibial Artery

- The distal anterior tibial artery may serve as a suitable distal bypass target, especially when substantial disease is present more proximally. It may also be preferable to bypass to this segment in the presence of a dorsal foot wound.
- The incision is placed between the tibialis anterior medially and extensor hallucis longus and the extensor digitorum longus laterally (FIG 6B).
- Anterior tibial artery and peroneal nerve usually course through the groove between them.
- Dissect between these tendons and retract them to expose the supramalleolar segment of anterior tibial artery.

Exposure of the Dorsal Pedal Artery

- The dorsal pedal artery (or "dorsalis pedis" in Latin) is the extension of the anterior tibial artery as it passes beneath the extensor retinaculum. It can serve as a suitable distal bypass target, especially in patients with diabetes.
- The artery is best exposed beyond the inferior extensor retinaculum. Place an incision between the 1st and 2nd metatarsal shafts and distal to the extensor retinaculum (FIG 6B).
- The dorsalis pedis artery resides in the groove between the 1st and 2nd metatarsal heads, usually just lateral to the extensor hallucis longus tendon, which is readily identified by dorsiflexion of the great toe, and medial to extensor hallucis brevis.
- Carry down dissection through subcutaneous tissue and longitudinally divide the fascia to expose and control the artery.

PEARLS AND PITFALLS

- Preoperative ultrasound duplex mapping aids the selection and placement of the incision. Dissection can be guided by palpation of the underlying arterial pulse. In most cases, because distal pulses are frequently absent or difficult to palpate, use of an intraoperative Doppler probe will aid the localization and dissection of vessel. Nonetheless, knowledge of appropriate anatomic landmarks will greatly facilitate careful and expeditious exposure. In all circumstances, dissection should be directly targeted on and around the artery. This guidance is similar in many ways to the orthopedic axiom to "stay on the bone" during dissection—keeping exposure centered on the target artery minimizes venous bleeding and damage to surrounding structures. Placement of an encircling silastic vessel loop will aid in further mobilization.
- In the exposures of the thigh arteries, the sartorius muscle serves as an important landmark for the exposure of the common, superficial, and profunda femoral arteries.
- In the setting of reoperation, alternative surgical exposures allow operation in a virgin field that is unscarred by previous operation.

COMPLICATIONS

- Bleeding complication: Aim to achieve satisfactory hemostasis for surgical bleeding prior to skin closure. Full anticoagulation from heparin can be reversed with protamine to reduce the risk of postoperative bleeding.
- Vessel injury: Vascular clamps or silastic loops can lift atherosclerotic plaques and create dissection and arterial injury in the presence of arterial calcification. The vascular clamp should be placed at a relatively soft, disease-free segment. Occasionally, this requires lateral positioning of a clamp to provide anterior/posterior rather than lateral compression of a vessel. In the CFA, the accumulation of significant posterior plaque often mandates modification of "atraumatic" clamp placement. In the tibial vessels, care should be taken to obtain control in the least traumatic fashion possible to limit compression of inelastic runoff vessels and the potential for clamp injury and restenosis. Often, alternative devices such as "flow arresters" or intraarterial no. 2 embolectomy catheters attached to stopcocks may provide sufficient control to maintain a hemostatic field during completion of the distal anastomosis without exerting undue force on the target artery. In any extent, pressure is reduced to begin with in distal tibial arteries, so the amount of force exerted to obtain control should be modified accordingly. As previously mentioned, strategic use of proximal thigh tourniquets and Esmarch bandage, deployed following creation of the proximal anastomosis and graft tunneling, may also be useful in limiting bleeding and the risk of clamp injury and dissection in diseased tibial vessels.
- Distal embolization: Most frequently, periprocedural embolization is due to fragmentation of atherosclerotic plaque fragments or thrombus during dissection or clamping. Full systemic anticoagulation with intravenous (IV) heparin prior to clamping the vessel and intraoperative monitoring of active coagulation time (ACT) will minimize the risk of graft or native vessel thrombosis. Prior to closure of arteriotomy and clamp release, all involved arteries must be meticulously and repeatedly flushed and back-bled to remove residual thrombus or loosen plaque fragments. Attention to this portion of the procedure, as well as to the precise course of graft tunneling, will optimize outcome and eliminate the need for reanticoagulation, embolectomy, and revision at the end of an often long procedure.
- Nerve injury: Nerves and vessels are often intimately associated. Nerve injury can be caused by dissection, a poorly placed retractor, injudicious spreading and clamp placement, and thermal energy from the electrocautery. These injuries can be reduced by knowledge of appropriate anatomic landmarks, accurate incision placement, and meticulous sharp dissection directly down to and immediately around the intended artery. Importantly, excessively deep placement of self-retaining retractors in an extended common or deep femoral artery exposure can cause traction injuries to motor branches of the femoral nerve, significantly limiting the ability of patients to stand or bear weight for weeks following the procedure. In general, to avoid nerve injury, retractors should be placed in the most superficial plane possible to obtain sufficient exposure of target vessels. In all circumstances, retractors should be removed immediately as soon as they are no longer needed or if attention is turned to alternative sites or other portions of the procedure that do not require continuous exposure.
- Lymphatic leakage: Lymphatic vessels usually course close to the arteries and veins. Avoid transection of lymph nodes. If necessary, cauterize the divided end of lymphatics. Visible lymphatic vessels should be suture ligated. Careful dissection respecting tissue planes allows layered closure to eliminate dead space and lymphatic accumulation, formation of seroma, or hematoma. When lymph nodes are injured, extra time should be taken to control, ligate, and divide afferent and efferent vessels and remove the node completely.

POSTOPERATIVE CARE

- Following bypass, patients should be maintained on a comprehensive medical regimen to optimize their cardiopulmonary status. Lower extremity bypass operations are often performed on patients with diabetes and debilitating symptoms of claudication or CLI. Postoperative care should also aim to optimize nutritional status, functional status, and control of blood sugar level.
- Most surgeons routinely employ routine antiplatelet and selective anticoagulation therapy to improve graft patency in lower extremity bypass patients. The Dutch Bypass Oral Anticoagulants or Aspirin (BOA) trial suggested that oral anticoagulation improved vein graft patency compared with aspirin, whereas aspirin improved prosthetic graft patency compared with anticoagulation. The antiplatelet and/or anticoagulation regimen must be tailored to individual patient with lower extremity bypass considering their risk for graft failure and risk of bleeding. We routinely

administer aspirin to bypass patients and reserve warfarin for high-risk situations (redo bypass, marginal or alternative vein conduits, spliced vein grafts, poor outflow, prior graft thrombosis) due to the increased bleeding risk associated with anticoagulation.

- Wound care: Considerable efforts on wound care are required to achieve wound healing after lower extremity revascularization in patients with CLI with tissue loss. Meticulous nursing care and early ambulation are also crucial to prevent decubitus ulcer in the lower extremities and the sacrum, creating new wounds in patients with lower extremity ischemia.

OUTCOMES

- Outcomes of revascularization should be reported and interpreted through the reporting standards created and updated by the Society for Vascular Surgery.
- In general, autogenous vein conduits are superior to all others for infrainguinal bypass, even for the AK popliteal insertion site, where vein has proven superior to polytetrafluoroethylene (PTFE) beyond 2 to 3 years. Ipsilateral and contralateral greater saphenous vein (GSV) conduits exhibit patency rates superior to alternative veins such as small saphenous vein, arm vein, and spliced veins. Vein graft primary patency rates for femoral BK popliteal bypasses are approximately 70% to 75% at 5 years, and assisted primary patency can be improved even further by a duplex vein graft surveillance protocol. Infrapopliteal vein graft primary patency rates range from 60% to 70% at 5 years. Multiple randomized trials have shown no benefit of reversed versus in situ vein configurations. PTFE grafts have acceptable short- and intermediate-term patency rates only in the AK popliteal position and therefore should only be used in limb salvage situations if autologous vein is truly unavailable. When PTFE must be used, an adjunctive venous Miller cuff or Taylor patch may improve results. The primary factors influencing graft patency are indication, conduit type, and conduit quality. Poor runoff adversely impacts prosthetic graft patency.
- The reader is further referred to standard textbook sources such as Cronenwett et al.'s *Rutherford's Vascular Surgery*, 7th edition, Chapter 109 for a more detailed discussion of the expected outcomes after surgical revascularization for infrainguinal disease.

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Chapter **29**

Percutaneous Femoral–Popliteal Reconstruction Techniques: Reentry Devices

Danielle E. Cafasso *Peter A. Schneider*

DEFINITION

- Reentry devices facilitate true lumen reentry after subintimal recanalization for endovascular treatment of complex lesion morphologies and occlusions in the femoral–popliteal segment.
- Subintimal recanalization and reconstruction of the femoral and popliteal arteries have diminished reliance upon femoral–popliteal bypass. Reentry into the true lumen can be challenging and is often the rate-limiting factor for the success of this procedure. Improved wires and support catheters, and also reentry devices, have been developed for crossing chronic total occlusions (CTOs).
- Tools for managing CTOs are listed in Table 1. CTO support catheters may be used to support the guidewire that is being used to cross the occlusion. These typically have lubricious surface and a stiff tip. Distal access may be used to recanalize infrainguinal occlusions from a retrograde direction. Reentry catheters may be used to reenter the true lumen. CTO crossing catheters are not discussed in the chapter. These are relatively new and use either mechanized or hand power to manipulate through an occlusion in hopes of remaining in the true lumen.
- Planning and performing subintimal recanalization and reentry into the true lumen of the femoral and popliteal arteries are described herein.

Table 1: Tools for Managing Chronic Total Occlusions in the Lower Extremity

Tool for Managing CTO	Purpose	Examples
CTO support catheters	Support during wire crossing	CXI™ (Cook Medical) Quick-Cross™ (Spectranetics) TrailBlazer (Covidien) Gopher (Vascular Solutions)
Distal access	Access for bidirectional approach	Retrograde puncture of SFA–popliteal Tibial–pedal
Reentry catheters	Enter true lumen from subintimal space	Outback™ (Cordis) Pioneer™ (Medtronic) Enteer (Covidien) OffRoad (Boston Scientific)
CTO crossing devices	True lumen crossing	Crosser (Bard) Frontrunner (Cordis) Laser (Spectranetics) TruePath (Boston Scientific) Wildcat (Avinger) Viance (Covidien)

CTO, chronic total occlusion; SFA, superficial femoral artery.

PATIENT HISTORY AND PHYSICAL FINDINGS

- Patients with clinical symptoms and signs of lower extremity ischemia may benefit from subintimal recanalization and the use of reentry techniques in the course of their clinical care.
- Patients present with claudication, rest pain, nonhealing ischemic ulcers, or gangrene. The history and physical examination is consistent with these lower extremity presentations and is described elsewhere in this atlas.

IMAGING AND OTHER DIAGNOSTIC STUDIES

- Patients who might benefit from subintimal recanalization and reentry typically have complex lesion morphology, such as arterial occlusion, that may be managed by creating a new channel outside of the potential space offered by the subintimal area. Imaging studies that define the anatomy and lesion morphology are useful prior to revascularization. This may include duplex scanning, magnetic resonance angiography, or computerized tomographic angiography. We usually perform duplex mapping prior to any lower extremity intervention. Long lesions, occlusions, and complex lesions are typically identifiable with preoperative imaging.
- Patients with lower extremity ischemia should have objective physiologic confirmation of the degree to which perfusion is diminished. This may be accomplished by ankle–brachial indices or toe pressures.

SURGICAL MANAGEMENT

Preoperative Planning

- Preoperative planning includes identifying the best access site for arterial entry. Subintimal recanalization of the femoral–popliteal segment may be performed using an up and over approach, from the contralateral common femoral artery, or using an antegrade approach from the ipsilateral common femoral artery. A reentry catheter may be used through either of these access choices. Preoperative noninvasive imaging is very helpful in making this plan for approach.
- The location of lesion helps determine access site and approach. Many patients with superficial femoral artery (SFA) and/or popliteal artery disease are treated with an up and over approach. If the patient has inflow iliac artery disease or has an SFA lesion that begins near the origin of the SFA, an up and over approach is warranted. Reentry devices require placement of a 6-Fr sheath. If an up and over approach is anticipated, the aortic bifurcation should also be assessed to make sure that the reentry device can be passed.
- Patients with extensive disease below the knee and without iliac or proximal SFA disease and who are not obese can be treated using an antegrade approach.

RECANALIZATION STRATEGY

- In managing complex lesions of the femoral and popliteal arteries, it is quite common to attempt to recanalize the true lumen. Stenosis can almost always be crossed transluminally using a wire supported by a catheter. A steerable, hydrophilic, low-profile wire is best. Long lesions, especially if occluded, may not be possible to cross in the true lumen. In this case, subintimal recanalization and reentry is the best option.
- Strategy is based on selection of a reentry site where the artery has an acceptable lumen, collaterals can be preserved, calcification is avoided, and potential bypass sites remain intact. Staying in the true lumen when possible offers the shortest reconstruction and preservation of most collaterals. When subintimal passage is required, reenter the true lumen as close to the distal reconstitution as possible. The most common method of subintimal recanalization is using a loop of hydrophilic wire to dissect the subintimal space and the loop can also be used to reenter the true lumen.
- There is typically a large incoming collateral feeding the reconstituted segment. If the reentry site is calcified, the success rate for loop passage is lower and use of a reentry catheter is more likely to be indicated.
- If there is a substantial plaque at the intended reentry site, consider a site more distal than the initial reconstitution site. If there is another lesion distal to but near the reentry site, this can pose a challenge for passing the guidewire distally after it has popped into the true lumen.
- The operator must decide in this case whether it would be appropriate to reenter distal to all the lesions, given that it might negatively affect bypass options. If the reentry fails and the patient needs a bypass, target sites for distal anastomosis should be anticipated, although failed reentry usually does not result in thrombosis of that segment.

TREATMENT PLATFORM

Sheath Placement

- Place sheath tip close to the origin of the occlusion. Contrast administered through sheath fills the distal reconstitution site through collaterals. For an SFA occlusion, the tip of the sheath is usually positioned near the femoral bifurcation and the distal artery is visualized with contrast flowing through profunda collaterals. Use a sheath that is one size larger than that used for angioplasty and stenting, usually 7 Fr. This permits contrast administration even if a reentry device is being positioned (FIG 1).

Entering the Subintimal Space

- Place an angled tip catheter pointing toward the artery wall at the origin of the occlusion. Point it opposite the location where the largest runoff collateral is located. Advance a Glidewire™ into the wall. Push it and the tip will catch and a loop will form (FIG 2).

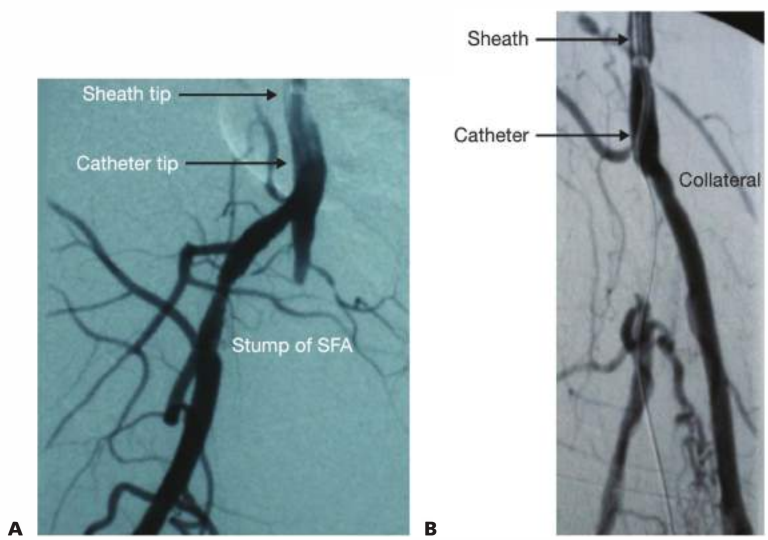


FIG 1 ● Sheath placement. **A.** There is a stump of proximal SFA that is patent. The sheath was placed up and over the aortic bifurcation. The tip of the sheath is in the common femoral artery and can be recognized by a radiopaque tip. The catheter is used to direct the guidewire into the blind sac of the occluded proximal SFA. **B.** This arteriogram shows a short popliteal artery occlusion. The tip of the sheath is placed directly into the proximal popliteal artery to support the recanalization. There is a large perigenicular collateral that originates from the popliteal artery at the location where the artery occludes. Typically, the subintimal space is entered by directing the catheter tip and the guidewire to the arterial wall on the side opposite the origin of the large collateral.

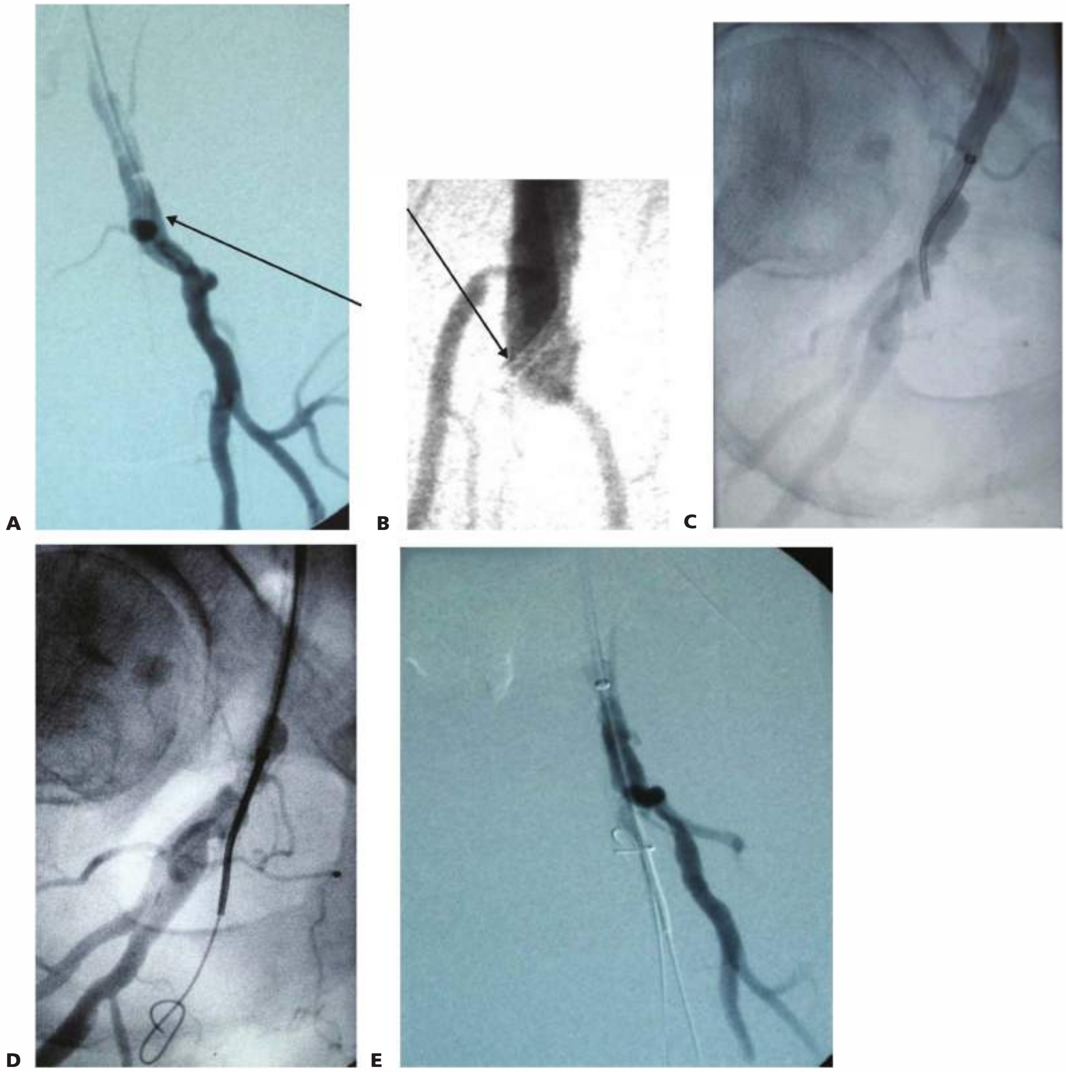
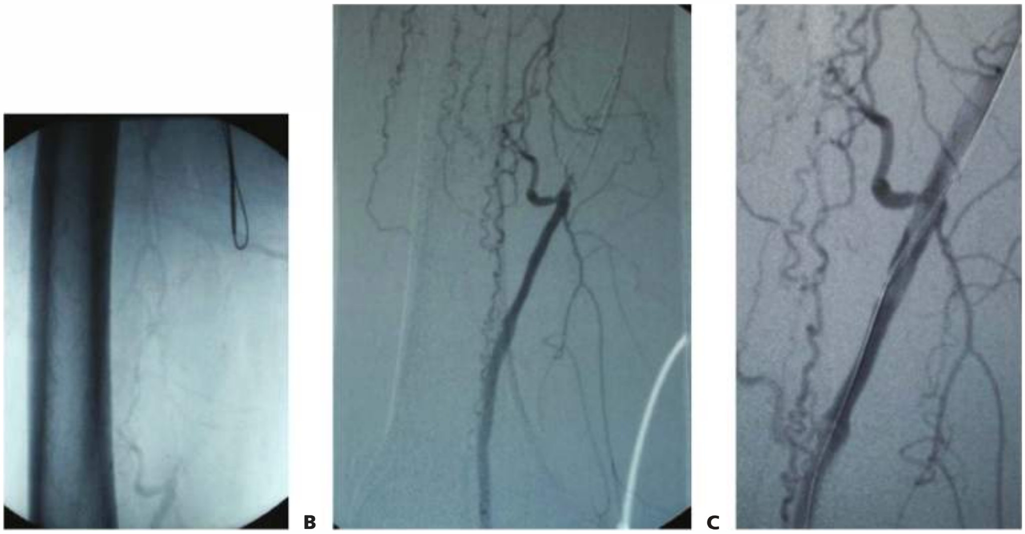


FIG 2 ● Enter the subintimal space. **A.** After sheath tip placement near the origin of the occlusion and where the administered contrast will opacify the location where the artery reconstitutes. An angled tip catheter is used *(arrow)* to direct the wire toward the superficial femoral artery origin. **B.** In the popliteal artery, the catheter is pointed to the interface between the artery and the occlusion on the side opposite the largest exiting collateral *(arrow)*. **C.** The tip of the catheter is pointed against the artery wall at the location where the occlusion starts. **D.** The hydrophilic guidewire is pushed into the wall until the tip of the wire catches and a loop forms. The loop usually forms at the transition zone along the wire between the soft, floppy tip of the hydrophilic wire and the stiffer shaft of the wire. **E.** After the wire loop is embedded within the occlusion, the supporting catheter is advanced.

LOOP MANAGEMENT

Loop Advancement

- Visualization, loop management, and assessment of the reentry site are the maneuvers that enhance success. The looped hydrophilic wire is advanced past the lesion (FIG 3). The loop is kept narrow and is optimal if less than the diameter of the artery lumen, and this is done by closely following the loop with a supporting catheter. Because the loop is in the subintimal space, keeping the loop narrow keeps the subintimal space tight. This helps to direct the wire in a straighter trajectory toward its target and also makes the knuckle of the wire loop a more effective tool for piercing tissue to get into the true lumen.
- The standard Glidewire™ (Terumo) has a directional tip with a soft shaft. If subintimal passage is being performed past a heavily calcified lesion, the artery wall may be more adherent to the calcified segment, making



A B C

FIG 3 ● Loop advancement. **A.** After entering the subintimal space, the loop is advanced with the support of the catheter. The loop works best when it is maintained in a narrow configuration. This is enhanced by closely following the loop with the supporting catheter. If the loop encounters a heavily calcified segment, it tends to widen or to spiral around the calcific segment. **B.** The loop is advanced to the arterial segment where the true lumen is reconstituted. Quite commonly, the loop of wire will pass into the true lumen. The location where the artery reconstitutes is visualized by administering contrast into the sheath. **C.** After the loop passes into the true lumen, advance the catheter into the true lumen. Always confirm location in the true lumen before starting reconstruction. This is usually done by removing the wire and administering contrast into the catheter. The guidewire of choice for use during treatment can then be placed.

wire passage alone more difficult. Catheter support is required, and sometimes a low-profile balloon must be used to create space in the subintimal plane. Typically, a standard Glidewire™ is used, but when passing a very calcified lesion, a stiff Glidewire™ should be considered. A nylon catheter, 4 or 5 Fr, with an angled tip and a hydrophilic coating is best.

- A recent development is the availability of CTO support catheters, such as the Quick-Cross™ (Spectranetics) or the CXI™ (Cook Medical) offering more support and low profile. The loop usually seeks the weakest point in the tissue and breaks across the membrane from subintimal potential space to true lumen more than 70% of the time in our experience. Orthogonal views are helpful in assessing the trajectory of the loop and whether it is progressing toward the reentry site.
- Even if the reentry site is calcified, a wire loop or a stiff wire with catheter support may reenter the true lumen and it is worth an attempt. If this approach is unsuccessful, select a reentry catheter as the next step. This saves time and the reentry site is best for success before too much manipulation has taken place.

REENTRY DEVICE

Reentry Device Placement

- The subintimal wire is exchanged for a stiff 0.014-in guidewire.
- The reentry device is advanced.
    - If the proximal part of the subintimal space is too tight to allow passage of a 6-Fr reentry catheter (approximately 2 mm), a long, low-caliber balloon may be used to slightly enlarge the subintimal space. Do not dilate the area intended for reentry. If the subintimal space at the reentry site is enlarged, it prevents the reentry needle from having adequate support to puncture the true lumen.

Reentry into True Lumen

- After the catheter is in place, a needle in the tip of the catheter is advanced into the true lumen.
- A 0.014-in guidewire is advanced from the reentry catheter into the true lumen.
    - The direction of the needle is oriented using fluoroscopy.
    - Orthogonal views are obtained to locate the juxtaposition of the true and false lumens.
    - The image intensifier is positioned so that the catheter and an acceptable target vessel segment are viewed side-by-side.
- Rotate the catheter until the "L" shape appears at the tip.

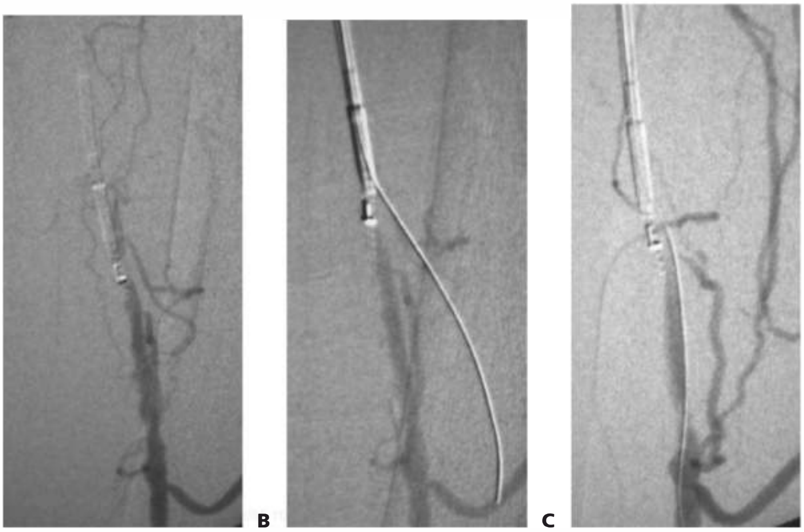


FIG 4 ● Use of a reentry catheter. **A.** If the wire loop does not pass into the true lumen, consider a reentry device. In this example, the Outback™ (Cordis) device is used. This is a 6-Fr catheter that is advanced in the subintimal space, along the same course where the channel was created by the catheter and guidewire. The reentry catheter is oriented side-by-side with the true lumen. The catheter is rotated so that the "L" shape at the tip of the reentry catheter is pointing toward the true lumen. **B.** The needle is advanced. In this case, the tip of the needle had passed beyond the true lumen and the wire is outside the artery. **C.** The needle is passed again, this time not quite so deeply, and the wire passes into the true lumen. After each throw of the needle, if it appears to be going in the correct direction into the true lumen, the wire is passed to explore and see if the tip progresses into the correct location in the true lumen.

- Advance the needle into the true lumen
  - Multiple needle passes may be required. The risk of a needle pass is low.
  - The needle may only require a partial advancement to get into the true lumen. A full advancement may go through the true lumen and into the wall on the opposite side.
  - Multiple small adjustments are often required before the true lumen is reentered, especially if the reentry site is diseased.
- The needle throw is oriented with intravascular ultrasound (IVUS) when using the Pioneer™ catheter (Medtronic). The needle is at 12 o'clock position on the IVUS image and the catheter is rotated to face the true lumen. Using color ultrasound, the true and false lumens can be distinguished and the wire passed into true lumen.
- After passing the wire, the needle is retracted and the reentry catheter is removed over the wire.
- Some commercially available reentry catheters are listed in Table 1. Reentry catheters may be guided by fluoroscopy or IVUS, and reentry is achieved by passage of a needle, stiff wire tip, or drill. Orthogonal views are obtained to locate the juxtaposition of the true and false lumens and the image intensifier is positioned so that the catheter and an acceptable target vessel segment are viewed side-by-side (FIG 4).

ALTERNATIVE REENTRY OPTIONS

Reentry Device Cannot Be Used

- Use a catheter with a stiff tip to bluntly push on the reentry site or use low-profile balloon angioplasty to break up the tissue membrane in hopes of achieving a fenestration as shown by active blood return.
- This approach is sometimes successful but it enlarges and occasionally perforates the subintimal space at the reentry site and will render the reentry catheters less efficacious because they rely on a tight subintimal space to provide leverage for the needle passage into the true lumen.
- Another option is to consider a straight 0.035-in Glidewire™ or a straight 0.014 in, or 0.018 in CTO wire and push on the location desired for reentry and see if it can be drilled into place.

Retrograde Approach

- Retrograde puncture can be performed on a distal artery, such as a tibial or pedal artery. Retrograde passage of a wire is often possible, even when antegrade passage

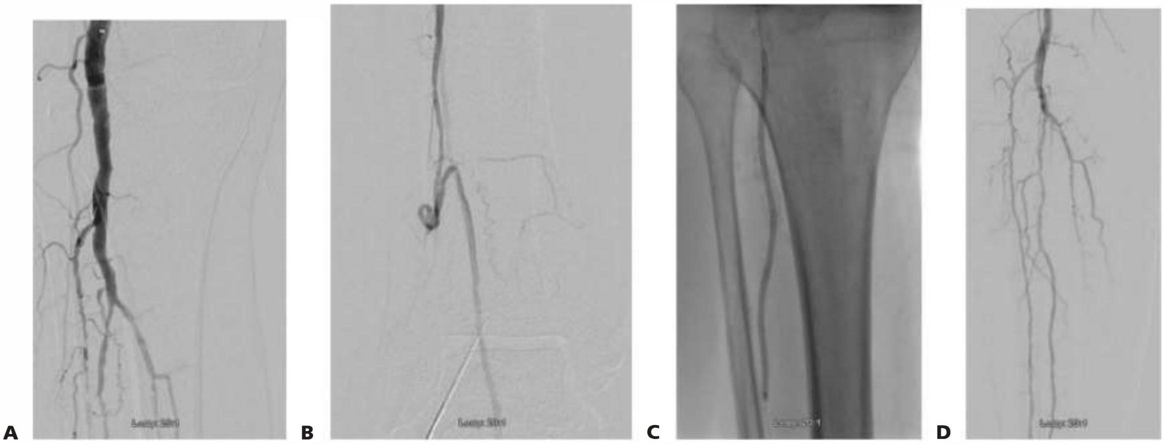


FIG 5 ● Retrograde puncture using pedal access. **A.** This patient has a pedal gangrene in an angiosome that is perfused by the anterior tibial artery. Revascularization of the anterior tibial artery using a traditional antegrade approach was not successful. **B.** A roadmap of the distal anterior tibial artery was performed. The arterial access needle is advanced into the distal anterior tibial artery under roadmapping. **C.** After retrograde access, the guidewire is passed into the antegrade sheath. The angioplasty balloon is then introduced through the antegrade sheath. **D.** After angioplasty, the anterior tibial artery is patent.

across the same lesion was not. This is especially the case for occlusions of the popliteal and proximal tibial level where there are collaterals that an antegrade wire tends to follow blindly along and where reentry devices are not as applicable.

- Contrast is administered through the proximal access to obtain a roadmap of the distal puncture site or ultrasound used to guide the access.
- A 4-cm 21-gauge micropuncture needle is used.
- A V18 wire (Boston Scientific) is introduced.
  - Sheath placement is avoided if possible to keep the arteriotomy small.
  - If the retrograde wire cannot break into the true lumen, a coronary balloon catheter is passed over it.
- A balloon introduced from the antegrade direction and the balloon introduced retrograde are juxtaposed and inflated and are usually able to split the dissection flap to open the true lumen (FIG 5).

PEARLS AND PITFALLS

Staying in true lumen	■ Shortest reconstruction ■ Preservation of most collaterals ■ May increase risk of embolization at time of recanalization
Subintimal passage	■ Intraluminal contents are excluded. ■ The subintimal space often can be converted to a smooth, large diameter conduit. Usually, the entry and reentry sites require extra angioplasty or mechanical support from implants.
Optimal reentry site	■ Minimal calcifications ■ Healthy true lumen ■ Shortest subintimal channel
Collaterals	■ Reenter as close to distal reconstitution as possible ■ Typically large incoming collateral feeding reconstituted segment ■ Subintimal space (flow channel)—no collaterals and can fail suddenly
Reentry catheters more likely	■ Calcified reentry site ■ Worse disease morphology

POSTOPERATIVE CARE

- Postoperative care involves standard care after endovascular procedures. True lumen recanalizations have collaterals, whereas subintimal passages do not. The subintimal recanalization should be monitored with duplex because they may fail suddenly in a manner similar to a bypass. We typically perform duplex surveillance every 6 months.

OUTCOMES

- Loop reentry using standard technique is successful in about 70% to 80% of cases.[1,2]
- Patients that failed loop reentry were treated with reentry catheters and approximately 80% of these were successful.[2]
- Reentry success was 90% successful in a study using the Outback™ (Cordis) reentry catheter for all-comers.[3]

COMPLICATIONS

- Complications are similar to other endovascular procedures.
- Access site complications are the most common and include bleeding, hematoma, pseudoaneurysm, and arteriovenous fistulae.
- Embolism to the runoff may be slightly more common in this patient population because it involves treatment of the most complex infrainguinal lesions.
- Perforation may also occur with greater frequency because angioplasty and manipulation in the subintimal space are key maneuvers in this procedure. However, when perforation occurs, it is only rarely clinically significant.

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Chapter **30**

Percutaneous Femoral–Popliteal Reconstruction Techniques: Antegrade Approaches

F. Gallardo Pedrajas *Peter A. Schneider*

DEFINITION

- Overview: Femoral–popliteal revascularization, for indications of limb salvage or claudication, is performed using open, endovascular, or hybrid approaches. Advanced open surgical techniques are detailed elsewhere. Guidewire-catheter combinations are particularly effective and widely used to cross femoral–popliteal stenoses or occlusions. Once across, reconstructions are performed with any combination of angioplasty, stenting, stent grafting, or atherectomy.
- Basic procedural goals: Improve functional status, quality of life, and, in the setting of ischemic tissue loss, augment wound healing and limb preservation.
- Challenges influencing long-term clinical success: (1) superficial femoral and popliteal artery movement during activities of daily living, including flexion, compression, torsion, and stretching; (2) compromised runoff; (3) the generally diffuse nature of femoral–popliteal disease, requiring angioplasty of long segments of diseased and stiffened artery; (4) complex pathology, including ostial lesions, luminal thrombus accumulation, and mural calcification.
- Indications for intervention:
  - Rutherford class 1, 2, and 3 ischemia—exercise therapy and medical management are pursued as primary intervention.[1]
  - Rutherford class 4, 5, and 6 ischemia—rest pain, ischemic ulcer, and gangrene warrant revascularization as initial therapy.
- Technical approach: Utilization patterns are trending toward percutaneous-first approaches to management of Inter-Societal Consensus for the Management of Peripheral Arterial Disease (TASC II) type A, B, and C lesions.[2] Full consideration of current indications for open versus percutaneous interventions is beyond the scope of this text; reference should be made to most recent TASC updates.[3]

PATIENT HISTORY AND PHYSICAL FINDINGS

- History includes a detailed description of ischemic symptoms pertaining to claudication, rest pain, or tissue loss. The progression of symptoms and timeframe are helpful in determining the urgency of therapy.
- The presence and severity of cardiovascular disease risk factors should be assessed and managed to ensure optimal perioperative and long-term clinical results, including tobacco use, diabetes, hypertension, hyperlipidemia, renal dysfunction, and sedentary lifestyle.
- Previous vascular or endovascular surgery procedures should be reviewed in detail, including obtaining operative notes, prior imaging and surveillance studies, and prior physiologic testing results whenever possible.
- For claudicants, the potential presence and contribution of nonvascular causes of leg pain with exercise should be considered; for example, neurologic claudication secondary to lumbar radiculopathy and other degenerative spine diseases.[4]
- Physical examination should document peripheral pulses at all levels, both lower extremities, including the strength and quality of femoral pulses and skin integrity at potential access sites.
- The severity and extent of ischemia, degree of existing tissue damage, and presence of infection are documented prior to initiating intervention.

IMAGING AND OTHER DIAGNOSTIC STUDIES

- Physiologic vascular testing provides objective determination of the location and severity of disease, assists in procedural planning, and provides documentation of baseline conditions.
  - Ankle–brachial index (ABI): ratio of the continuous wave Doppler–determined blood pressure in the anterior or posterior tibial arteries (whichever is higher) to the blood pressure in the brachial artery (>0.9 = normal; 0.5 to 0.9 = usually consistent with mild to severe claudication; <0.5 = present in patients with very short distance claudication, rest pain, or tissue loss)
  - Toe pressures: The ABI may be artifactually elevated in diabetic patients with calcified tibial arteries. Toe pressures may provide more reliable assessment of pedal and forefoot perfusion when the ABI is greater than 1.2. Hallux pressure less than 50 mmHg may predict delayed or inadequate wound resolution, 50 to 80 mmHg is indeterminant, and greater than 80 mmHg is generally sufficient to promote healing.
  - Duplex arterial imaging: Direct insonation provides insight into the location and severity of disease. The ratio of the peak systolic velocities (PSV) obtained from the most compromised location divided by PSV from the most adjacent, proximal noninvolved segment provides additional guidance regarding the severity of disease; greater than or equal to 2.5:1 usually identifies a stenosis greater than 50% (**FIG 1**).
- Computed tomographic arteriography (CTA): CTA has assumed an increasing role in guiding peripheral vascular intervention, particularly in regard to choosing appropriate devices and optimal interventional approach (e.g., ipsilateral antegrade vs. contralateral retrograde). This additional guidance, however, comes at the cost of substantially more iodinated contrast and radiation exposure than that provided by catheter-directed, intraarterial contrast arteriography, augmented by direct ultrasonic visualization and physiologic testing (**FIG 2**).

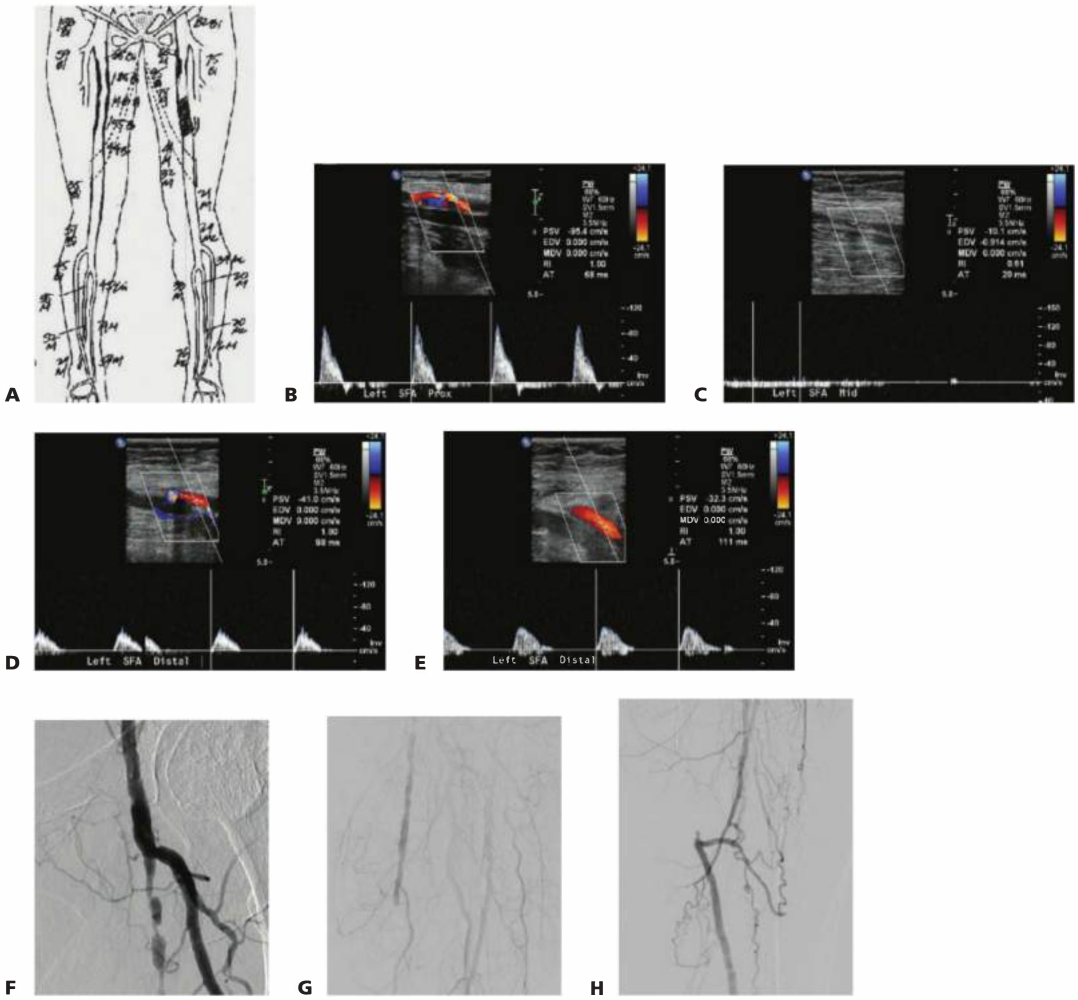


FIG 1 ● Duplex evaluation of lower extremity arteries. **A.** Duplex mapping was performed on a patient with very severe left lower extremity claudication. There is a left SFA occlusion with reconstitution of the distal SFA. **B.** Duplex image of proximal left SFA shows some plaque formation and a peak velocity of 95 cm per second. **C.** This duplex image demonstrates no flow in the occluded segment of the SFA. **D.** The left distal SFA duplex image shows the point of reconstitution of the artery with a patent distal artery and low velocity flow. **E.** The more distal SFA is a healthier artery with a reasonable lumen, but it has a low peak velocity of 32 cm per second. **F.** The arteriogram performed on the left lower extremity of this patient at the time of intervention showed a patent but diseased proximal SFA. The CFA and profunda femoris artery do not have significant occlusive disease. **G.** There is a mid-SFA occlusion as demonstrated by duplex evaluation. **H.** There is reconstitution of the left distal SFA as indicated by duplex mapping.

- Magnetic resonance arteriography (MRA): MRA may also assist preoperative planning. Although MRA does not expose patients to ionizing radiation, artifactual overestimation of disease severity is common in low flow conditions. Also, gadolinium contrast administration is contraindicated in patients with a glomerular filtration rate of less than 30 mL per minute due to risk of contrast-associated glomerulosclerosis (**FIG 3**).

SURGICAL MANAGEMENT

- Overview—Success in percutaneous management of femoral–popliteal occlusive disease has catalyzed a reciprocal decline in the use of open bypass for definitive revascularization. Key features of percutaneous management include detailed preoperative planning, choice of access site and closure techniques, and familiarity and facility with a wide range of complementary intraluminal wire-guided devices.[4]

Preoperative Planning

- The operative plan includes access site selection, planned method of crossing, and options for arterial reconstruction.
- Endovascular inventory: An essential element of endovascular success is a robust and redundant device inventory. In contrast to open reconstruction techniques, where similar instruments will suffice for all lower extremity bypass configurations, regardless of routing, a unique and task-specific

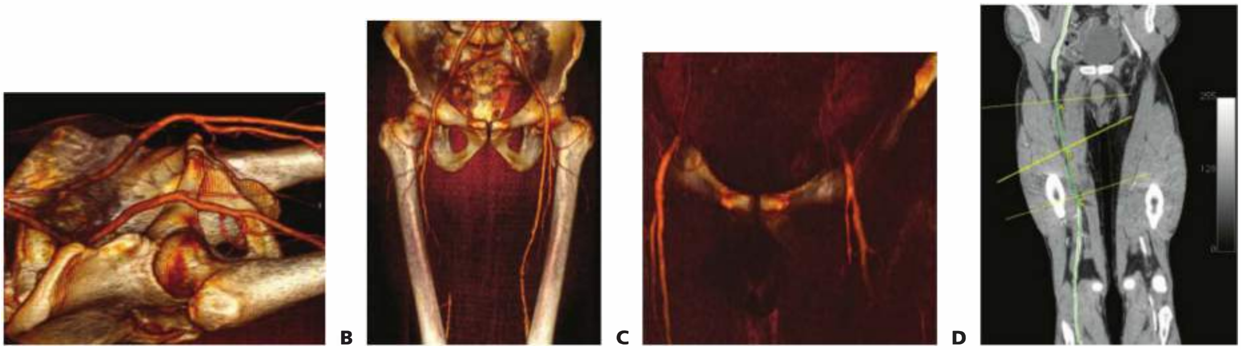


FIG 2 ● CT angiography for infrainguinal occlusive disease. Volume rendering technique. Preoperative study of puncture zones in the CFA in a patient with a long right SFA occlusion. **A.** Evaluation of iliac artery inflow. **B.** Long right SFA occlusion with reconstitution of the above-the-knee popliteal artery. **C.** CT evaluation of the CFAs and femoral bifurcations prior to access. **D.** Centerline measurements performed to measure diameters and plan for stent graft placement in the right SFA.

repertoire is required for almost every endovascular approach. Procedural success requires that the necessary devices, including guidewires, sheaths, catheters, angioplasty balloons, stents, reentry devices, stent grafts, and atherectomy catheters are identified and available before intervention is attempted.

- Appropriate radiation protection must be available for all individuals involved in interventional procedures. All team members must conscientiously wear a radiation dosimeter, submitted monthly for aggregate exposure documentation. Leadership ensures that all team members adhere to basic radiation safety tenants, including limiting the length and intensity of exposure to the minimum required for precision imaging and intervention (the "as low as reasonably achievable" [ALARA] principle). Safety principles, including distance from the radiation source, appropriate shielding and optimal table height, and source-image intensifier distance, must be understood and applied during every procedure.

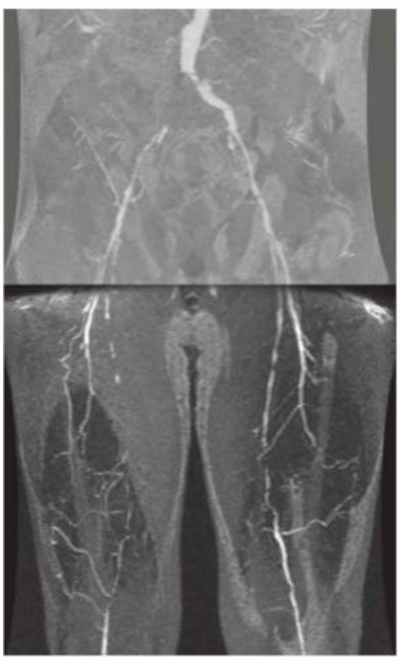


FIG 3 ● Magnetic resonance angiography as preoperative assessment of lesion location and severity. This patient has extensive iliac and femoral artery occlusive disease. Both femoral artery puncture sites are compromised. There are long lesions in both superficial femoral arteries.

- Antibiotic prophylaxis is administered prior to the initiation of the procedure, whenever permanent implants are considered.
- Percutaneous procedures are performed under local anesthesia with appropriate sedation. Care should be taken to avoid oversedation to ensure that patients can cooperate with instructions and imaging requirements during the procedure. When hybrid open endovascular procedures are contemplated, general anesthesia may facilitate more rapid and accurate device deployment, with reciprocally less radiation exposure for the patient, cath lab team, and operator.
- An important initial consideration is the approach and optimal puncture site. The common femoral artery (CFA) is the most frequent access site. The approach is typically either up and over the aortic bifurcation from the contralateral femoral artery or ipsilateral antegrade femoral puncture. The transbrachial, transthoracic approach may also provide optimal antegrade access under certain circumstances.

Positioning

- Surgeon position should provide forehand access, whenever possible (**FIG 4**).
- Retrograde femoral puncture: This is the most common type of access for all endovascular procedures, including femoral–popliteal revascularization (**FIG 5**). The needle is placed in the CFA and the guidewire is advanced retrograde into the iliac artery.
- The femoral area is examined prior to puncture of the artery. The inguinal ligament extends from the anterior superior iliac spine to the pubic tubercle. The best puncture

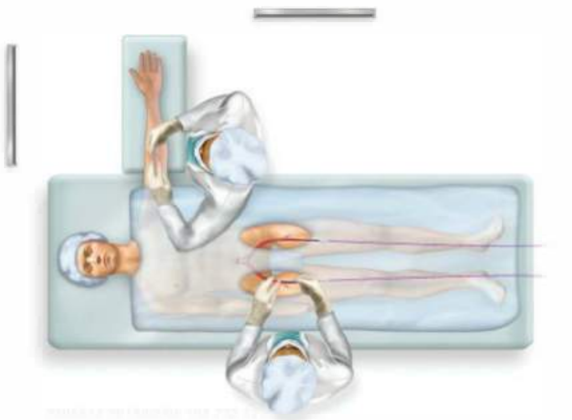
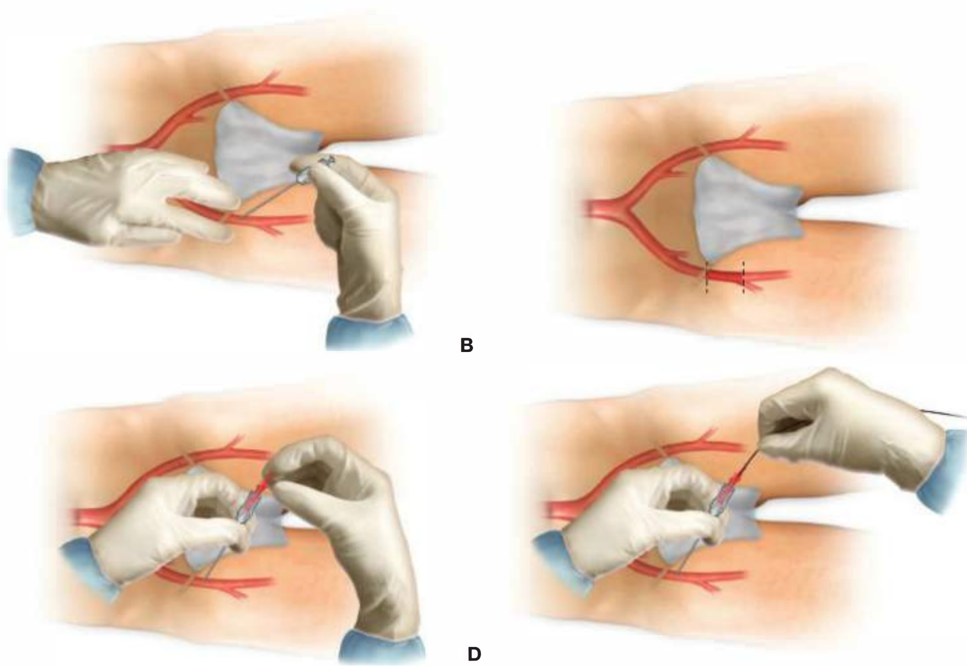


FIG 4 ● Patient positioning. The operator works forehand when possible. The right-handed operator stands on the patient's right side for a retrograde femoral puncture of either groin. The right-handed operator stands at the inferior aspect of the left arm when performing a left brachial puncture. The monitors are placed so that they can be comfortably observed by the operator.

site is inferior to the inguinal ligament and at least a centimeter superior to the femoral bifurcation. Ultrasound provides useful guidance for arterial puncture (**FIG 6**). Following needle insertion, spot fluoroscopy from an ipsilateral oblique angle is obtained to confirm position. If arterial insertion is determined to be proximal to the femoral head, the access attempt is aborted before larger devices are inserted to minimize the risk of retroperitoneal hematoma formation due to inadequate compression or control following the procedure. Common femoral access also enables closure devices to be employed with confidence when necessary.

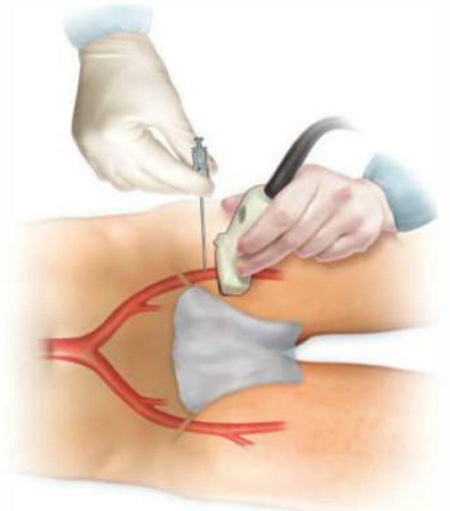
- Closure devices: recommended for retrograde femoral access site management following insertion of greater than or equal to 6-French (Fr) sheaths. Sheath puncture less than 6 Fr is best managed by compression for 10 to 15 minutes, with or without adjuncts such as a thrombin-impregnated dressing (e.g., D-stat® patch).
- When pulses are not palpable at the desired access site, ultrasound or fluoroscopic guidance (assisted by mural femoral artery calcification) may provide valuable assistance. Under these circumstances, bilateral femoral access and ipsilateral iliac intervention may be required for procedural success. Ideally, this eventuality is anticipated based on the results of preprocedural examination and physiologic testing. Fortunately, the pulseless femoral artery is often palpable based on mural calcification alone. Patience and spot fluoroscopic images to confirm needle and artery position following failed needle passes often ensures ultimate success.
- Secondary puncture of the postoperative groin presents special challenges. Whenever possible, scar tissue and anastomoses should be avoided. Access in native artery is preferable to prosthetic or autogenous grafts. Considerable force may be required for needle and micropuncture set access; consideration should be given to using "stiff" 0.018-in wires and



A B C D

FIG 5 ● Retrograde femoral puncture. **A.** The anatomic relationships are evaluated. The left hand may be used to help guide the needle. **B.** The access needle is placed in the CFA inferior to the inguinal ligament and superior to the femoral bifurcation. **C.** The needle is advanced into the CFA until arterial blood return is apparent. **D.** In the image a prolongation of the guide inside the retrograde femoral should be included, in order to understand that with this approach and these needle angulation the guide should never go to the SFA, or profunda artery.

A



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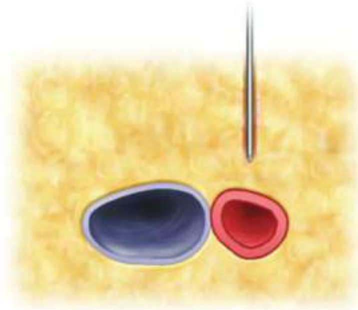

C

FIG 6 ● Ultrasound-guided puncture. **A.** In this case, the operator is evaluating the left CFA using the ultrasound probe with a longitudinal orientation. The monitor is placed in a location where the operator can visualize the arterial puncture real time. **B.** In the drawing, the operator is preparing for an antegrade femoral puncture with ultrasound guidance. **C.** In this rendering of an ultrasound image that is seen during common femoral arterial puncture, the common femoral vein is typically much larger in diameter, lies side-by-side to the artery, and the vein is typically easily compressible. The entry needle can be visualized as it enters the artery to ensure the correct location of the puncture.

micropuncture sets specifically manufactured to facilitate difficult groin access.

- Antegrade femoral puncture: The femoral pulse and inguinal ligament are carefully marked (**FIG 7**). Needle placement is directed proximal to the femoral artery bifurcation under real-time ultrasound guidance.
- Guidewire placement into the superficial femoral artery (SFA) requires patience and practice. Ultrasound imaging in a longitudinal view may facilitate SFA wire intubation. When using a micropuncture set with a "steerable" 0.018-in wire (e.g., one with a slight curve placed at the tip), fluoroscopic control may also be employed. If repeated attempts result in deep femoral artery placement, the micropuncture set should be exchanged for an 11 cm 4- or 5-Fr sheath over a standard multipurpose (e.g., Bentsen) wire. Once safe antegrade deep femoral access is obtained, the 5-Fr sheath may be gradually withdrawn with sequential fluoroscopic contrast "puffs" of 1 mL or less performed until the femoral bifurcation is imaged (but while the sheath tip is still in the CFA). At this juncture, roadmapping or last-image-hold digital subtraction angiography from an ipsilateral oblique angle is performed to outline femoral bifurcation anatomy, after which a steerable hydrophilic guidewire and, ultimately, the 5-Fr sheath is directed under fluoroscopic imaging into the SFA.
- Antegrade femoral access should be avoided in the obese, in patients with a short CFA, or in patients with extreme proximal or orificial SFA disease. Although antegrade access improves "pushability" across total occlusions and enables usage of a wider inventory of guidewire-catheter combinations, there is no option for inflow disease management using this approach. Also, the safety of current generation closure device placement is uncertain in antegrade approaches and should be avoided whenever possible.
- Brachial puncture and transaortic sheath placement may provide an alternative option for "antegrade" femoral access. Upper extremity arteries are smaller, less forgiving, more prone to spasm, and less predictably managed with compression following access. Notoriously, small amounts of arterial extravasation may catalyze debilitating and permanent neurapraxia, even when brachial access is obtained well distal to the axillary fossa. Debilitating nerve injury from "axillary" sheath hematomas may occur at any location proximal to the antecubitum. In our practice, we minimize this risk by defaulting to surgical exposure and direct arterial puncture with suture closure for essentially all brachial artery access procedures. Exposure is easily obtained with local anesthetic in most patients.
- The longer guidewires and catheters required to access the femoral and popliteal arteries are also less responsive to surgeon manipulation from a brachial approach and also limit the available inventory of appropriate devices for femoral or popliteal intervention.
- When brachial access is required, the level of access is determined by the diameter of the largest sheath required

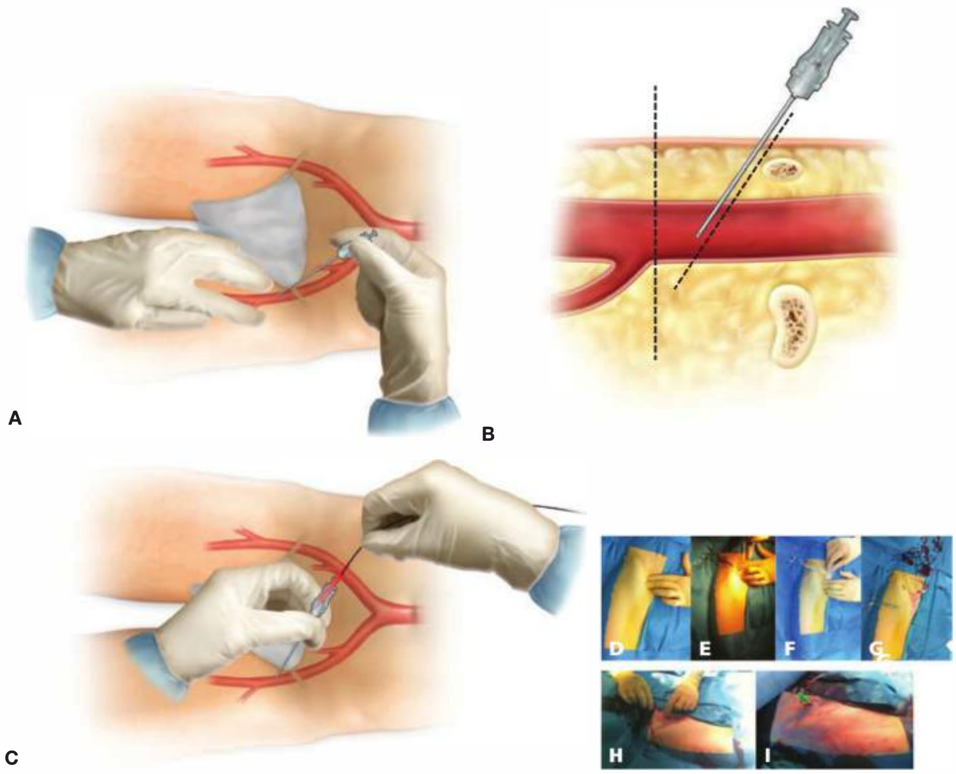

FIG 7 ● Antegrade puncture. **A.** The needle punctures the skin at the level of the inguinal ligament or just superior to that level. The angle of trajectory of the needle will permit the artery puncture to be proximal to the femoral bifurcation. **B.** The further proximal to the femoral bifurcation the artery puncture is located, the easier it is to steer the wire into the SFA. The best location for needle placement is inferior to the inguinal ligament but well proximal to the femoral bifurcation. **C.** The needle enters the CFA and when arterial return is achieved, the floppy-tip guidewire is advanced into the artery. **D.** The artery and the anatomic boundaries are palpated. **E.** A clamp is used to assist with fluoroscopic identification of the desired puncture location. **F.** The needle is placed. **G.** Arterial return is achieved. **H.** A guidewire is placed. **I.** A sheath is advanced.

to complete the procedure. For 6- or 7-Fr sheaths, the segment immediately proximal to the antecubital fossa is sufficient. For larger sheaths, access should be obtained in the distal axillary artery, proximal to the bifurcation of the deep brachial artery. The left arm should be used whenever possible to minimize risk for embolic iatrogenic stroke. During micropuncture access, even under direct vision, back-bleeding may not be pulsatile due to the smaller caliber of the brachial artery. Sheaths should be managed with frequent flushing with 100 units/mL heparin, as well as systemic anticoagulation once definitive interventional sheaths (6 to 7 Fr, 55 to 90 cm from the arm) are positioned in the target artery, or whenever sheaths appear to be occlusive. Intraarterial nitroglycerine injection may reduce arterial vasospasm to the distal extremity when necessary.

- Percutaneous femoral–popliteal revascularization techniques include balloon angioplasty alone, or self-expanding stent graft implantation as an adjunct to angioplasty. These techniques require placement of interventional-grade sheaths, braided when required to cross the aortic arch or bifurcation to prevent kinking as well as sufficient length to reach the treatment site without limiting device selection. Sheath access also permits serial angiographic imaging to guide device positioning, deployment, and confirm procedural success.

SHEATH PLACEMENT

- Ensure that the appropriate sheath is selected and that alternatives are available should plans or needs change.
- Decide on optimal sheath positioning. Usually, placement immediately adjacent to the target lesion maximizes the ability to cross the lesion, control the procedure, and minimize contrast usage. In many circumstances, it may not be possible or practical to advance the sheath past

the femoral bifurcation when approaching from the contralateral femoral artery.

Up and Over Approach

- Crossing the aortic bifurcation (**FIG 8**): Through a contralateral retrograde puncture, an infrarenal aortogram is performed to evaluate aortic bifurcation anatomy and location. Usually located at the level of the iliac crest, vascular calcifications may outline the bifurcation and guide positioning. The aortic bifurcation must be free of occlusive or aneurysmal disease to ensure safe sheath passage. Occasionally, iliac artery lesions must be treated prior to femoral intervention to ensure optimal outcome.

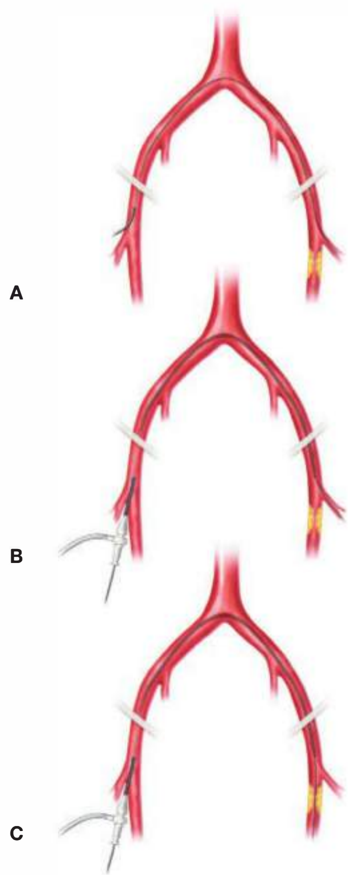

FIG 8 ● Sheath access. **A.** An exchange guidewire is placed over the aortic bifurcation. The tip of the guidewire is placed in a large, safe branch. In this example, the profunda femoris artery is used to anchor the wire. **B.** The sheath is advanced over the stiff guidewire. The advancement of the sheath is observed under fluoroscopic control to ensure that it is being passed safely. **C.** After sheath placement over the aortic bifurcation, the stiff wire is removed and the directional wire is advanced across the lesion in preparation for treatment.

- Selective catheterization of the aortic bifurcation is performed, followed by antegrade catheterization of the contralateral iliac artery system, either with the flush or pigtail catheter used for the aortogram or an exchange catheter advanced at least to the femoral bifurcation.
- The sheath tip is placed somewhere between mid-iliac artery and the mid- to distal SFA, depending on lesion location and interventional intention. A 6-Fr sheath may be adequate for this purpose, but 7 Fr may be required for many devices (read the package insert). The angioplasty catheter length for proximal SFA lesions is 75 to 80 cm; for more distal lesions, 90 to 110 cm.
- Access to the deep femoral artery may be required to safely advance the "up and over" sheath over a stiff exchange wire (e.g., Rosen®). After flushing and dilator placement, ensure that the sheath sidearm stopcock is turned to the "off" position. The skin incision may need to be enlarged to facilitate placement. Consider serial dilator exchanges when upsizing a sheath by two or more French sizes. Occasionally, depending on the angle of the aortic bifurcation, sheath placement may be facilitated by passage over a stiff, exchange length hydrophilic wire. When using hydrophilic wires for this purpose, care should always be taken to keep the tip of the wire in the image screen field to prevent inadvertent arterial puncture and extravasation from wire injury. Similarly, when confronted by extreme tortuosity in the iliac arterial system, interval advancement of the sheath into the internal iliac artery may be required to gain access to the contralateral iliac artery with a second or "buddy" wire, following which, standard catheter and guidewire techniques may be used to advance the sheath to its ultimate desired location.
- Regardless of procedure or access approach, it is always advisable to keep the wire tip in the imaging field whenever sheaths are exchanged or advanced—arterial perforation and extravasation may limit procedural options, or the ability to initiate systemic anticoagulation, and may increase compartment pressures to the point of requiring surgical release if not recognized and managed promptly.

Ipsilateral Approach

- See prior recommendations for securing access (Table 1). Obesity and excessive abdominal pannus may significantly limit the use of this approach. Before initiating treatment, obtain angiographic documentation of existing ipsilateral anatomy, including infrapopliteal runoff.
- Shorter guidewires and devices improve the efficiency of the ipsilateral antegrade approach.
- If balloon angioplasty alone is planned, 4- or 5-Fr sheath can be used to treat ipsilateral SFA lesions. More complex reconstructions require 6 Fr and occasionally 7-Fr sheaths.

Table 1: Approach: Up and Over or Ipsilateral Antegrade

Approach	Antegrade	Up and Over	Brachial
Puncture	More challenging	Simple retrograde femoral	Retrograde brachial
Catheterization	Proximal femoral puncture and selective catheters	Challenging with tortuous arteries, diseased bifurcation Easy to catheterize SFA	Challenging, long distance, diseased aorta
Catheter control	Excellent	Fair	Fair
Catheter inventory	Minimal	More supplies, long catheters Up and over sheaths	Specific material, long sheaths, catheters
Indications	Infrapopliteal, femoropopliteal disease	Proximal SFA disease	Proximal SFA, femoropopliteal disease
Limitations	Obesity, CFA disease, proximal SFA disease	Contralateral disease, bifurcation disease	Aortic disease, infrapopliteal disease

SFA, superficial femoral artery; CFA, common femoral artery.

CROSSING OCCLUSIVE LESIONS

- Guidewire-catheter skills form the basis of all endovascular procedures. Successful guidewire positioning requires familiarity with a range of devices and guidewire-catheter pairings. The guidewire required for crossing the lesion could not be adequate for working or deploying a stent or a stent graft. Familiarity with and access to a wide selection of wires (depending on length, diameter, tip pressure, and hydrophilic qualities) is essential for success (**FIG 9**).
- Guidewire features to be considered:
  - Length: Must be adequate to cover the cumulative distance, both inside and outside the patient, to perform the procedure and support the catheter. Guidewire lengths vary from 145 to 300 cm. For an ipsilateral antegrade approach, 145- to 180-cm guidewires are adequate, but for contralateral or brachial access, 260- to 300-cm lengths are necessary. As a general rule of thumb, guidewire length must be at least twice that of the coaxial device to be positioned over the wire.
  - Diameter: Most femoral–popliteal procedures are performed with 0.035-in guidewires, but smaller caliber angioplasty is generally performed with 0.018-in or 0.014-in guidewires.
  - Stiffness: An inner steel core confers different magnitudes of stiffness on the shaft of the wire. A stiffer wire may help to cross a calcified lesion, but it is

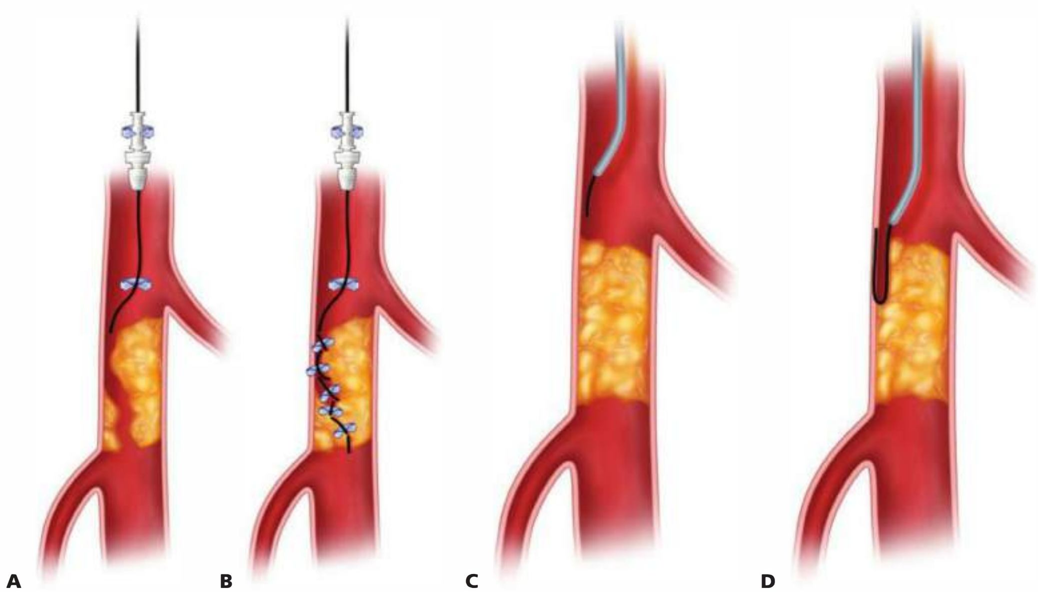

FIG 9 ● Crossing the lesion. **A.** In this case, a critical stenosis is crossed. The image intensifier is angulated to get the best view of the pathway through the lesion. **B.** Typically, a hydrophilic wire with a directional tip is used and the wire tip is steered through the lesion. **C.** In this case, an occlusion is crossed using subintimal technique. The guidewire is advanced and is supported by a catheter with an angled tip. **D.** The guidewire is pointed toward the arterial wall at the beginning of the lesion and is pointed away from the collateral that fills the segment and is near the location where the lesion begins. The wire is pushed until an elbow forms and enters the subintimal space. *(continued)*

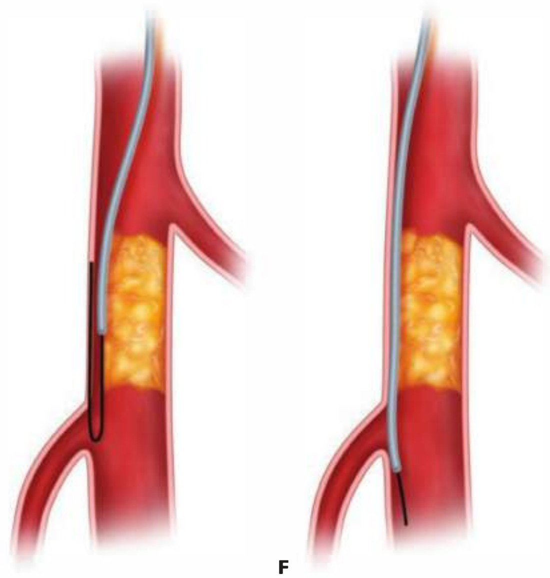

FIG 9 ● *(continued)* **E.** The loop is advanced. The loop is maintained in a narrow configuration by supporting it closely with the catheter. **F.** After the loop pops into the patent distal segment, the catheter is advanced. The wire is removed and contrast is administered to confirm the location of the catheter tip in the true lumen.

also easier to injure the vessels. In wires specifically designed to cross femoral–popliteal lesions, tip pressure may also vary across wires with similar stiffness along the majority of their length.
  - Coating: Hydrophilic guidewires may reduce the coefficient of friction. Typically, they are passed in conjunction with purpose-specific crossing catheters.
- Crossing catheters support guidewire passage and, depending on design, confer varying degrees of support and directionality. After the guidewire is used to cross the lesion, the catheter may be advanced so that the choice working wire may be placed. Crossing catheter technology has advanced considerably in the last 5 to 10 years. Options abound for torsionality (braided or unbraided), tip taper, tip shape, length, and diameter. Examples include the Quick-Cross® and CTX® catheter families. Some experience is required to learn how to use these catheters optimally in most situations.

BALLOON ANGIOPLASTY

- The angioplasty process enlarges the lumen by compressing and rupturing the plaque, as well as stretching and, in some cases, damaging the media and adventitia (**FIG 10**).
- Heparin is typically administered, 50 to 100 units/kg following sheath placement and prior to intervention.
- The balloon length and diameter are typically selected to treat the entire lesion, with minimal proximal or distal overlap, to restore original diameter as determined by proximal or distal measurement. The balloon catheter is positioned over the guidewire and inflated to nominal pressure to achieve the specified diameter. Occasionally, higher pressures may be required to reduce lesion "waisting."
- Inflate slowly. Balloon inflation is maintained for 2 minutes.
- Deflate slowly, and ensure full deflation fluoroscopically before withdrawal.
- The balloon angioplasty catheter may be used repeatedly during the same procedure; however, its capacity to recover the predeployment diameter following deflation degrades with sequential use.
- Balloon diameters range from 4 to 7 mm for the SFA and 3 to 6 mm in the popliteal artery.
- Conventional angioplasty is limited somewhat by target artery dissection. Not all dissections need further treatment. In general, only flow-limiting dissections as judged by sequential contrast injections through the interventional sheath need additional treatment. Dissections may be managed by prolonged periods of inflation followed by gradual deflation to "tack" the plaque up to the arterial wall. Persistent flow obstruction following angioplasty is the most common indication for subsequent secondary stenting.

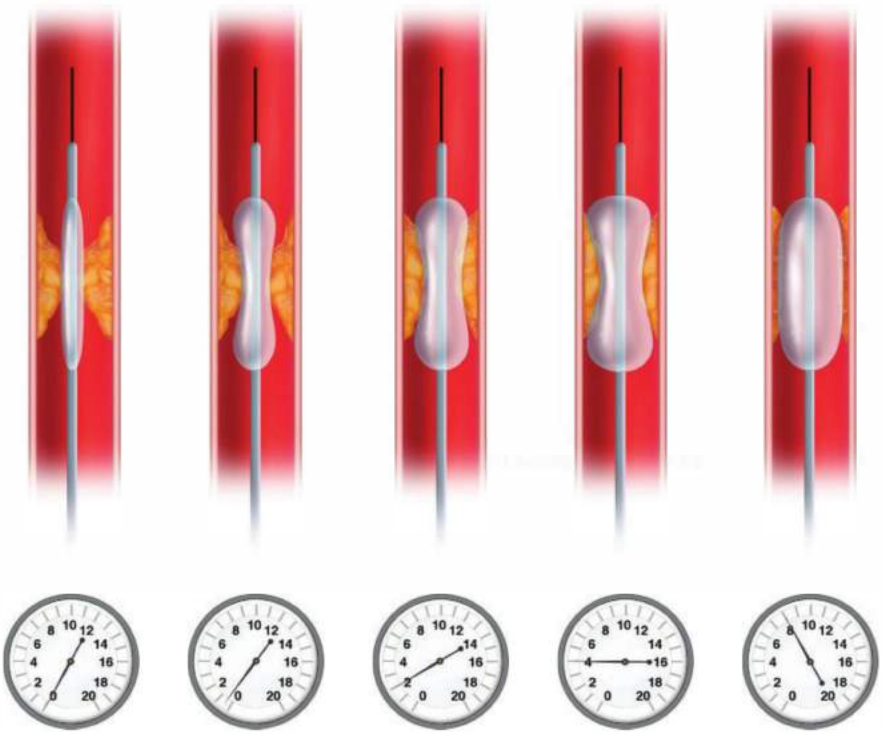

FIG 10 ● Balloon angioplasty. **A.** The balloon catheter is advanced over the guidewire and into the lesion. If possible, an angioplasty balloon is selected that is able to treat the whole lesion length with a single inflation. **B.** The balloon is inflated and this is observed using fluoroscopy. At very low pressure, the balloon will inflate freely in the locations where there is minimal or no impingement of the lesion on the balloon. **C.** Usually with 2 atm of pressure, the waist on the balloon becomes apparent and the lesion begins to yield to the outward force exerted by the balloon. **D.** The balloon is inflated gradually. This helps to avoid delivering more pressure to the artery than is required. This also allows the lesion to gradually give way. At higher pressure, the waist becomes smaller. **E.** Pressure in the balloon is gradually increased until the balloon reaches its full diameter. The balloon is typically inflated for 2 to 3 minutes in situations where the operator is hoping to use angioplasty as stand-alone therapy.

STENTS

- Although all vascular-compatible, size-appropriate, self-expanding (nitinol) stents may be deployed in the superficial femoral or popliteal arteries as clinically indicated, select devices have obtained specific indications for this application from the U.S. Food and Drug Administration. The operator is encouraged to familiarize himself or herself with this designation and to use application-approved devices whenever appropriate to ensure optimal outcome.
- Material and characteristics of peripheral stents have evolved in recent years. Self-expanding nitinol stents are most appropriate for SFA and popliteal applications. The ideal stent should have the ability to adapt to the vessel with a precise deployment and without kinking, collapsing, or fracturing as well as limit long-term arterial injury and restenosis. More recently, drug-eluting stents have been developed and are approved for use in the United States to limit chronic restenosis of the stent arterial segment following deployment. The potential clinical benefits derived from these devices are offset to a significant degree by their substantial increase in cost over "bare metal" stents.
- Femoral–popliteal stents may be placed routinely or selectively. Selective stent placement may be considered for significant postangioplasty dissection, long lesions (>15 cm), residual stenosis postangioplasty, pressure gradient (>10 mmHg) after angioplasty, recurrent stenosis, occlusion, or to prevent or limit postangioplasty embolization of plaque.
- Localization: A stent is typically deployed to span the distance between relatively healthy artery proximal and distal to the target lesion. "Healthy" is a relative term in this sense, and care should be taken to limit stent coverage to the minimal distance required to achieve an optimal result. Long lesions in the SFA are the most commonly stented segment, but be aware that stents in the distal superficial femoral and popliteal arteries may be damaged by stress from knee flexion (**FIG 11**). Excessive

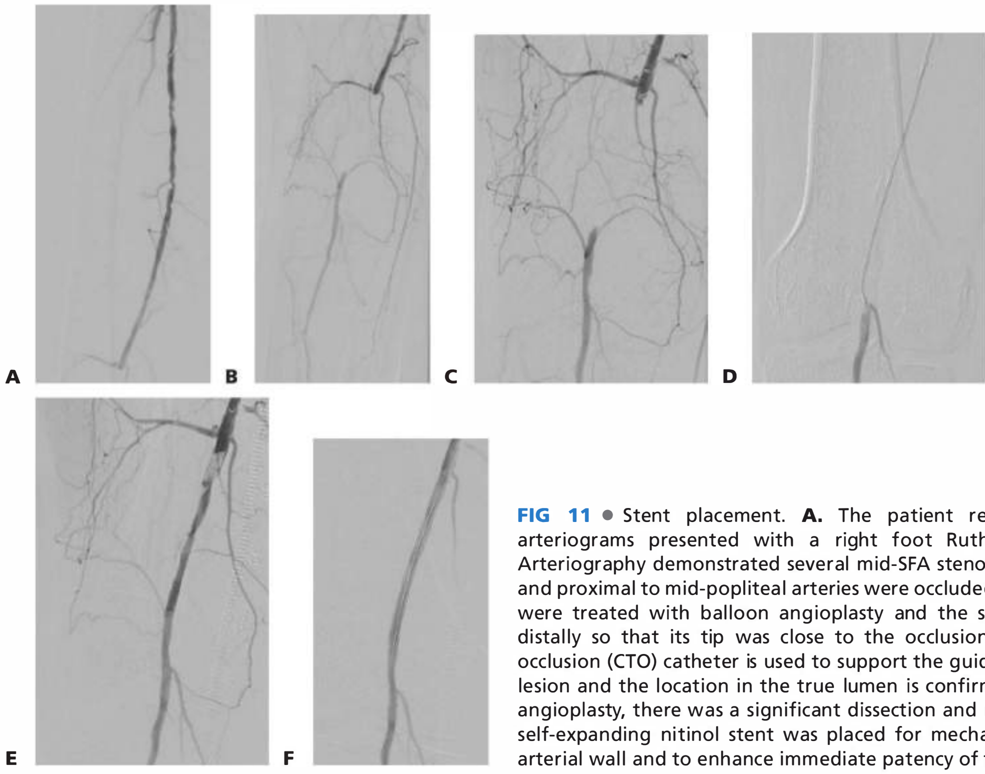

FIG 11 ● Stent placement. **A.** The patient represented by these arteriograms presented with a right foot Rutherford 5 gangrene. Arteriography demonstrated several mid-SFA stenoses. **B.** The distal SFA and proximal to mid-popliteal arteries were occluded. **C.** The SFA stenoses were treated with balloon angioplasty and the sheath was advanced distally so that its tip was close to the occlusion. **D.** A chronic total occlusion (CTO) catheter is used to support the guidewire in crossing the lesion and the location in the true lumen is confirmed. **E.** After balloon angioplasty, there was a significant dissection and residual stenosis. **F.** A self-expanding nitinol stent was placed for mechanical support of the arterial wall and to enhance immediate patency of the reconstruction.

stent coverage may accelerate long-term restenosis and luminal compromise, regardless of the degree of initial success or the type or size of deployed stent.

- Sheath size: Most stents for infrainguinal deployment require a 6- or 7-Fr sheath. Refer to the individual instructions for use for each individual device.
- Deployment: Most infrainguinal nitinol stents are deployed using a pin and pull maneuver that retracts the cover from the constrained stent and the underlying mandrel. A ratcheting mechanism may also be integrated into the deployment process. Typically, these may be removed for basic pin/pull deployment if the ratchet becomes jammed or disabled. After deployment, completion angioplasty is performed to bring the stent to profile.
- Complications of stent deployment:
  - Acute: arterial dissection, occlusion, rupture, stent migration or embolization, embolization of atherosclerotic material, thrombosis
  - Chronic: intimal hyperplasia, recurrent stenosis, infection, stent damage, thrombosis

STENT GRAFTS

- Nitinol-based, flexible stent grafts may be deployed over long and calcified SFA lesions as an alternative to bare metal or drug-eluting stents. As a general rule of thumb, the longer and more complex the target lesion(s) and length of required coverage, the more suitable the indication for covered stent placement.
- Stent grafting may require exchange of a 0.035-in wire system for smaller guidewires (e.g., 0.025 in or 0.018 in); the operator is again cautioned to refer to the instructions for use for each device considered for placement. Stent grafts must be deployed over the specific guidewire adequate for the stent graft. Sheath upsizing may also be required, depending on the diameter selected. Choosing a larger sheath at the outset will minimize the need for awkward or inefficient sheath exchange after the procedure is well underway. Aggressive predilatation is also often necessary in order to create sufficient space for bulkier covered stent to pass the lesion prior to deployment. Similar to bare metal stents, covered stent deployment is usually followed by completion angioplasty to bring the covered lumen to profile (**FIG 12**).
- Relative advantages of stent grafting, compared to bare metal stents, include the ability to create an entirely new lining for a disease arterial segment. This coverage obviates the possibility of in-stent stenosis within the graft. However, experience has shown that unlike surgically placed prosthetic bypass grafts, covered stents in the superficial femoral and popliteal arteries tend to incite restenosis at the proximal end. Thus, placement usually requires coverage up to the origin of the SFA. Any uncovered artery in this region is likely to develop critical restenosis. Disadvantages include the necessary coverage

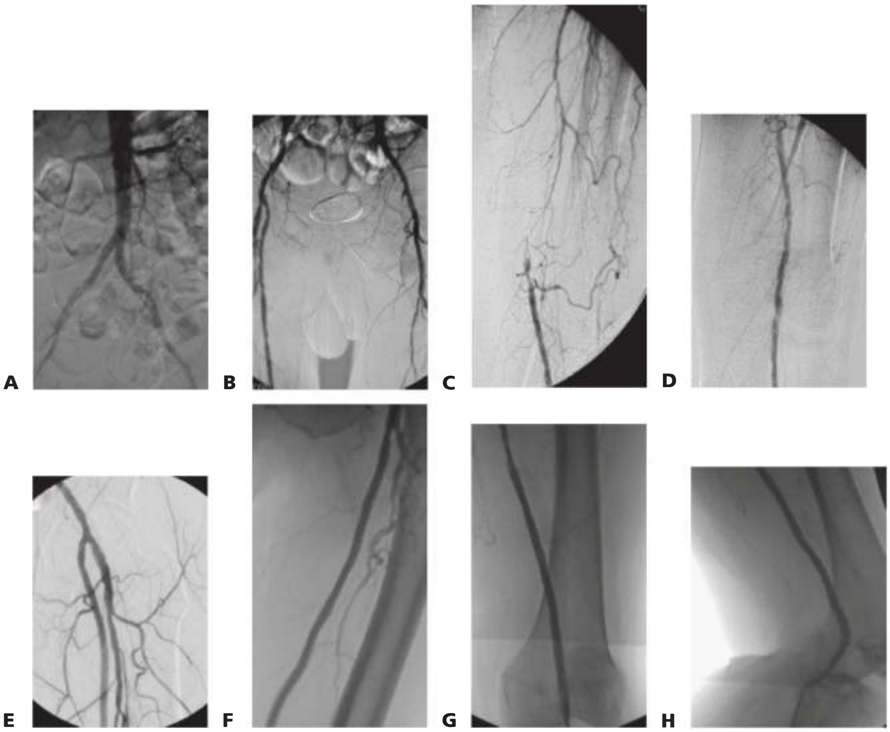

FIG 12 ● Stent graft. **A.** This patient has a long SFA occlusion that was relined with Viabahn® stent graft. An aortoiliac arteriogram was performed using contralateral access. **B.** The left SFA is occluded. There is a patent proximal stump of SFA. **C.** The point of reconstitution is the above-the-knee popliteal artery. **D.** The proximal popliteal artery, extending to the knee, is diffusely diseased. **E,F.** After recanalization and aggressive balloon angioplasty, the artery is reconstructed with Viabahn® stent graft placement. **G,H.** The distal end of the graft is fully dilated and without flow limitation in the straight leg and bent knee positions.

of all collateral vessels encompassed in the covered segment, as well as the increased risk for graft infection inherent in fabric-covered metal stents. Also, although some stent grafts are heparin-bonded, the thrombogenicity of covered stents varies directly with the length of segment covered, such that complete SFA coverage from the origin to the adductor canal necessitates long-term oral anticoagulation therapy in patients treated in our practice. Anticoagulation in this circumstance is designed to limit thrombus extension following future graft occlusion rather than increasing long-term graft patency. Anticoagulation does not typically extend prosthetic graft patency in the lower extremity, regardless of open or endovascular placement.

PEARLS AND PITFALLS

Indications	A complete vascular history is essential to accurately confirm the diagnosis. Objective evidence of ischemia is required to justify intervention and to provide a baseline for future comparison.
Artery puncture	The puncture is planned prior to the procedure. Access site issues are the most common type of complication. A well-performed access will set the procedure up for success.
Specific material	In planning the procedure, check to make sure that all the necessary inventory is available prior to the procedure.
Crossing the lesion	Do not force the wire across the lesion.
Closure	Closure devices can simplify the procedure and allow for more patient comfort and earlier discharge, but accurate CFA access should be confirmed, typically at the outset of the procedure, before therapeutic sheaths are placed.
Follow-up	The patient is evaluated after the procedure at 1 week and 1 month and then 6-month intervals after that. We typically obtain some assessment of perfusion (ABI). Duplex mapping may also be performed for surveillance.

POSTOPERATIVE CARE

- The patient should remain at bedrest for at least 6 hours after the procedure. After use of a closure device, usually 2 hours of bedrest is required.
- Puncture site management: Obtaining hemostasis is made safer and simpler when the arteriotomy site is carefully managed during the procedure. Ensure the patient is comfortable prior to removing the sheath.
- Holding pressure: After ipsilateral antegrade puncture, use two hands to hold pressure, one is placed proximal to the inguinal ligament to apply pressure over distal external iliac artery to decrease the pressure flowing through the puncture. The other hand applies pressure over the area of arterial puncture just distal to the inguinal ligament. There are no approved closure devices for antegrade puncture. Following a retrograde puncture, digital pressure is held at the location of arteriotomy, proximal to the skin puncture site.
- Closure devices: Closure devices are used whenever possible to reduce risk of access site complications and limit patient immobility following the procedure. Newer generations of closure devices are easier to use and are considered a good option for closing the arteriotomy in puncture procedures for 6 Fr and larger.
- The patient should be encouraged to
  - Avoid smoking
  - Walk daily
  - Follow best medical treatment
  - Follow-up with the vascular clinic

OUTCOMES

- Patients with peripheral artery disease (PAD) and critical limb ischemia (CLI) have a shorter life expectancy than the general population. The most effective method of revascularization that returns patients to their premorbid functional state in the shortest period of time, with the least amount of surgical risk, is considered ideal. In this regard, most centers have adopted a percutaneous-first approach to lower extremity revascularization, when intervention is indicated.[5] This rubric reserves open surgical reconstruction for patients who fail percutaneous intervention. More recently, controversy has arisen as to how many unsuccessful secondary interventions constitute "failure."
- Successful percutaneous revascularization is considered equivalent to traditional standard management strategy—that is, bypass surgery—in providing freedom from major and minor amputation, in patients with severe limb ischemia, up to 2 years following revascularization. To date, the Bypass versus Angioplasty in Severe Ischemia of the Leg (BASIL) trial remains the only randomized prospective trial comparing the success of open surgical bypass versus endovascular therapy for CLI. When life expectancy extends beyond 2 years, bypass patency is superior.[6]
- Although percutaneous transluminal angioplasty (PTA) provides superior limb salvage rate and assisted patency rates than prosthetic bypass, care should be taken to avoid outcomes that limit future bypass options (e.g., injury or occlusion of significant infrageniculate arteries that could serve as future bypass targets). Modern surgical practice should incorporate a full range of postprocedural outcomes, beyond arterial patency alone, in the assessment of procedural success. As such, consideration to postoperative ambulatory status, potential for independent living, wound care requirements, and pain management is essential and comparable to the impact on graft patency on long-term patient satisfaction and quality of life.[7]
- A comparison of self-expandable stents versus femoral–popliteal above-the-knee bypass had been published by Kedora et al., reporting similar limb salvage, with comparable primary (73.5% vs. 74.2%) and secondary patency rates (83.9% vs. 83.7%) at 1 year with both techniques.[8]
- Others studies reported that despite the reduced primary patency, limb salvage rates remain comparable to surgical bypass and range from 74% at 5 years to 84.7% at 8 years.[9]
- Lower limb revascularization of diabetic patients affected by intermittent claudication, in addition to improved walking performance, is associated with a reduction in the incidence of future major cardiovascular events when accompanied by increased physical exercise and improved glucose management and weight control.[10]

FIG 13 ● Complications. Hematoma is the more common access site complication and most common complication of endovascular procedures.

COMPLICATIONS

- Artery puncture: hematoma, occlusion, dissection, pseudoaneurysm, arteriovenous fistula (**FIG 13**)
- Failure of recanalization: intimal dissection, branch occlusion, thrombosis, embolization, vessel rupture, remote hemorrhage
- Stent/stent graft complications: stent embolization, stent will not expand lesion, stent kink, stent thrombosis
- Infection

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Chapter 31 Maximizing Vein Conduit for Autogenous Bypass

Gregory J. Landry

DEFINITION

- Autogenous conduit is preferred for all lower extremity bypasses when available. The greater saphenous vein (GSV) is the most frequently used conduit. Other options for native conduit include the short saphenous vein, arm vein (basilic, cephalic, brachial), and femoral vein.

DIFFERENTIAL DIAGNOSIS

- The majority of patients for whom autogenous vein bypass is necessary will have atherosclerotic peripheral vascular disease.
- Other conditions for which autogenous vein bypass may be necessary include aneurysms (e.g., femoral, popliteal), trauma, and vasculitis.

PATIENT HISTORY AND PHYSICAL FINDINGS

- A history of cardiovascular risk factors should be elicited in all patients undergoing lower extremity bypass, including smoking history and history of cardiac and cerebrovascular disease and history of diabetes, chronic kidney disease, hyperlipidemia, and chronic obstructive pulmonary disease.
- Upper and lower extremity pulse exam should be performed. Because atherosclerosis is a systemic disorder, the following pulses should be assessed bilaterally: carotid, brachial, radial, femoral, popliteal, dorsalis pedis, and posterior tibial. Both the presence and strength of pulses should be recorded.
- If lower extremity pulses are absent, which is usually the case in patients undergoing surgery for peripheral vascular disease, ankle–brachial indices should be measured. The highest ankle pressure is divided by the highest brachial pressure.
- Lower extremities should be evaluated for the presence of ulcerations or gangrene.
- A history of prior vein use or removal should be elicited. Veins may have previously been used for prior lower extremity or coronary artery bypass. Patients with varicose veins may have undergone prior vein stripping or ablation. Patients with chronic kidney disease may have had prior upper extremity arteriovenous fistula placement. In dialysis-dependent patients, upper extremity veins should be used judiciously as they may be necessary for future arteriovenous access.

IMAGING AND OTHER DIAGNOSTIC STUDIES

- All patients considered for lower extremity bypass should undergo arteriography to define the proximal (inflow) and distal (outflow) targets.
  - Digital subtraction angiography remains the gold standard and provides the greatest anatomic detail for operative planning.
  - Alternative imaging modalities include computed tomography (CT) and magnetic resonance (MR) angiography or duplex ultrasonography.
- Duplex ultrasonography should be used for preoperative vein mapping to identify suitable autogenous conduit (**FIG 1**). If the patient has good-quality GSV, no further vein mapping is typically necessary. If the GSV is of poor quality or absent, small saphenous vein and arm vein should be mapped (**FIG 2**).
  - Ideal conduit diameter is 3.5 mm or greater.
  - Vein should be easily compressible. Thick-walled or noncompressible vein indicates prior superficial venous thrombosis and vein is likely not suitable for bypass.
  - Mapping should ideally immediately precede surgery with vein course marked with an indelible marker on the skin. This allows precise placement of incisions, which avoids the creation of skin and tissue flaps that might impede wound healing.

SURGICAL MANAGEMENT

- Preoperative planning
  - If not previously marked or if marks have faded, it is useful to remark the intended venous conduit with ultrasound guidance prior to surgery (**FIGS 3 and 4**).
  - Open foot lesions or gangrene should be covered with sterile adhesive to prevent contamination of sterile incisions.
  - Prophylactic intravenous antibiotics should be administered to reduce risk of perioperative infection.

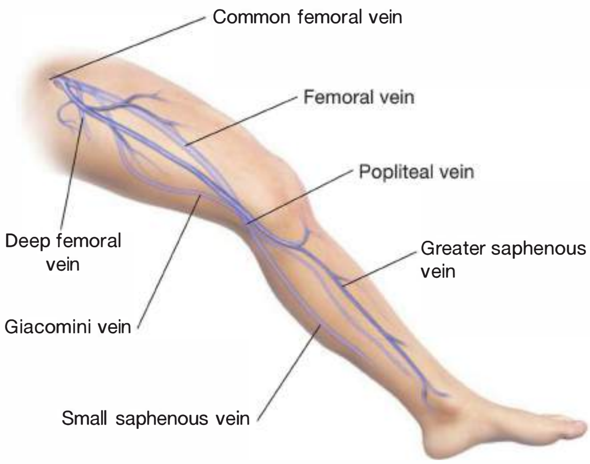


FIG 1 ● Lower extremity venous anatomy.

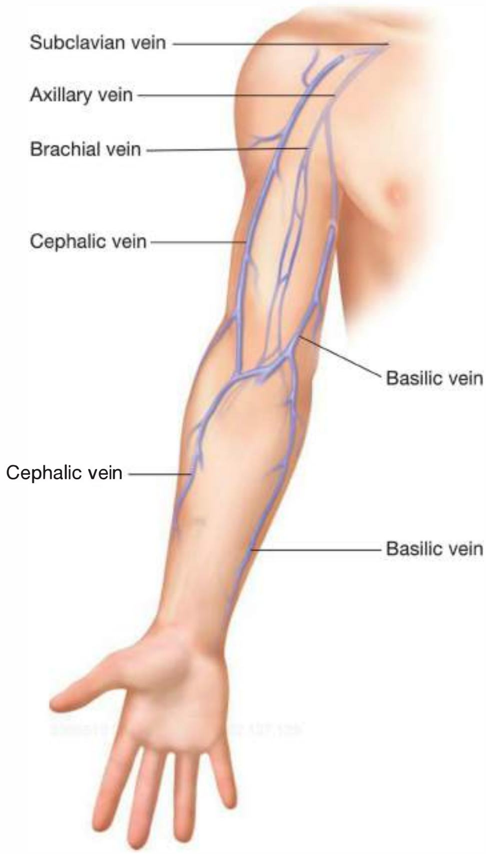


FIG 2 ● Upper extremity venous anatomy.

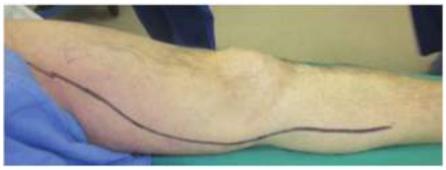


FIG 3 ● Lower extremity vein mapping with marking of GSV.

- If arm vein is to be harvested, it is important to avoid blood draws or intravenous lines in the intended arm(s). If veins from both arms are necessary, central venous access may be necessary.
- Positioning
  - The majority of the procedures are performed with the patient supine. If small saphenous vein is the intended conduit, it is often easier to perform this part of the procedure with the patient prone and then to reprepare and drape with the patient supine.
  - If arm vein is to be harvested, the arms should be abducted and placed on arm boards.

FIG 4 ● Upper extremity vein mapping with marking of the cephalic and basilic veins.

- Open vein harvest: GSV
  - A longitudinal incision is made directly over the marked vein. Either a single incision or multiple skip incisions can be used, with some evidence of fewer wound infections with the latter approach (FIG 5).
  - The necessary length of vein is unroofed. Using blunt and sharp dissection with Metzenbaum scissors, the vein is freed from surrounding structures. Side branches are ligated and divided with silk ligatures and hemoclips.
  - The GSV is divided proximally at the saphenofemoral junction (FIG 6), distally according to the length of vein needed.
  - It is helpful distally to identify a branch point in the vein that can subsequently be used for the proximal anastomosis if the graft is placed in reversed configuration (FIG 7A,B).
- Open vein harvest: small saphenous vein
  - The same technique is used as for the GSV, except typically with the patient prone.
  - Proximally, the vein is typically divided at the saphenopopliteal junction. Some patients will have continuation of the small saphenous vein in the thigh (Giacomini vein) which allows harvesting additional length of vein in the thigh.

FIG 5 ● Open GSV harvest through skip incisions. The vein is encircled with silastic vessel loops.

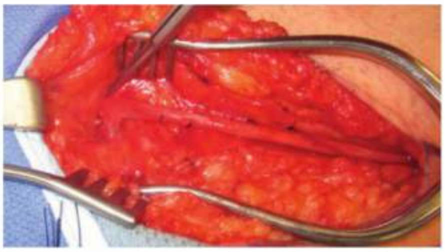
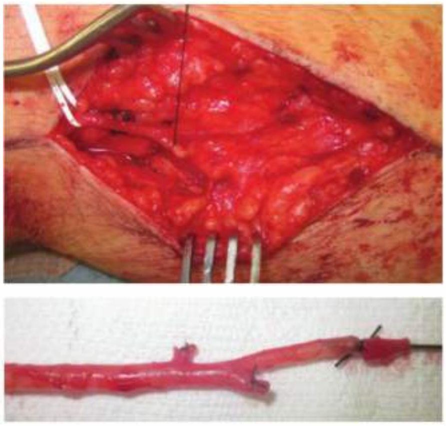


FIG 6 ● GSV mobilized proximally to saphenofemoral junction. Side branches ligated with silk ligatures.



A

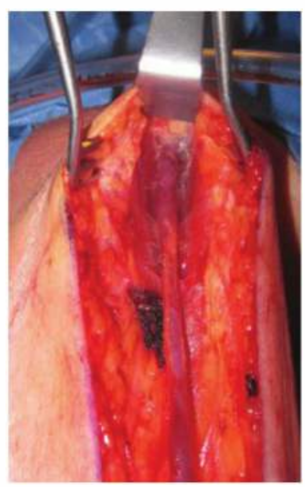
B

FIG 7 ● **A,B.** Distal GSV divided at branch point to provide starting spot for proximal anastomosis of reversed vein graft.

- Open vein harvest: arm vein
  - Both the cephalic and basilic veins can be harvested through longitudinal arm incisions. The same technique is used as for leg vein; however, care must be taken as the arm veins tend to be more thin walled and fragile than leg vein.
  - The cephalic vein can frequently be harvested as a single conduit from the wrist to the deltopectoral groove (**FIG 8A–C**). A single segment is frequently adequate for a femoral–popliteal or femoral to proximal tibial bypass.
  - The basilic vein tends to be larger in diameter than the cephalic vein, although often, only a short segment in the upper arm is available. The basilic vein is well suited for use as an extension graft when revision of a previously placed bypass is necessary. When used as a new bypass, a composite graft composed of two or more vein segments is frequently necessary.
  - The basilic vein often has large branches that communicate medially with the brachial vein. These branches are often broad based and are better ligated with a running monofilament suture than simple ligation.
  - The median antebrachial cutaneous nerve frequently interdigitates with the basilic vein. With meticulous dissection, this nerve can be preserved (**FIG 9**).
  - Brachial vein is intimately associated with both the brachial artery and median nerve. This vein can also be harvested as conduit, but great care needs to be taken to avoid injury to adjacent structures (**FIG 10**).
- Open harvest: femoral vein
  - Although typically used for larger vessel reconstruction, femoral vein can be used for autogenous lower extremity bypass if necessary.
  - Proximal femoral vein is harvested medial to Sartorius muscle. Vein is adjacent to superficial femoral artery. Vein can be harvested proximally up to the profunda femoral vein.
  - Distally, the femoral vein is easier to harvest with the Sartorius muscle reflected posteriorly. The vein can easily be harvested as far as the adductor canal.
  - If a longer segment is needed, the vein can be further harvested caudal to the adductor tendon into the popliteal fossa.
- Endoscopic harvest: GSV
  - Endoscopic harvest works best for veins within the saphenous fascial envelope (**FIG 11A**). It is technically more difficult in cases where the vein leaves this fascial envelope and is situated more

A

B



C

FIG 8 ● **A.** Cephalic vein harvested the full length of the arm with skin bridge at antecubital fossa. **B.** Upper arm cephalic vein. **C.** Cephalic vein harvested medially to deltopectoral groove.

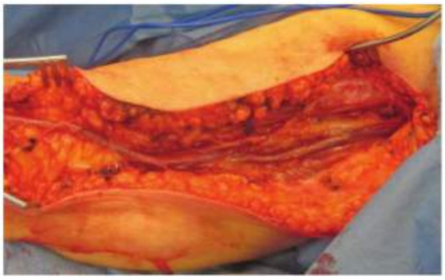


FIG 9 ● Basilic vein harvested in upper arm. Median antebrachial cutaneous nerve adjacent to and interdigitating with vein.

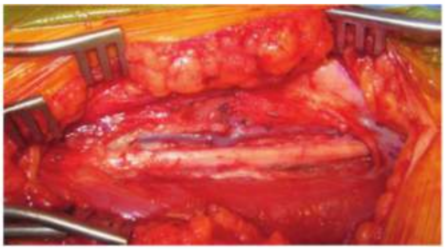


FIG 10 ● Brachial vein harvest with vein adjacent to median nerve. Brachial artery deep to nerve.

superficially or in the subcutaneous fatty tissue (**FIG 11B**).

- Available harvesting systems are described in Table 1.
- A 2-cm incision is made at the level of the knee and the GSV dissected free at this site and encircled with a silastic vessel loop (**FIG 12**).
- The vein is dissected from the knee to the saphenofemoral junction using a conical dissecting tip (**FIG 13**). CO_2 insufflation is performed through an inflatable trocar.
- The vein is held in place with the C-ring or V-lock mechanism and side branches are divided with bipolar electrocautery or harmonic scissors depending on the manufacturer (**FIG 14**).
- Harvesting can also be performed in the calf; however, this is more technically challenging due to multiple geniculate venous branches, subcutaneous position of vein, and close approximation with saphenous nerve.
- If an incision in the groin is going to be made for the proximal anastomosis of the graft, the incision can be made at this point to complete the proximal harvest. If an incision is not going to be made in the groin, a stab incision is made in the groin and the vein grasped under direct vision with a tonsil clamp.

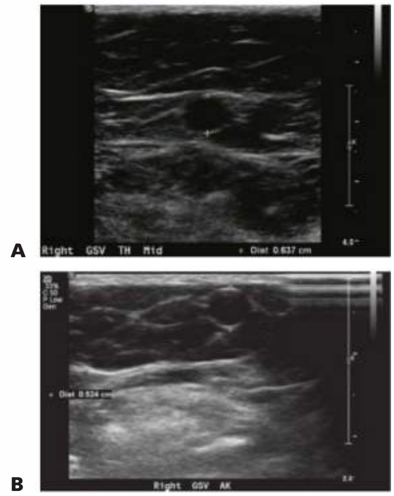


FIG 11 ● **A.** GSV (marked by *cursors*) within the saphenous fascial envelope suitable for endoscopic vein harvest. **B.** Subcutaneous GSV outside of saphenous fascial envelope, less suitable for endoscopic harvest.

FIG 12 ● A 2-cm incision at the level of the knee through which GSV (encircled with silastic loop) dissected for endoscopic harvest.

FIG 13 ● Conical dissecting tool mounted on camera used to isolate GSV. Operator standing opposite screen depicting endoscopic image.

Table 1: Endoscopic Vein Harvesting Systems

Manufacturer	Device	Dissecting Tool	Vein Securing	Side Branch Ligation
Maquet	Vasoview	Conical tip	C-ring	Bipolar ligating forceps
Maquet	Vasoview Hemopro	Conical tip	C-ring	Thermostatic cut and seal
Terumo	VirtuoSaph	Conical tip	V-lock	Bipolar cut and coagulation

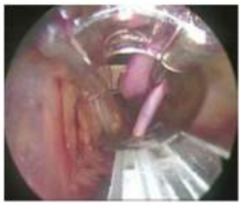


FIG 14 ● GSV held in plastic cradle while side branch ligated and divided with bipolar electrocautery.

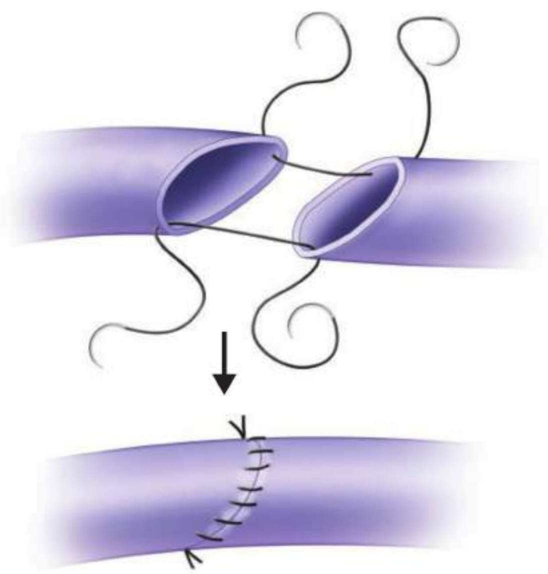
The vein is then pulled through the incision and ligated and divided with silk ligatures.

- After proximal division, the vein can be pulled out of the tunnel through the knee incision.
- A below-knee incision can be made to harvest the distal vein if this incision is already intended for the distal anastomotic site.

- Back-table vein preparation
  - Harvested veins are prepared on a back table (**FIG 15**). Veins are distended with the surgeon's solution of choice. The author prefers using chilled, heparinized autologous blood, although heparinized saline is also sufficient.
  - Any side branches not ligated during the initial harvest are ligated with silk ligatures or, if too small or short, with 7-0 polypropylene suture.
  - For endoscopically harvested veins, because the side branches are not ligated during the initial harvest, they are ligated at a back table with silk ligatures or 7-0 polypropylene suture after vein removal.

FIG 15 ● Back-table preparation of harvested vein.

- Composite graft creation
  - A venovenostomy can be performed with two (or more) venous segments to create a single conduit of adequate length. The vein of larger diameter should be placed proximally. The veins are spatulated and sewn end-to-end with running 7-0 polypropylene suture (**FIG 16A–E**). Additional vein segments can be added as necessary with the same technique to create a conduit of adequate length.
- Graft tunneling
  - Grafts are best tunneled using a hollow tube tunneler, such as a Scanlan tunneler, in order to avoid unnecessary tension on the vein as it is pulled through the subcutaneous tissue. This is particularly important in a composite graft where suture line disruption can potentially occur.
  - Tunneling performed after the proximal anastomosis allows the graft to be passed under pressure,



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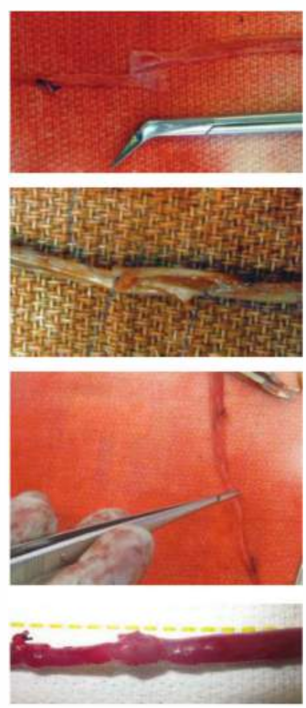


B C D E

FIG 16 ● **A.** Diagram depicting vein splicing. **B.** Splicing of arm veins to create single conduit. Veins spatulated with Potts scissors. **C.** A 7-0 polypropylene suture placed to approximate the heel and toe of the two veins. **D.** Venovenostomy performed with running suture. **E.** Final spatulated venovenostomy.

FIG 17 ● Anatomic tunnel through popliteal fossa for femoral to below-knee popliteal artery bypass.

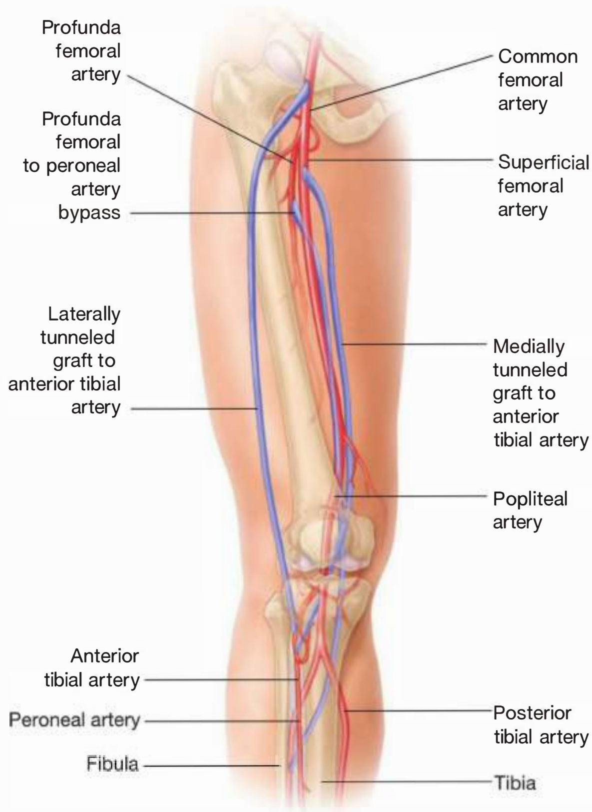
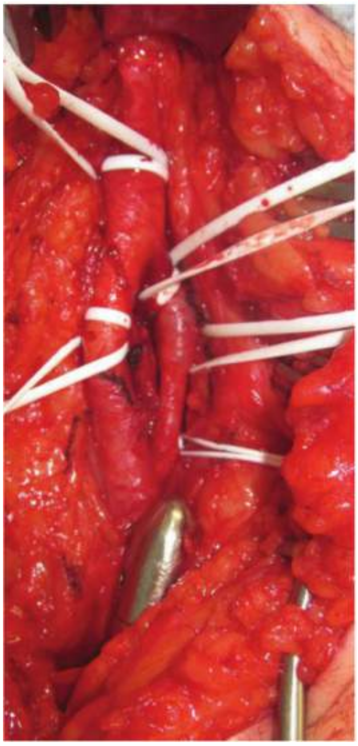


FIG 18 ● Diagram depicting tunneling options for tibial grafts.

which lessens the likelihood of twisting or kinking during tunneling.

- In a first-time bypass, tunneling anatomically through the popliteal fossa for below-knee targets provides the most direct route to maximize vein length (**FIG 17**). In redo procedures in which previous grafts were tunneled through the popliteal fossa, a subcutaneously tunneled graft may be necessary.
- Two options exist for grafts tunneled to the anterior tibial artery. For grafts based on the common femoral artery, a lateral, subcutaneously tunneled graft is the most straightforward. For grafts based further distally on the superficial femoral or profunda femoral arteries, an anatomic tunnel through the popliteal fossa and interosseous membrane is more direct and maximizes vein length. The interosseous membrane should be directly visualized and a cruciate incision made to prevent graft stricture. Grafts to the posterior tibial or peroneal artery are tunneled either through the popliteal fossa or medially and subcutaneously (**FIG 18**).

- Choice of proximal anastomotic site
  - The choice of proximal anastomotic site depends on the anatomy and vein length and quality.
    - If adequate vein length is present, an anastomosis to the common femoral artery is generally preferred.
    - If vein length is insufficient, the graft can be based on either the superficial or profunda femoral artery. For patients with atherosclerotic lower extremity arterial occlusive disease, the profunda femoral artery is more likely to be better preserved than the superficial femoral artery, which is more likely to be affected by atherosclerosis (**FIG 19A,B**).
    - In the presence of common femoral or proximal profunda femoral artery stenosis, a common and/or profunda femoral endarterectomy with placement of a vein or prosthetic patch (Linton patch) can provide adequate inflow for the graft, with the proximal anastomosis to the distal end of the patch (**FIG 20**).
    - In patients with patent superficial femoral arteries and more distal tibial artery disease, as is often seen in patients with diabetes, grafts may be based on either the above- or below-knee popliteal artery.
    - For patients requiring tibial or pedal bypasses with insufficient vein length, the superficial femoral artery can be treated with angioplasty with or without stenting to provide inflow for a graft based on the above- or below-knee popliteal artery. This is ideally performed either in a hybrid operating room (OR) suite or in a standard OR with C-arm fluoroscopy.
- Choice of distal anastomotic site
  - In general, the shortest bypass configuration that provides adequate distal flow is chosen.
    - If direct runoff to the foot can be achieved through a bypass to the popliteal artery, this is preferred.
    - If the popliteal artery is occluded and a tibial artery serves as the distal target, a direct angiosome revascularization should be chosen if possible in cases of foot ulcers or ischemia. For rest pain or claudication, the dominant tibial vessel should be chosen.
- Proximal anastomosis
  - Proximal and distal arterial control is obtained with atraumatic vascular clamps, silastic loops, or Fogarty catheters as needed and per surgeon's choice.



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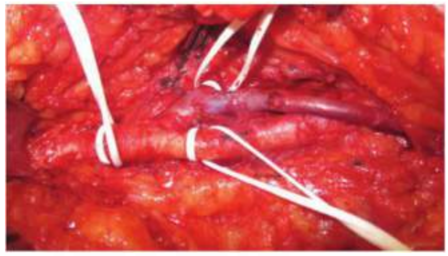

B

FIG 19 ● **A.** Common, superficial, and profunda femoral arteries dissected for proximal anastomosis. Vessels encircled with silastic loops. **B.** Proximal anastomosis to profunda femoral artery in patient with inadequate vein length to base graft on common femoral artery. Note tunneling device in subsartorial position.

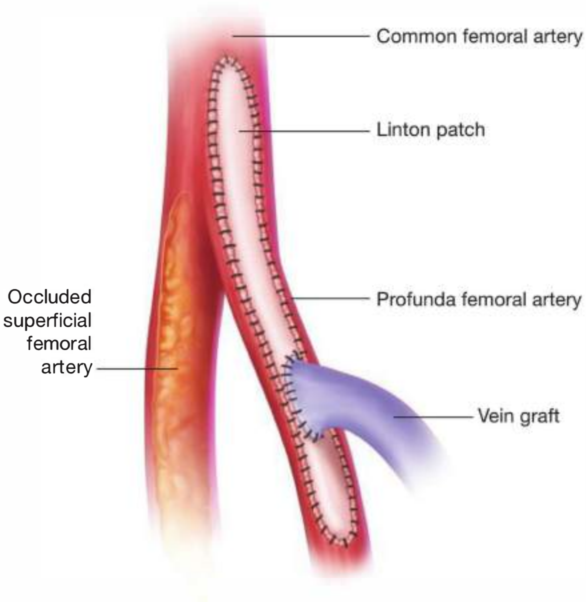

FIG 20 ● Diagram of Linton patch on common and profunda femoral arteries from which proximal anastomosis of bypass is based.

    - The anastomotic arteriotomy is made with a no. 11 scalpel and extended with Potts scissors. The arteriotomy length should be about 1.5 to 2 times the diameter of the vein.
    - The proximal anastomosis is ideally performed using a vein branch as the heel in order to avoid heel stricture (FIG 21). The vein is spatulated through the heel (FIG 22A–C).
    - The anastomosis is performed with running polypropylene rule. As a rule of thumb, suture diameter is 4-0 in the iliac artery, 5-0 femoral, 6-0 popliteal, and 7-0 tibial (FIG 23).
- Distal anastomosis
    - This is performed in similar fashion to the proximal anastomosis, although spatulation through a side branch is generally not possible and less necessary as for the proximal anastomosis, because the graft toe geometry is more important for patency than the heel geometry in the outflow (FIG 24).
- Intraoperative assessment
    - Augmentation of Doppler signals at the ankle with the graft open compared to the graft occluded generally indicates graft patency with improved arterial perfusion. Intraoperative duplex or arteriography should also be considered to rule out technical problems with the graft.

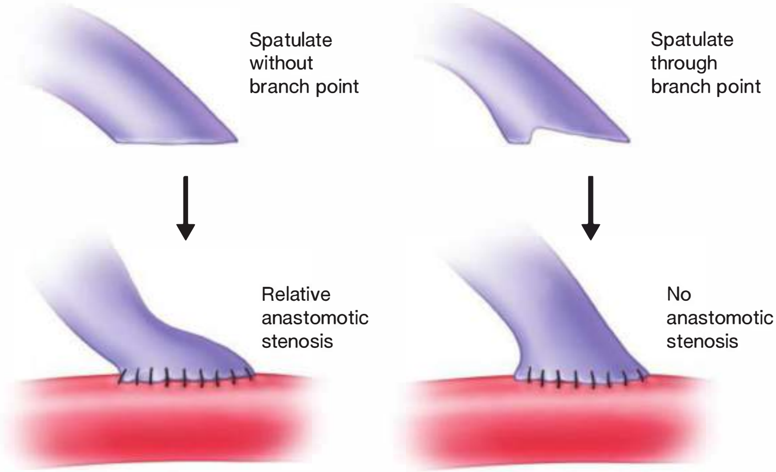

FIG 21 ● The vein is spatulated through a branch point to avoid a stricture at the heel of the proximal anastomosis, which can occur if a side branch is not used.

A

B

C

FIG 22 ● **A.** Preparation of vein for proximal anastomosis. If possible, side branch is chosen for heel of proximal anastomosis to prevent anastomotic stricture. **B.** Vein spatulated with Potts scissors through branch point. **C.** Spatulated vein prepared for proximal anastomosis.

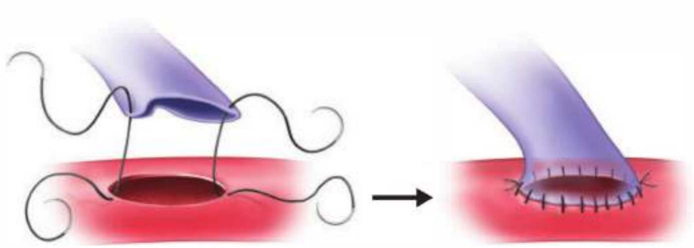

FIG 23 ● Diagram demonstrating proximal graft anastomosis.

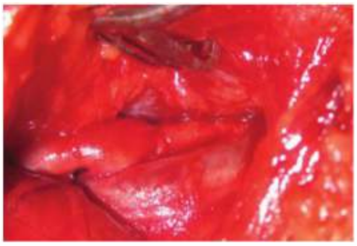

FIG 24 ● Distal anastomosis to below-knee popliteal artery.

PEARLS AND PITFALLS

Open vein harvest	■ Preoperative vein mapping is important to localize the site of the incision to avoid tissue flaps that can lead to poor wound healing. ■ Vein branches should not be ligated flush with the vein as "dimpling" can occur when the vein is distended. It is good to ligate the vein branch at least 1 mm away from the vein to allow proper vein expansion (**FIG 25**). ■ Arm veins tend to be more fragile than leg veins, requiring gentler handling during harvest.
Endoscopic vein harvest	■ Avoid harvesting veins that are subcutaneous or not enclosed within a fascial envelope as these are technically more difficult to harvest and therefore more prone to injury.
Vein preparation	■ Avoid overdistending the vein during preparation. A good technique is to inject a small amount of fluid into the vein and then manually distending the vein in segments rather than trying to inflate the vein with the syringe.
Graft tunneling	■ Passing the graft while distended reduces the risk of twisting or kinking. ■ Using a sterile marking pen, a line can be drawn on the anterior surface of the vein to help orient the graft distally and prevent twisting.
Anastomotic placement	■ Severely diseased vessels tend to delaminate when handled. Great care must be taken to include all layers in the anastomosis to prevent dissection. ■ In severely calcified vessels, vessel loops may not provide adequate control and vascular clamps may cause a crush injury. In these cases, Fogarty balloons may be needed for arterial control.

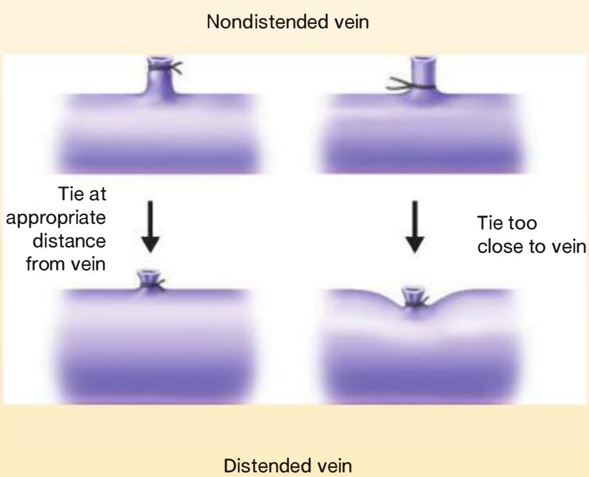

FIG 25 ● "Dimpling" can occur with graft distention if side branch tie is too close to vein.

POSTOPERATIVE CARE

- Patients should be monitored postoperatively in either an intensive care unit or a surgical ward. Hourly vascular checks should be performed with continuous wave Doppler.
- Early ambulation, generally on the first postoperative day, is encouraged, particularly in patients with claudication or rest pain. Patients with ulcers or gangrene may require a longer period of non–weight bearing if lesions are on a weight-bearing surface.

OUTCOMES

- Anticipated 3-year primary patency rates for reversed saphenous vein grafts are 70% to 80% for femoral–popliteal and 60% to 75% for femoral–tibial. Comparable patency rates for arm vein bypasses are 60% to 70% and 50% to 60%, respectively, and for prosthetic grafts, 45% to 65% and 20% to 30%, respectively. Anticipated 5-year limb salvage in patients with critical limb ischemia is 80% to 90%, with 5-year survival in 40% to 70%.[1–5]
- Reversed and in situ vein grafts have been shown to have comparable patency rates in multiple studies.[6]
- Ambulatory function and independent living status is preserved in the majority of patients who undergo successful revascularization.
- Quality of life measures are improved in the majority of patients who undergo successful revascularization.[7]
- Up to 20% of patients will develop vein graft stenoses requiring either open or endovascular revision during follow-up.
- Data on patency rates of open versus endoscopically harvested vein grafts are mixed, making definitive recommendations on the preferred approach difficult.

COMPLICATIONS

- Wound infection
- Seroma
- Hematoma
- Graft occlusion
- Myocardial infarction

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Chapter **32**

Tibial Interventions: Tibial-Specific Angioplasty Considerations and Retrograde Approaches

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DEFINITION

- Endovascular tibial intervention is a minimally invasive, endoluminal revascularization of the infrapopliteal vessels. It is an accepted treatment of critical limb ischemia (CLI) in patients with tibial occlusive disease. It is usually performed from a transfemoral access (antegrade approach) and, in selected cases, from transpedal or tibial access (retrograde approach).
- Therapeutic interventions performed in tibial arteries include balloon angioplasty, drug-eluting balloon angioplasty, stenting, and atherectomy.
- Procedures are most commonly performed under local anesthesia with moderate conscious sedation in a fixed-imaging hybrid operating room or in the interventional angiography suite. Portable imaging systems may also provide sufficient resolution for precise, image-guided intervention depending on circumstances.

FIG 1 ● **A.** Patient with tibial occlusive disease and ischemic right first toe ulceration. Rutherford class 5. **B.** Patient with severe multilevel occlusive disease with gangrene of the left first toe and ulcerations on the dorsum of the foot. Rutherford class 6.

DIFFERENTIAL DIAGNOSIS

- Neuropathic pain is commonly described as burning sensation, stabbing, or aching pain that is commonly accompanied by numbness or hypoesthesia. Diabetic neuropathy is probably most common and is frequently nocturnal as well. The symptom complex of diabetic neuropathy may be confused with ischemic rest pain or metatarsalgia, given the similar dermatomal distribution and overlapping risk factors.
- Venous ulcers are associated with skin pigmentation, induration from chronic venous hypertension, and inflammation. They develop primarily in the perimalleolar region of the ankle and usually do not involve the forefoot.
- Musculoskeletal pain resulting from mechanical etiology, stress fracture, arthritis, and plantar fasciitis
- Soft tissue infection and malperforans ulcers in diabetic patients with advanced sensory neuropathy and/or Charcot deformity of the foot
- Chronic, nondiabetic peripheral neuropathies such as dorsal foot paresthesias and dysesthesias following long saphenous vein harvest

PATIENT HISTORY AND PHYSICAL FINDINGS

- Patients with infrainguinal occlusive disease present with symptoms of claudication (Rutherford ischemia classification categories 1, 2, and 3), ischemic rest pain, or tissue loss (Rutherford categories 4, 5, and 6). When the atherosclerotic disease is limited to the infrapopliteal arterial segments, pain is mainly located in the forefoot. Advanced arterial insufficiency can also lead to ischemic ulceration, gangrenous changes, and nonhealing wounds. This constellation of symptoms represents CLI and typically occurs when the ankle pressure is less than 50 mmHg, the ankle–brachial index (ABI) is less than 0.4, and the great toe pressure is less than 30 mmHg (**FIG 1A,B**).
- CLI with tissue loss often occurs in the setting of multilevel arterial occlusive disease. In the case of isolated diabetic tibial occlusive disease, femoral, and frequently popliteal, pulses remain palpable. In either circumstance, limb-threatening ischemia may ensue. In the latter circumstance, multilevel approaches to complete revascularization, either staged or simultaneous, should be pursued.
- Neurovascular exam, with particular focus on the wound location and the extent of tissue loss, should be evaluated and documented. Probably, the most deterministic variable is the extent of tissue loss—Wagner wound classification, the presence and severity of osteomyelitis, exposure or involvement of the calcaneus bone, residual intact skin on either the dorsal or plantar foot. These conditions all impact decision making and clinical outcome.
- Patient functional capacity also plays an important role in the therapeutic strategy. Options and outcome goals vary substantially between ambulatory and nonambulatory patients.

IMAGING AND OTHER DIAGNOSTIC STUDIES

- Pulse volume recordings (PVRs) (**FIG 2**)
- Duplex (**FIG 3**)

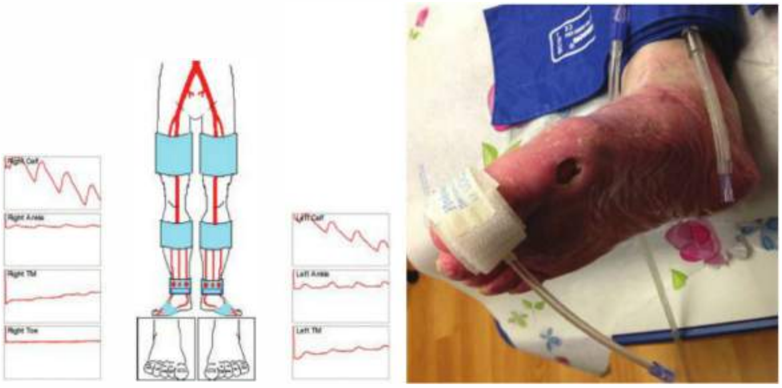

FIG 2 ● PVR on a patient with severe right tibial occlusive disease and nonhealing toe ulcer. The tracings are pulsatile at the calf level consistent with adequate femoropopliteal flow; however, the waveforms are flat, distally suggestive of tibial occlusive disease.

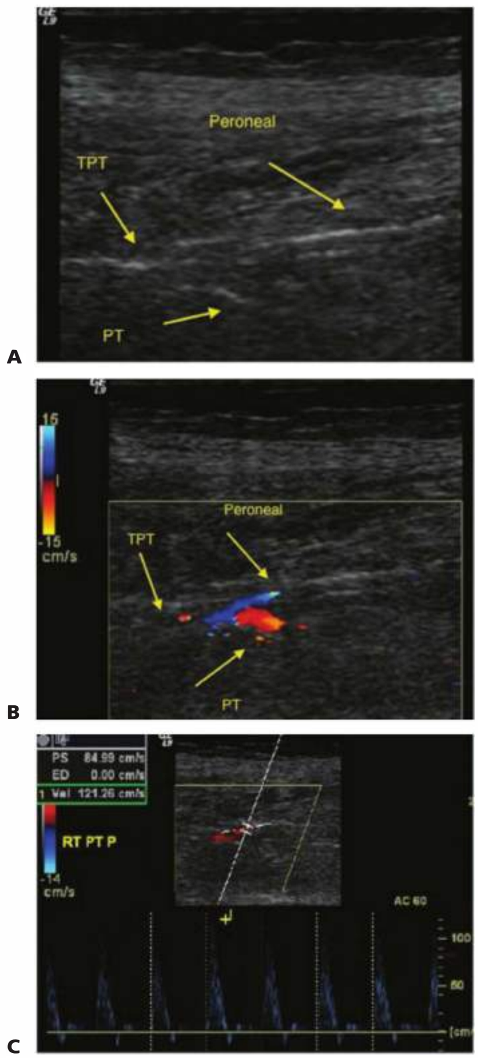

FIG 3 ● **A.** Duplex B-mode image shows the calcified tibioperoneal trunk bifurcation into the posterior tibial artery and peroneal artery. **B.** Duplex of the tibioperoneal trunk bifurcation shows flow into the posterior tibial artery. **C.** Duplex of the proximal posterior tibial artery shows normal triphasic Doppler waveform.

- Computed tomography (CT) and magnetic resonance (MR) angiograms can be obtained; however, their diagnostic use in planning tibial interventions is frequently limited by the imprecision of bolus timing with distal extremity cross-sectional imaging techniques, heavy medial calcification frequently present in target arteries, and the diminutive size of reconstituted target arteries, which may be present in the peri- and inframalleolar regions.
- Catheter-directed, intraarterial angiography remains the gold standard imaging study for tibial occlusive disease for both diagnostic and therapeutic purposes (**FIG 4**).

SURGICAL MANAGEMENT

- Technical skills, careful planning, and knowledge of the relevant arterial anatomy determine tibial revascularization strategies for limb salvage. Current controversies include the potential value of restoring patency in more than one tibial vessel to optimize blood flow and maximize the chances of

FIG 4 ● Selective left leg angiogram shows patent popliteal artery, patent tibioperoneal trunk, complete occlusion of the anterior tibial artery, and complete occlusion of the peroneal artery.

wound healing. Proponents of this approach reference the "angiosome" concept of the foot or the idea that specific skin regions derive primary perfusion from end-arterioles arising primarily from either the dorsal pedal or posterior tibial arteries as they cross the ankle. This practice is pursued in marked contradistinction to the open surgical imperative to restore in-line flow to the foot in the single largest, most continuous crural artery. The many advantages of endovascular reconstruction techniques in tibial reconstruction include restoring partial flow in multiple target arteries as compared to a single artery following surgical bypass, as well as opportunities to repeat procedures with relatively simple outpatient interventions as needed, to maintain patency and skin integrity. Treatment decisions regarding revascularization strategy in individual circumstances should be guided by patient-specific anatomic considerations, arterial runoff into the foot, patient habitus and ambulatory status as well as patency and feasibility considerations related to either open or endovascular options.

- Currently available endovascular technology facilitates successful treatment of complex occlusive lesions at and below the malleolar level. Technical limitations remain, however, highlighted by risks of arterial perforation (**FIG 5**), difficulty in true lumen reentry in complete occlusions (**FIG 6**), procedure-related distal arterial embolization, and limited pedal vessel outflow in certain circumstance.
- The retrograde or SAFARI (SubintimAl Flossing with Antegrade-Retrograde Intervention) tibial intervention technique may improve technical results in challenging lesions, particularly those resistant to ipsilateral antegrade access, including flush occlusions at the origin of the target artery or with large collateral arteries adjacent to the occluded origin. In nearly every circumstance, even chronic and recalcitrant occlusions may be crossed more easily from the retrograde rather than antegrade approach; this is true regardless of the chronicity of the lesion in question, degree of calcification, or length of occlusion.

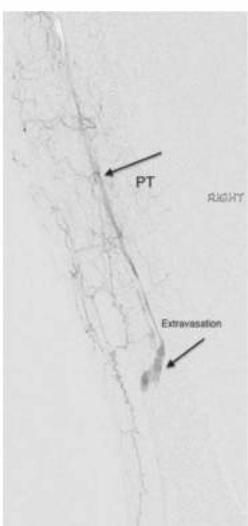

FIG 5 ● Angiogram shows extravasation from distal posterior tibial artery in an attempt to cross a total occlusion with a catheter and wire.

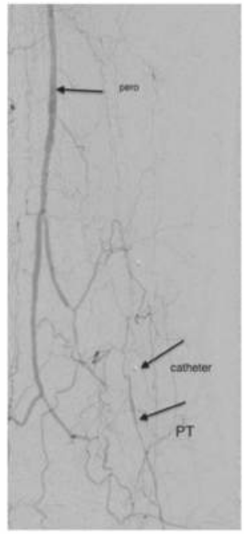

FIG 6 ● Angiogram from sheath shows the catheter in the subintimal plane after recanalization of posterior tibial (PT) with reconstitution of distal PT away from the catheter.

Preoperative Planning

- Preoperative vein mapping prior to the diagnostic angiogram is helpful in handicapping potential surgical alternatives and determining the extent to which interventional alternatives to be pursued.
- Patients should be medically optimized prior to their procedure: Preventive strategies are advised to reduce the risk of kidney injury in patients at risk for contrast nephropathy; smoking cessation is encouraged as well as antiplatelet and statin therapy.
- Tibial interventions can entail significant radiation exposure. Protective shields, lead glasses, and judicious use of fluoroscopy are recommended to protect all participants in the procedure. Ultrasound-guided access can minimize radiation exposure, particularly for pedal access; needle extenders allow the operator to puncture remotely and minimize hand exposure.
- Micropuncture and pedal access kits are essential access tools.
- Sheaths: 5 and 6 Fr, braided, 90 cm or 110 cm from contralateral femoral access; 45- to 55-cm sheath from the ipsilateral transfemoral access
- Wires: 300-cm, 0.014-in or 0.018-in wires; 260-cm, 0.035-in floppy Glidewire™
- Catheters: 150- to 170-cm catheters and balloons
- Medications: heparin (or other anticoagulant), clopidogrel, nitroglycerin, papaverine, alteplase, and calcium channel blockers. Consider preprocedural perioperative antibiotics prior to procedures potentially requiring prosthetic implants.

Positioning

- The patient is placed supine on the angiographic table with both groins prepped and draped. Consider preparing the foot and the leg in anticipation for retrograde approach if needed. Stockinette can be placed over the involved foot and the leg is covered with the angiographic drape (**FIG 7**).

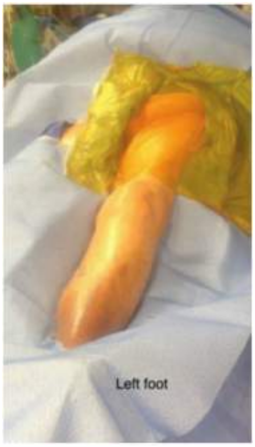

FIG 7 ● Patient is placed in the supine position on the angiographic table; the groins and lower extremity are prepped and draped in anticipation of antegrade and retrograde approaches.

ANTEGRADE TIBIAL REVASCULARIZATION

First Step: Femoral Access and Anticoagulation

- Contralateral femoral access with standard up and over technique is our routine approach for diagnostic arteriograms and most tibial interventions.
- Antegrade femoral approach has distinct advantages for tibial or pedal interventions, especially in the setting of a hostile and narrow aortic bifurcation or occluded or severely diseased contralateral iliofemoral system. Antegrade access generally provides easier pushability and reduced radiation to the patient and procedural team.
- Ultrasound-guided access may minimize risk for access site complications.
- Diagnostic arteriogram to image the inflow is performed.
- A 5- or 6-Fr sheath is advanced over a stiff wire to the popliteal artery, positioned as close as possible to the tibial trifurcation. (Sheath: 90 to 110 cm from the contralateral femoral access and 45 to 55 cm from the ipsilateral femoral access) (**FIG 8**).
- Sheath tip positioning close to the target vessel maximizes pushability across total occlusions. Also, improved visualization of tibial vessels is achieved with reduced contrast volumes.
- Anticoagulation is established using unfractionated heparin or other alternatives to achieve an activated clotting time (ACT) of more than 250 seconds.

FIG 8 ● After obtaining femoral access, the sheath is advanced to the popliteal artery for the intervention. It allows better visualization of the tibial vessels and facilitates the pushability and the ability to cross total occlusions.

Second Step: Selective Angiogram

- Imaging of the tibial outflow is obtained from sheath injections or through diagnostic catheters (5- to 10-mL power or hand injection). To reduce contrast load, contrast may be diluted 50% for all but the most distal arterial beds.
- Anteroposterior or ipsilateral anterior oblique projections are obtained to visualize the popliteal "trifurcation" and separate the tibia and fibula. True lateral oblique projections are obtained to visualize pedal outflow.
- Arteriographic images must be carefully examined to optimize outcome; multiple projections may be required to sufficiently opacify tibial and pedal vascular anatomy, especially distal to extended or serial occlusions. Delayed views (prolonged digital subtraction angiography [DSA] time) may improve opacification of patent tibial or pedal vessels distal to occluded segments (**FIG 9**). Withdrawing the sheath to the femoral bifurcation may uncover reconstitution of distal tibial artery segments through extended deep femoral artery collateral pathways.

Third Step: Crossing the Occlusion

- Angled catheters and guidewires are typically used to select the respective tibial arteries.
- The catheter/guidewire combination is advanced into the target tibial artery proximal to the occlusion or stenosis.
- Anatomy is confirmed with magnified arteriographic views.

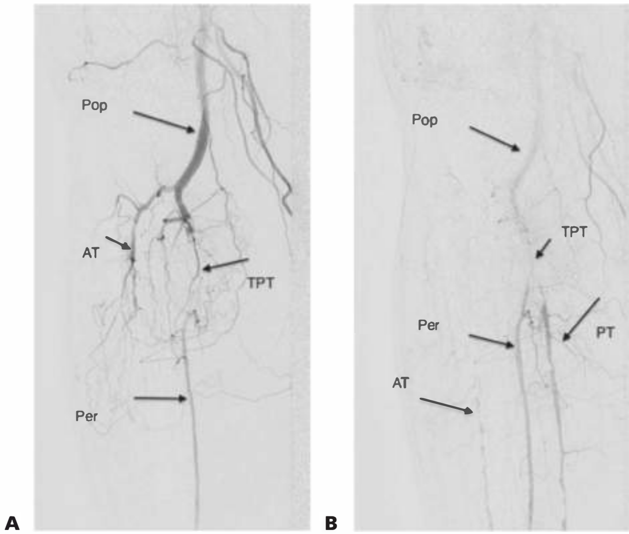

FIG 9 ● **A.** Diagnostic angiogram from the popliteal sheath demonstrates patent right popliteal artery, occluded anterior tibial artery, and occluded distal tibioperoneal trunk with reconstitution of peroneal artery. The posterior tibial artery appears to be occluded. **B.** Angiogram with delayed DSA time identifies a patent diseased posterior tibial artery distal to the occluded tibioperoneal trunk and patent peroneal artery.

- "Road mapping" may improve guidance across occlusions. The wire leads through the occlusion, followed by the crossing catheter (e.g., Quick-Cross™ or Cook CXI™, 0.014 in or 0.018 in) (**FIG 10**).
- Transluminal passage is preferred to subintimal access, because reentry into the true lumen may be unpredictable and challenging.
- Soft-tipped hydrophilic guidewires are used to negotiate and traverse tibial stenosis with the support of crossing catheters under magnified road map guidance.
- Heavier weighted tip, chronic total occlusions (CTO) guidewires (either 0.014-in or 0.018-in platforms) are designed to provide improved performance and penetration across total occlusions.
- For longer occlusions, leading with a 2-mm percutaneous transluminal angioplasty (PTA) balloon as an alternative to low-profile crossing catheters (e.g., Quick-Cross™ or CXI™) can improve access by extending or reestablishing the recanalization plane during transit.

Fourth Step: Reentry into the True Lumen

- Reenter into the true lumen under road map guidance (**FIG 11**).
- Advance the catheter over the wire into the true lumen beyond the target lesion and remove the wire.
- Aspirate to check for back-bleeding and subsequently perform a selective angiogram through the catheter to confirm the proper intraluminal position (**FIG 12**).

FIG 10 ● Recanalization of occluded PT. Under road map guidance, the PT was selected, and using a wire and support catheter, the occlusion was crossed.

FIG 11 ● Angiogram from catheter in PT during recanalization of occluded PT.

FIG 12 ● Angiogram from catheter in the plantar artery to confirm the proper intraluminal position after recanalization of PT.

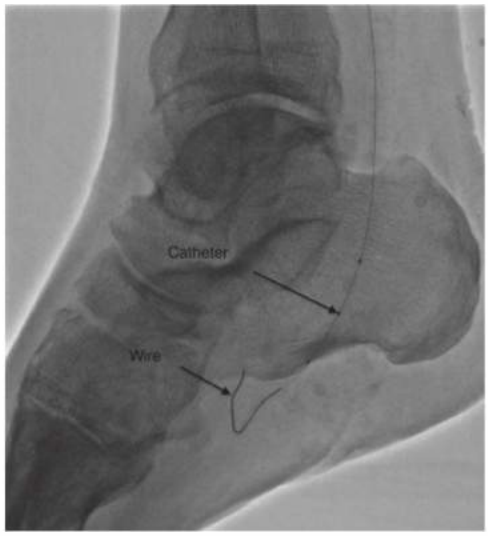

FIG 13 ● Placement of wire into the plantar artery prior to angioplasty of the occluded PT.

- Advance a stiff wire with long, soft tip into the target vessel as distal as possible (**FIG 13**).
- Remove the catheter carefully under fluoroscopic guidance while maintaining wire access into the distal patent artery.
- Reentry devices can be used to select the true lumen from a dissection plane. Alternatively, if failure to reenter the true lumen persists despite the use of reentry devices or balloon angioplasty to disrupt the dissection membrane, access into the distal true lumen can be reattempted in a staged future setting.

Fifth Step: Treatment with Balloon Angioplasty

- The proximal and distal ends of the lesion are demarcated by a repeat contrast injection through the sheath. The use of radiopaque adhesive rulers applied on the affected leg may help with measurement and device selection.
- Deliver the appropriate size balloon (typically 2 to 3.5 mm in diameter) to the target lesion and perform the balloon angioplasty for 2- to 3-minute inflation time (**FIG 14**).

A B

FIG 14 ● **A.** Balloon angioplasty of distal PT with 2-mm balloon for 2-minute inflation time. **B.** Balloon angioplasty of PT with 3-mm balloon for 2-minute inflation time.

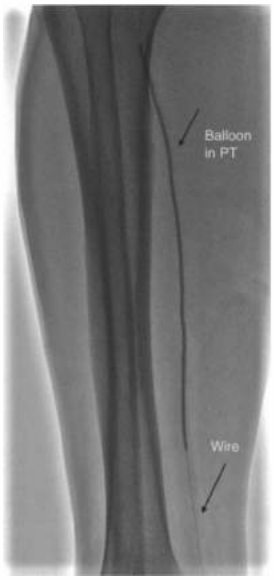

FIG 15 ● Angioplasty of PT with long balloon.

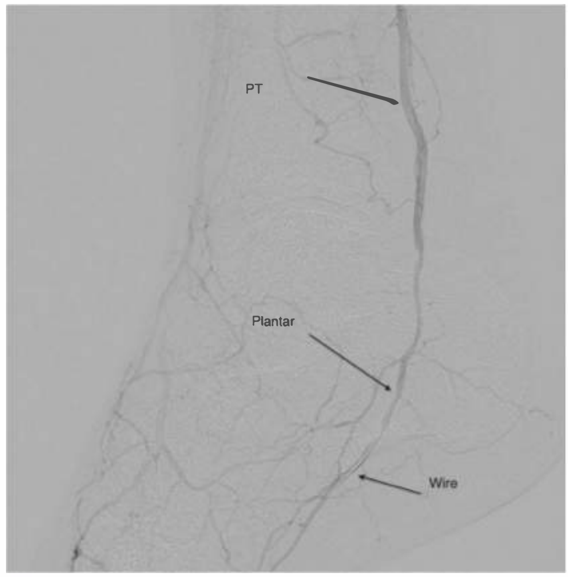

FIG 16 ● Angiogram from sheath postrecanalization and angioplasty of PT shows good flow without any flow-limiting dissection.

- Single inflation using a long balloon decreases the procedural time and reduces the risk of postangioplasty dissection requiring reintervention (FIG 15). Tapered balloons can help treat lesions across vessels of variable size.
- Heparin flush, continuous or intermittent, through the sheath is recommended during balloon inflation and throughout the procedure.
- Selective injection of intraarterial nitroglycerin through the sheath will minimize the effects of spasm at or distal to the intervention.

Sixth Step: Angiogram Post–Balloon Angioplasty

- The treatment balloon is retracted back over the wire to the popliteal artery level.
- The completion arteriogram is performed from a sheath injection to assess the angioplasty outcome and pedal runoff (FIG 16).
- Recoil or dissections are treated with sustained reinflation of the balloon for 3 to 5 minutes or by upsizing the balloon, followed by more gradual deflation.
- Flow-limiting dissections in the proximal tibioperoneal trunk and proximal tibial arteries may be resolved with stent placement when necessary.
- Distal embolization can be managed by aspiration through the existing catheter or aspiration with a purpose-specific catheter such as the Export™.
- Other modalities may be useful in restoring patency, such as atherectomy devices and can be used as stand-alone therapy or as adjuncts to balloon angioplasty.
- The routine use of tibial stenting is not advocated at this stage. Although there is some evidence to suggest that drug-eluting stents may result in improved durability, these are subject to cost restrictions, regulatory approvals, and availability depending on the country of practice.

Seventh Step: Reconstruction of Another Tibial Vessel

- The ultimate goal is to reestablish direct, in-line arterial flow to the ischemic part of the foot. A secondary goal is to optimize flow by reconstructing more than one occluded tibial artery, when possible.
- The wire is redirected into another tibial vessel and recanalization is performed as described earlier (FIG 17).
- When the peroneal artery is the sole outflow vessel, revascularization to the level of the peroneal collaterals at ankle is needed.
- Ostial lesions at the bifurcation of anterior tibial artery and tibioperoneal trunk can be treated with kissing balloon technique to prevent plaque shifting.

Eighth Step: Completion Angiogram and Hemostasis

- If the completion angiography is satisfactory (FIG 18), the sheath is pulled back to the common femoral artery and injection from that level is recommended to rule out any complications in the femoropopliteal segment related to sheath position.
- The sheath is removed and hemostasis is obtained at the access site either by using closure device or manual compression without heparin reversal unless necessary.

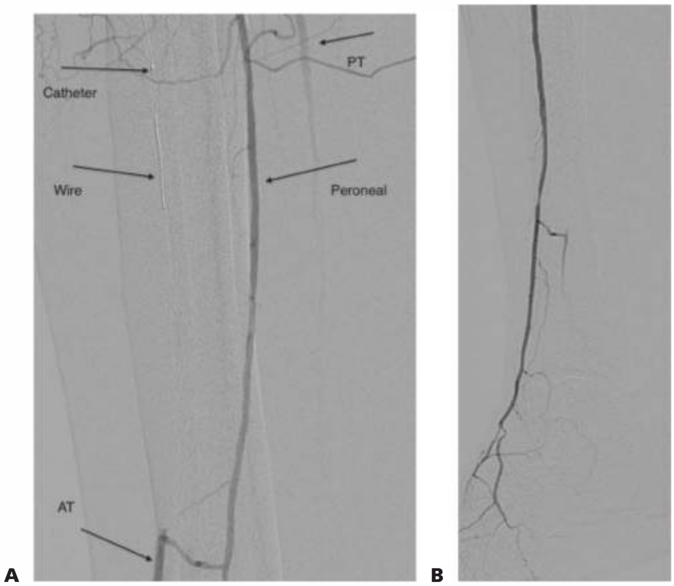

FIG 17 ● **A.** Angiogram from the sheath at the time of recanalization of anterior tibial (AT) artery with a wire and catheter. The peroneal artery is patent and reconstitutes a distal anterior tibial artery. **B.** Angiogram from the sheath postangioplasty of the AT with 3-mm balloon, shows patent AT without any dissection or flow-limiting stenosis.

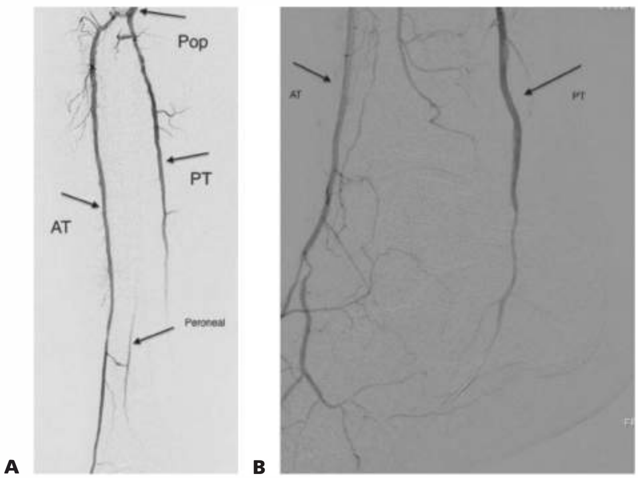

FIG 18 ● **A.** Completion angiogram from the sheath postrecanalization of occluded AT and PT shows patent vessels with good flow mainly in the AT without any significant dissection. The peroneal artery reconstituted in a retrograde fashion from the AT. **B.** Patent distal AT and PT runoff into the foot.

RETROGRADE TIBIAL RECANALIZATION

First Step: Retrograde Access

- Antegrade access is obtained first as described earlier. This is used for initial imaging and delivery of treatment devices.
- Retrograde tibial arterial access is performed under ultrasound or fluoroscopic guidance using a micropuncture 21-gauge needle; a 300-cm, 0.018-in or 0.014-in wire; and balloon or support catheter. An introducer dilator, although potentially useful, is not essential.
- Sedation should be managed to minimize movement when road mapping is used to identify target arteries.
- Local anesthesia is infiltrated at the intended puncture site.
- Access to the posterior tibial artery is obtained in the region of the medial malleolus. Dorsiflexion and/or eversion of the foot may facilitate access.
- Access to the anterior tibial artery is obtained on the dorsum of the foot or the distal aspect of the leg anteriorly, where the target artery may be larger. Dorsalis pedis access is facilitated by plantar flexion of the foot.
- The peroneal artery should be approached laterally through the interosseous membrane.
- More proximal access to the posterior or anterior tibial arteries may be obtained with road map guidance when necessary.
- Inadvertent venous puncture may occur during attempts at retrograde access, and when it does, consider leaving

FIG 19 ● Retrograde approach: access to PT under ultrasound (US) guidance.

the wire in place to help guide further attempts at arterial access.

- Ultrasound-assisted retrograde access, as an adjunct to road map guidance alone, may help to define the three-dimensional orientation of the needle in relation to the target artery (FIG 19).
- Image quality is optimized by incorporating a sufficient delay following contrast injection to maximize opacification of the target artery. Selective use of intraarterial vasodilators through the antegrade may reduce the severity of access-related vasospasm, when present, distally.
- The C-arm is adjusted to best align the needle to the target vessel, typically using an ipsilateral oblique projection.
- Surgical exposure may become necessary to ensure adequate access for retrograde tibial reconstruction. Retrograde access may also be obtained concomitant with planned transmetatarsal amputation by identifying and cannulating the open end of transected distal dorsal pedal artery.

Second Step: Retrograde Angiogram

- Once good back-bleeding is achieved, the wire is advanced under fluoroscopic guidance (FIG 20), followed by an appropriately sized support catheter, balloon, or the inner dilator of the 4-Fr microsheath.
- In most cases, retrograde sheaths are generally *not* deployed to minimize trauma to the puncture site and distal target artery (FIG 21). When sheaths are required, use of a radial access sheath will facilitate atraumatic access.
- Intraluminal position is confirmed by retrograde angiography through the catheter or dilator (FIG 22).

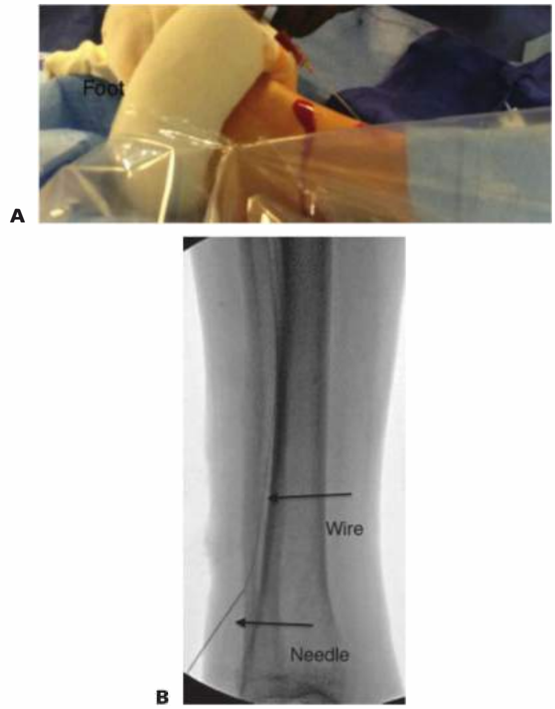

FIG 20 ● **A.** Retrograde access to AT with adequate arterial back-bleeding from the micropuncture needle. **B.** Needle in AT and wire advanced proximally under fluoroscopic guidance.

Third Step: Recanalization of Tibial Occlusion

- Antegrade sheath arteriography is used to delineate the extent of the target lesion.
- The occlusion is crossed using 0.018-in or 0.014-in wires, supported by a crossing catheter or low-profile angioplasty balloon (FIG 23).
- The wire and crossing catheter combination is advanced from distal to proximal and into the popliteal artery if possible. The wire is removed.
- Following aspiration to confirm luminal position, a selective arteriogram is performed from the retrograde catheter.

FIG 21 ● Retrograde access: wire and inner dilator of the microsheath.

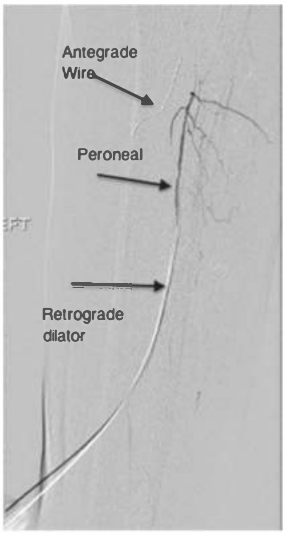

FIG 22 ● Retrograde access of the peroneal artery angiogram from the introducer confirms the intraluminal position.

Fourth Step: Exteriorization of the Wire from the Femoral Access Site

- Next, an attempt is made to advance the guidewire into the antegrade sheath.
- When this proves difficult on its own, a snare is deployed through the antegrade sheath to capture and externalize the distal retrograde wire (**FIG 24**).
- Following successful externalization of the retrograde wire, "wire access" is available from both ends.
- A crossing catheter is then advanced from the antegrade access site over the wire to the patent tibial vessel distal to the occlusion.
- Distal intraluminal position is confirmed with arteriography through the crossing catheter.
- Next, the through and through wire is removed from the antegrade sheath, leaving the crossing catheter across the lesion. The wire is exchanged for a 300-cm working wire, advanced distally through the antegrade crossing catheter.
- The retrograde access catheter or micropuncture 4-Fr access dilator is subsequently removed from the distal target artery. Hemostasis is obtained and maintained by manual pressure at the access site (**FIG 25**), the application of a blood pressure cuff across the site

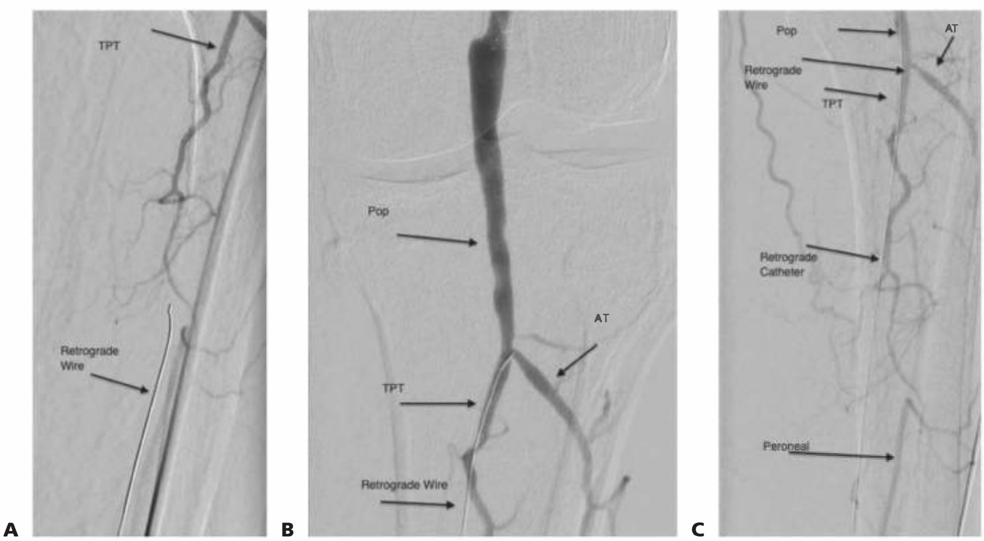

FIG 23 ● **A.** Angiogram from antegrade sheath. Wire crossing the occluded PT. **B.** Angiogram confirming entry of the wire into the tibioperoneal trunk (TPT). **C.** Angiogram shows the retrograde wire and catheter across the occlusion into the popliteal artery proximally.

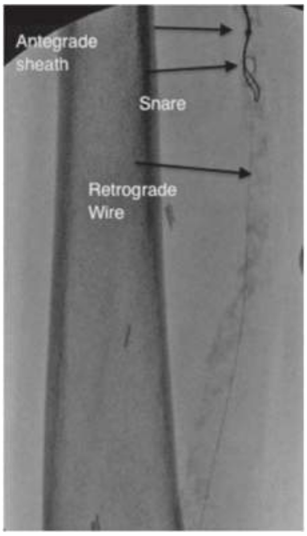

FIG 24 ● Snaring the retrograde wire into the proximal sheath.

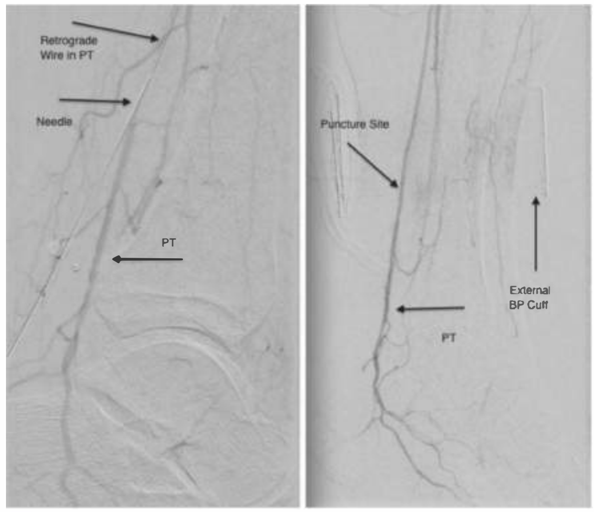

FIG 26 ● Angiogram of PT access site with blood pressure cuff used for hemostasis (image on the right of the screen).

(FIG 26), or a radial compression device (Dstat™ Radial Hemostat Band).

- Removing all devices from the retrograde access site as quickly as possible reduces instrumentation time and potential for arterial injury and distal thrombosis.
- Inflating a balloon advanced from the antegrade access sheath across the retrograde access site (FIG 27) may affect hemostasis but can also increase traumatic injury and access site bleeding and is thankfully rarely needed.

Fifth Step: Treatment with Balloon Angioplasty

- The intervention is then performed in the standard fashion from the antegrade approach (FIG 28).

Antegrade-Retrograde Approach

- If the retrograde wire is not able to cross the lesion and regain access to the true lumen, an antegrade-retrograde approach may be used to create adjacent subintimal planes in opposing directions (FIG 29).
- The dissection flap separating the adjacent subintimal spaces may be disrupted by simultaneous inflation in both directions.
- This allows visualization and recanalization of true lumen from either or both directions. The two PTA balloons selected for this maneuver should be sized appropriately to minimize risk for target arterial rupture.

FIG 25 ● Hemostasis with manual compression postretrograde PT access.

FIG 27 ● Angiogram shows extravasation from retrograde peroneal access site postrecanalization of TPT.

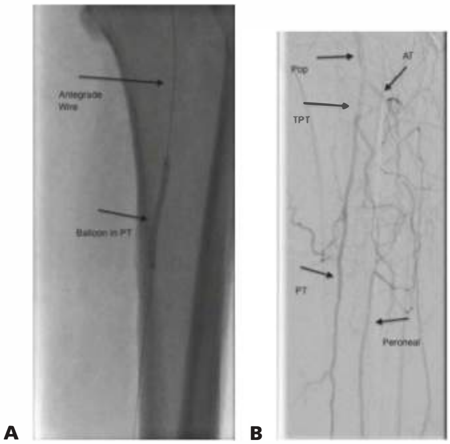

FIG 28 ● **A.** Balloon angioplasty of the occluded PT post-retrograde recanalization and exteriorization of the wire from the antegrade sheath. **B.** Completion angiogram shows good flow into the PT without any dissection.

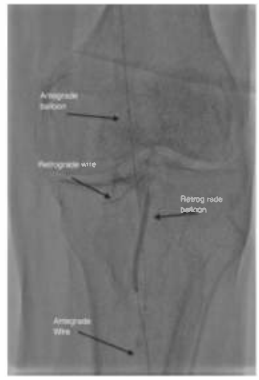

FIG 29 ● Retrograde/antegrade PTA to disrupt the membrane between two subintimal planes.

PEARLS AND PITFALLS

Goals for percutaneous tibial revascularization	■ Achieve direct in-line flow to the ischemic foot and, when possible, optimize pedal perfusion by recanalizing more than one occluded tibial artery.
Contralateral or antegrade femoral access	■ Choice based on inflow anatomy and target lesion. Advancement of the antegrade sheath tip into the popliteal artery is key for successful tibial revascularization.
Ultrasound-guided access	■ Can help access the anterior wall of the vessel in a relatively disease-free spot and minimize access site complications. It is recommended in antegrade femoral access and retrograde pedal access.
Retrograde approach	■ Should not be regarded as the first option for tibial interventions. It is selectively considered after failed attempts at antegrade access and in the setting of flush occlusions of the antegrade artery with large, adjacent collaterals.
Sheathless retrograde technique	■ Is preferred to minimize tibial artery access complications such as dissection and thrombosis. Recanalization is achieved with a wire and support catheter. Hemostasis with manual compression is usually sufficient.
Crossing total occlusions	■ The intraluminal plane is attempted first with a stiff wire and crossing catheter. The proper catheter position should be confirmed with a selective arteriography prior to definitive angioplasty.
Balloon-assisted recanalization	■ Inflation of a 2-mm balloon may assist with the recanalization of long calcified occlusions.
Kissing balloon technique	■ Is sometimes needed to treat the ostial lesions at the origin of the anterior tibial or posterior tibial artery, depending on the amount of plaque in the adjacent peroneal artery or tibioperoneal trunk.
Anticoagulation	■ Maintain an ACT of greater than 250 seconds throughout the intervention. Continuous or intermittent flushing of the popliteal sheath with heparinized solution is recommended.
Vasodilators	■ Are used from the antegrade sheath and at the pedal access site to prevent vasospasm and to allow better visualization of tibial vessels distal to the occlusion

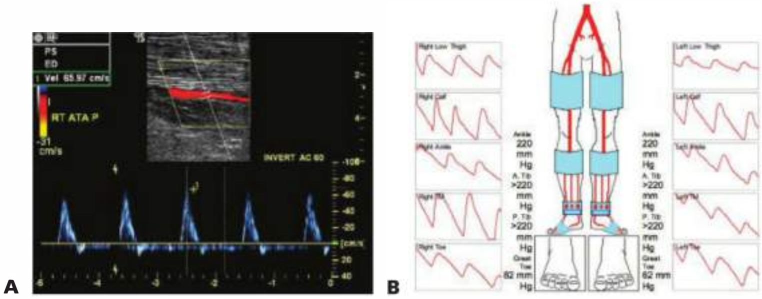

FIG 30 ● **A.** Duplex of the anterior tibial artery postrecanalization and angioplasty shows patent vessel with relatively normal Doppler flow. **B.** Follow-up PVRs postrecanalization and angioplasty of the right anterior tibial artery and right posterior tibial artery demonstrates normal PVR waveforms in the foot with adequate toe pressure.

POSTOPERATIVE CARE

- Following the procedure, the patient is observed in the recovery unit with serial postarterial intervention, neurovascular exams, and intravenous and oral hydration.
- A clopidogrel loading dose (usually 300 mg) is administered when the patient is not already on dual antiplatelet therapy. Dual antiplatelet therapy is recommended for at least 3 months; longer when stents are used.
- Clinical follow-up is obtained 2 to 4 weeks after the procedure is performed, including vascular lab studies (usually PVRs, segmental pressures, and Duplex arterial insonation) (**FIG 30**).
- Close follow-up is essential to ensure optimal symptom resolution and limb salvage.

OUTCOMES

- Tibial balloon angioplasty carries a relatively low primary patency rate but can greatly augment long-term limb salvage rates. The minimally invasive nature of the procedure is especially advantageous in high medical risk patients. One year primary patency rates in experienced hands range from 30% to 40%; secondary patency rates approach 60%, with ultimate limb salvage greater than 70%.[1,2]
- Use of a drug-eluting balloon may improve patency rates.
- Primary stenting does not appear to offer any advantage over tibial angioplasty alone.[3] There may be some patency advantage associated with drug eluting, as compared to bare metal stents.[4] Stenting under all circumstances should be considered as a "bail-out," used to improve suboptimal results of angioplasty alone.[5]
- Patients with significant tissue loss and gangrene should be followed very closely after successful tibial angioplasty. Lesional restenosis rates trend higher in patients at increased risk for limb loss.[6]
- Multilevel interventions, when necessary, are associated with improved limb salvage rate and wound healing compared to isolated tibial interventions.[2]
- Postangioplasty arterial restenosis may portend less clinical significance once healing is achieved in the distal limb or forefoot. The temporary increase in blood flow following angioplasty is often sufficient to heal small ulcerations.[7]
- There is some evidence of improved patency with drug-eluting stents and drug-eluting balloons.[4,8]

COMPLICATIONS

- Access site complications (hematoma, bleeding, pseudoaneurysm) are more common with the ipsilateral antegrade femoral approach.
- Contrast-induced nephropathy can be avoided by sufficient preoperative, intraoperative, and postoperative hydration as well as judicious use of contrast at all times.
- Vessel thrombosis can be avoided by maintaining a therapeutic anticoagulation level throughout the procedure. The use of nitroglycerin can help prevent vasospasm and a low-flow state. Dual antiplatelet therapy is recommended to avoid early postprocedural target artery thrombosis.
- Outflow embolization may be successfully treated with aspiration embolectomy or alteplase if needed.
- Retrograde access site bleeding, dissection, and vessel thrombosis are described after the retrograde pedal access. Using ultrasound-guided access, sheathless technique and the use of local vasodilators may minimize the risk of retrograde access site complications.
- Compartment syndrome may develop either from reperfusion injury following successful intervention or, more commonly, perforation of tibial arteries in the deep compartments of the leg.
- Limb loss may result from failed intervention, iatrogenic vessel thrombosis, distal arterial occlusion following embolization, and compartment syndrome.

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Chapter **33**

Perimalleolar Bypass and Hybrid Techniques

Geetha Jeyabalan Rabih A. Chaer

DEFINITION

- Perimalleolar bypasses are defined by the anatomic location of the distal target outflow vessel. Perimalleolar bypasses refer to any bypass in which the distal target vessel of revascularization is the posterior tibialis, anterior tibialis, or peroneal arteries at the level of the ankle. The pedal vessels (dorsalis pedis, posterior tibialis, lateral or medial plantar artery) are also target vessels in some patients with very distal disease.
- These bypasses are performed in patients with advanced critical limb ischemia (CLI), which includes tissue loss, or ischemic rest pain for which there is not a durable or feasible endovascular option. With the advent of advanced endovascular techniques, the indications for perimalleolar or tibial bypasses are evolving. The inflow vessel and conduit chosen are tailored to individual patients and their anatomic limitations.

DIFFERENTIAL DIAGNOSIS

- The three major etiologies of lower extremity ulceration include ischemic, neuropathic, and venous stasis disease. Although all of these can have poor perfusion as a primary contributing factor, the diagnostic workup and management may be slightly different. Arterial ulcerations typically have a punched-out dry appearance and usually occur on the distal forefoot and toes, whereas neuropathic ulcerations often occur on pressure points and are associated with calluses. Venous stasis ulcerations are typically located on the medial or lateral malleolus and have associated skin changes and brawny induration in addition to serous drainage.

PATIENT HISTORY AND PHYSICAL FINDINGS

- Patients with CLI typically present with ischemic rest pain and/or tissue loss or forefoot gangrene. Most of these patients have significant comorbid conditions such as diabetes mellitus, coronary artery disease, hyperlipidemia, and hypertension that will be important for risk stratification and in deciding between different revascularization modalities. Additionally, managing and optimizing these risk factors are keys to successful outcomes following lower extremity revascularization, regardless of the technique used. As such, optimizing lipid profile, glycemic control, smoking cessation; minimizing renal dysfunction; and managing hypercoagulable states are all essential components to the perioperative medical management, in addition to managing any concomitant coronary disease. The majority of patients are already followed by a team of physicians for their comorbidities (primary care physician, cardiologist, endocrinologist, nephrologist), whereas the surgical team is evaluating the peripheral vascular disease. It is imperative that these consultants remain actively involved in the perioperative period for both the short-term and long-term success of limb salvage and overall survival. The age of the patient, functional status, and comorbidities guide the vascular surgeon's decision making in terms of the type of revascularization offered to the patient.
- Most patients presenting as outpatients will have a history of symptoms of disabling claudication, rest pain, or tissue loss. Taking a careful history noting duration of symptoms, level of pain/claudication, areas of tissue loss, and history of traumatic neuropathic ulceration will guide the workup. Young patients, younger than 60 years of age, or patients with multiple arterial/venous thromboses should undergo a thrombophilia evaluation. Physical examination should include a thorough peripheral vascular examination, including assessment of the potential presence of a palpable aortic aneurysm on abdominal exam. The quality and symmetry of pulses and/or handheld Doppler signals between both legs at the femoral, popliteal, and pedal levels assist in determining the anatomic level of disease. Wound documentation, when present, should note location, depth, presence of infection, bone exposure, and extent of soft tissue defects. Neuropathic deformities of the foot should also be taken into careful consideration for offloading purposes. If there is gross purulence or systemic signs of infection, a debridement of the affected area is required prior to revascularization, even if the area is malperfused, for source sepsis control.
- The location and appearance of ulcerations will often assist in differentiating ischemic, neuropathic, or decubitus wounds. Location of the ischemic wound is important in determining which target vessel will be chosen for revascularization. If the history and physical examination suggest peripheral vascular disease as the primary diagnosis, then noninvasive vascular testing is the next step in determining need for revascularization and level of disease.

IMAGING AND OTHER DIAGNOSTIC STUDIES

- After a thorough history and physical examination, the diagnostic workup of patients with ischemic ulcerations, rest pain, or significant claudication involves noninvasive vascular testing. This involves calculation of ankle–brachial indices and pulsed volume recordings in addition to duplex imaging of the extremity. An ankle–brachial index (ABI) of less than 0.4 is typically seen in patients with CLI (**FIG 1**). Toe pressures of less than 40 mmHg suggest inadequate perfusion for wound healing. In cases of severely calcified vessels, it is important to obtain associated pulsed volume recordings and toe pressures because ABIs can be falsely elevated due to vessel incompressibility. Transcutaneous oxygen tension ($TcPO_2$) measurement can also be used to determine the severity of ischemia and probability of wound healing.

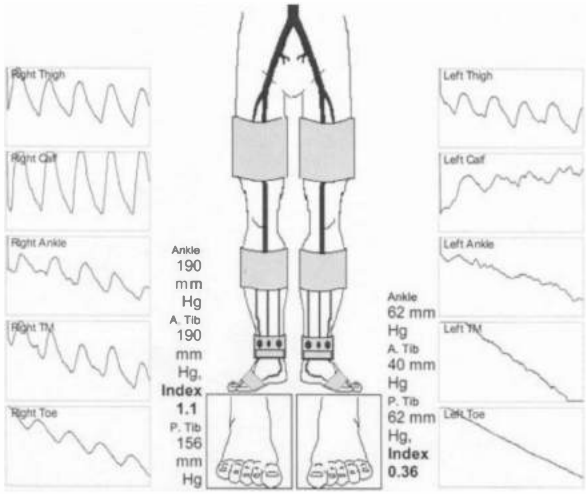

FIG 1 ● Severely reduced ABI and flattened distal pulsed volume recordings (PVRs).

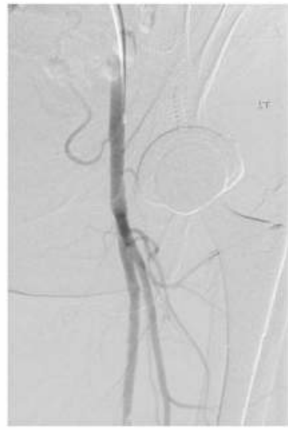

FIG 2 ● Digital subtraction angiography with catheter placed in the common femoral artery to fill collaterals from the profunda to more distal target vessels.

- Once the history, physical examination, and noninvasive testing are complete, the surgeon must determine the next step in imaging, which may be both diagnostic and therapeutic. The patient's functional status, cardiac risk profile, and other comorbidities (ambulatory status, etc.) will all play an important role in determining whether any revascularization attempt is even feasible. If femoral pulses are not palpable on physical examination and noninvasive testing is also suggestive of inflow disease, computed tomography arteriography (CTA) may be instrumental in evaluating the extent of aortoiliac disease, taking into account renal function and risk of contrast-induced nephrotoxicity. Alternatively, aortography obtained from contralateral femoral access or upper extremity arterial access may suffice. General management approaches to aortoiliac versus infrainguinal disease are discussed elsewhere in this book.
- Once the clinical determination is made that the level of disease is infrainguinal, digital subtraction angiography is an excellent diagnostic test and provides access for therapeutic intervention as well. This chapter focuses on patients with multilevel infrainguinal disease who, presumably, have either failed endovascular revascularization, prior open bypass, or who have no endovascular options for revascularization. Therefore, the primary goal of diagnostic angiography is to assess the caliber and quality of inflow vessels and bypass targets.
- The contralateral femoral artery is accessed and an aortogram with oblique pelvic views is obtained to rule out the presence of inflow disease that may need treatment prior to evaluating the infrainguinal segment. An ipsilateral oblique magnified projection will be helpful in determining if there is any significant common femoral or profunda femoris stenosis, which is especially important if these vessels are to be chosen as the source of inflow for an open bypass (**FIG 2**).
- Deciding on which type of intervention to perform, endovascular versus open, and how aggressive to be about either approach is determined by multiple considerations as outlined earlier and elsewhere in this section. Patients requiring open bypass typically have multilevel disease. As such, it is critically important to image the runoff with the catheter placed proximal to the profunda origin, as the distal runoff will likely be filling from profunda collaterals that are communicating with geniculate collaterals. With common femoral or profunda disease, the catheter will need to be placed in the common iliac artery to evaluate internal iliac collaterals that are in communication with the profunda and more distal collaterals. Performing magnified, time-delayed digital subtraction angiography will assist in revealing which tibial vessels are patent and filling through collateral networks. It is also essential to identify the primary named crural artery that is in continuity to the foot that will perfuse the tissue affected by ischemic ulceration (**FIG 3**).
- Using full-strength contrast, magnified projections of the foot will help delineate which pedal vessels are patent, which fill the tarsal and plantar branches, and confirm the status of the plantar arch. Occasionally, there are situations in which no suitable target (e.g., "named" artery) is identifiable and

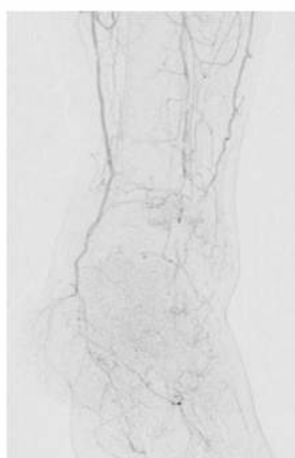

FIG 3 ● Magnified oblique projection of the foot demonstrating a patent plantar arch and digital vessels.

exploration of a tibial vessel at the time of operative intervention may be required. This exercise is fraught with risk, however, especially in the setting of a desperately ischemic foot, and should rarely be undertaken without conclusive pre- or intraoperative arteriography. Duplex ultrasonography may assist in further defining quality, caliber, and patency of tibial vessels in these situations. Choosing a patent posterior tibialis or anterior tibialis artery in direct continuity with the pedal arteries is preferred over a peroneal artery as a distal target when the former is available, especially in cases of forefoot wounds; however, peroneal arteries are perfectly suitable and serviceable in this situation in the absence of other alternatives.

- The decision to proceed with open perimalleolar bypass is made in the context of the patient's overall clinical functional status, cardiopulmonary and renal comorbidities, presence of autogenous saphenous vein conduit, and options for endovascular revascularization. Preoperative autogenous conduit assessment is best performed by detailed ultrasonographic imaging along the length of the vein. Preference is always given to a single segment of greater saphenous vein (GSV) from the ipsilateral leg that is at least 2.5–3 mm in diameter, compressible, and free of thrombus throughout. Assessment of the contralateral GSV is useful in case ipsilateral vein is found to be of poor quality during operative exploration.
- Inflow artery selection is usually based on length of available conduit and location of proximal disease. The common, superficial, or deep femoral or popliteal arteries may all serve as suitable inflow arteries in circumstances where minimal or insignificant occlusive disease is present proximally. This determination is best made during diagnostic angiography. The need for concomitant inflow endarterectomy should also be evaluated at this time.

SURGICAL MANAGEMENT

Preoperative Planning

- Type of anesthesia to be used is determined by the type of cardiopulmonary comorbidities and the anatomic level of arterial occlusive disease. Preoperative consultation with anesthesiology and cardiology is customary in this patient population to assess the appropriate amount of surgical risk. General anesthesia, peripheral nerve block, and spinal anesthesia are all potential options in this group of patients. Intraoperative fluid administration should be used judiciously and preoperative preparation should include blood type determination and crossmatching as necessary. It is our practice to hold therapeutic anticoagulation for at least a few days prior to the procedure, but most patients remain on antiplatelet agents through the day of surgery and continue through the perioperative period.

Positioning

- Any lower extremity bypass might require intraoperative angiography and, as such, all such procedures should be performed on a radiolucent table. The patient is positioned supine, with the leg slightly abducted and externally rotated to provide optimal exposure of the ipsilateral GSV harvest site (**FIG 4**). It is our practice to localize the GSV by ultrasound to assist in incision planning. This also helps determine whether the contralateral leg should also be prepped as an alternative site for vein harvesting.
- Other items that should be available in the room include a sterile pneumatic tourniquet and surgical bump. Both are useful when the below knee popliteal artery or tibioperoneal trunk is used for arterial inflow for the graft. Open forefoot wounds are excluded from the operative field with adhesive or Ioban drapes.

A **B**

FIG 4 ● **A.** Positioning of the leg in gentle external rotation to facilitate exposure of the GSV medially. **B.** Identifying and marking the GSV under ultrasonography.

PERIMALLEOLAR BYPASS TO THE DISTAL POSTERIOR TIBIALIS ARTERY

First Step: Exposure of the Posterior Tibialis Artery at the Ankle

- Simultaneous dissection of the inflow and outflow targets increases the efficiency of the operative approach. The distal incision is marked by palpating posterior to the medial malleolus, taking care to avoid injury to adjacent GSV (**FIG 5**). Dissection is carried sharply through skin and subcutaneous tissues and through the flexor retinaculum. The tendons of the flexor digitorum longus muscle and flexor hallucis longus pass anteriorly and posteriorly, respectively, to the neurovascular bundle at this level. The paired tibial veins are often seen first as overlying the artery. The tibial nerve travels posterior to the artery and may not be seen clearly during this exposure. The tibial artery does not need to be dissected circumferentially if a pneumatic tourniquet is deployed for proximal control. Use of a tourniquet minimizes risk for venous injury at the dissection site and trauma to the arterial endothelium from vessel loops and vascular clamps. For exposure of the medial and lateral plantar arteries, the same incision is typically carried further distally onto the medial aspect of the foot.

Second Step: Exposure of the Inflow Artery

- Concurrent dissection of the arterial inflow should be performed while the tibial target is being exposed. If the common femoral artery is chosen, then a longitudinal vertical incision just below the inguinal ligament will allow for simultaneous exposure of the femoral bifurcation in addition to the saphenofemoral junction for dissection of the GSV (**FIG 6**). If the deep femoral artery is to be used as inflow, then division of the lateral femoral circumflex vein may be helpful in controlling the first-order branches past the origin. If the deep femoral origin is truly deep, the muscle bellies of the adductor longus and vastus medialis should be divided to limit the angle from which the graft originates from the arterial anastomosis. If the below knee popliteal artery is to be used as the inflow, which might be the case in diabetic patients with severe tibial disease not amenable to endovascular revascularization, this exposure is best obtained through a medial calf incision.

FIG 6 ● Incision for the exposure of the femoral bifurcation and start of the GSV harvest incision.

Third Step: Harvest and Preparation of Autogenous Vein

- The course of the GSV is marked on the skin prior to prepping. The shortest segment of suitable caliber and quality GSV is harvested. Incision placement is partially determined by the location of the arterial access incisions. Care should be taken to avoid creating skin flaps during

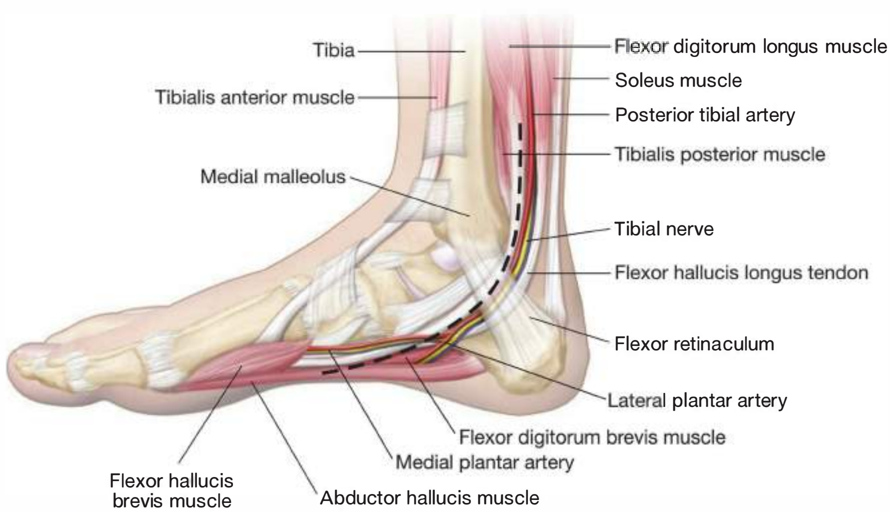

FIG 5 ● Incision for exposure of the posterior tibialis artery at the medial malleolus.

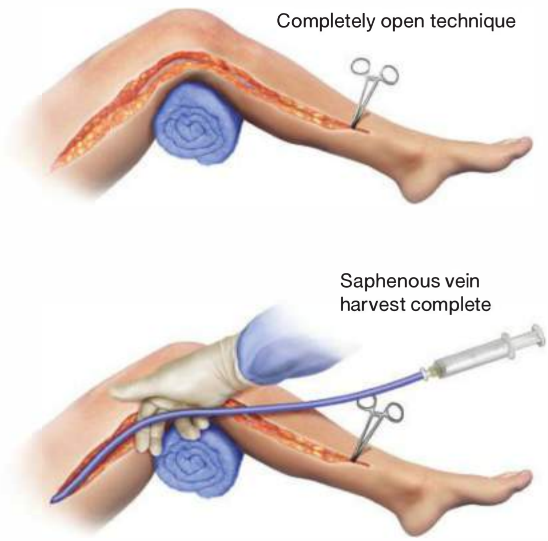

FIG 7 ● Preparation of the GSV.

vein exposure. Harvesting vein through skip incisions may help to minimize wound complications but is not necessary for a good result. Minimal vein manipulation, with care being taken to accurately ligate side branches with 4-0 braided permanent suture (or silk), is important. Minimal dissection of the vein is typically required when in situ bypass in planned. The vein can be left in its bed, with limited dissection of the anastomotic segments. Skip incisions provide access to ligate large side branches.

- After an adequate length of saphenous is exposed, it is removed from its bed for bypass placement or transposed into position after valve lysis for in situ bypass. When removed and repositioned, we generally try to use the largest diameter segment for bypass. The saphenofemoral junction is oversewn or suture ligated. The vein is then reversed and distended gently with heparinized saline or plasmalyte solution. Other vein preservative solutions can be used at the discretion of the surgeon. Any untied branches are carefully clamped and tied with silk suture. Small tears or holes are oversewn in a longitudinal fashion, taking care not to narrow the vein, using 7-0 polypropylene suture (**FIG 7**). Depending on institutional expertise, endovein harvest is an alternative method to minimize incisional length and potential wound complications.
- Once prepared, veins can be used in reversed or nonreversed configurations. We generally prefer reversed as to minimally disrupt the endothelium. If the distal portion of the vein is significantly smaller and concern exists regarding size mismatch at either end, then veins may be positioned in a nonreversed fashion by lysing the valve. To lyse the vein valves, a valvulotome is gently passed up the vein after the proximal anastomosis is complete and the vein is perfused and distended. It is critically important to have the first assistant provide gentle countertraction on the vein as the valvulotome is hooked on the valves in order to lyse them (**FIG 8A**). Care must also be taken to not hook the valvulotome on any ligated branches to avoid tearing the vein. Other commercially available valvulotomes can be used at the discretion of the surgeon.
- Tunneling the vein: The tunnel is created using a hollow tunneler (e.g., Gore, Scanlan, Jenkner) with a blunt appropriately sized tip (6 mm at least) in a subcutaneous plane away from the saphenectomy incision, if possible, to avoid wound complications. The vein is carefully inspected at the entry and exit site of the tunnel to ensure it is in a loose plane and not constrained by fascial or muscular bands (**FIG 8B**).

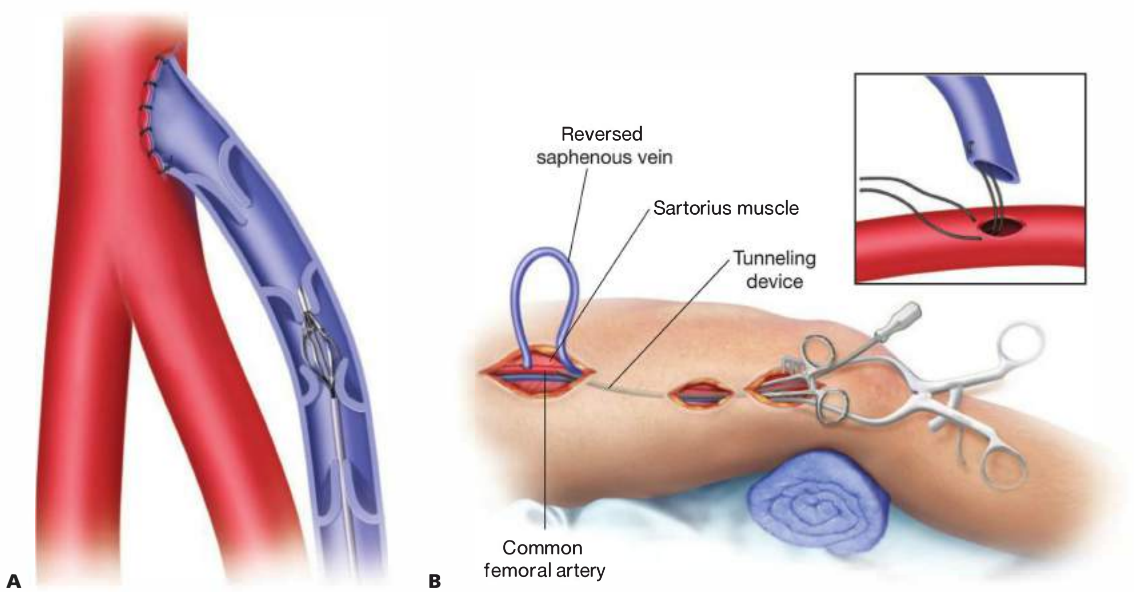

FIG 8 ● **A.** A valvulotome being used to lyse valves in a nonreversed vein under distension. **B.** Tunneling with hollow tunneling device through the subcutaneous tissues away from saphenectomy site.

- After systemic anticoagulation is achieved with unfractionate heparin, the proximal anastomosis is performed after controlling the inflow artery with vessel loops or vascular clamps. The loops or clamps are released and the anastomosis is confirmed to be hemostatic. Once this is assured, the vein is perfused and distended, the valves are lysed if applicable, and the vein is marked for orientation. It is then passed through the tunneler to exit the distal incision and clamped proximally with an atraumatic bulldog clamp or Yasargil clip. The length of vein needed is determined after the vein has already been tunneled and distended, with the leg in a maximally extended position. The leg can be manipulated in various positions with knee flexion to make sure any excess or redundant vein is appropriately trimmed prior to embarking on the distal anastomosis.

Fourth Step: Distal Anastomosis Creation

- If a tourniquet is to be used for distal control, then the lower leg is exsanguinated using an Esmarch bandage. The tourniquet is placed around the thigh if the inflow is at the level of the common femoral, profunda femoris, or proximal superficial femoral arteries. It is inflated to 250 to 300 mmHg. The target is then identified. Care is taken to identify the artery instead of the vein because they can appear deceptively similar when exsanguinated under tourniquet hemostasis. The distal anastomosis is created using a 6-0, 7-0, or 8-0 polypropylene suture depending on the size of the target artery. Loupe magnification is helpful and generally mandatory in this setting. The first assistant should sit beside the operating surgeon to maintain suture tension around the anastomosis and suction away blood and debris from the operative field (**FIG 9**).
- If the tourniquet fails to maintain sufficient hemostasis due to medial calcification in the larger proximal arteries, other options for hemostasis include vessel loops and vascular clamps for tibial control, use of vessel stoppers, or use of a carbon dioxide (CO_2) blower suction device. Circumferential tibial artery dissection must be done with care to avoid injury to the adjacent paired tibial veins, or venae comitantes, that give off several crossing branches above and below the target artery. Newer dissolving endoluminal occlusion gels are available for temporary hemostasis as well and may provide a less traumatic method of control in smaller arteries.
- Prior to completion of the anastomosis, the tourniquet is deflated and flushed. The proximal graft clamp or bulldog is released and the anastomosis is thoroughly flushed prior to tying down and completing the anastomosis. Topical agents such as thrombin/Gelfoam, Surgicel®, or Floseal® may be helpful in obtaining hemostasis following reversal of anticoagulation with protamine.
- Wound closure is a key component of the operation. Most of the morbidity from these procedures arises from wound complications. The vein harvest bed should be irrigated, inspected for hemostasis, and closed in multiple layers of running or interrupted absorbable suture. Care is taken to avoid injury to the saphenous nerve. At the ankle and around points of flexion, such as the knee, it is useful to use vertical mattress nylon suture. It is also important to close the ankle incision first before reperfusion edema makes tension-free closure challenging. It is often difficult to get more than one layer of subcutaneous tissue over the bypass and distal anastomosis at the perimalleolar level (**FIG 10**).
- The patency of the bypass is assessed intraoperatively by multiple potential methods. Feeling a strong bypass pulse in the tunnel and in the target vessel distal to the anastomosis is reassuring. Listening with a handheld Doppler to assess the quality of the Doppler signal of the artery distal to the distal anastomosis is also helpful. A multiphasic strong Doppler signal that augments significantly when the graft is first compressed and then released is suggestive of a patent bypass. In the absence of strong clinical signs of graft patency (e.g., palpable distal

FIG 9 ● Target artery is identified and anastomosis is created in an end-to-side technique.

FIG 10 ● Closure of the saphenous harvest site.

pulse), an intraoperative color flow duplex scan may be used to identify potential flow limiting defects, such as retained valves, focal velocity elevations, and low flow in the graft itself. However, intraoperative duplex scanning is not available in all operating rooms with sufficient resolution to recognize these defects. Finally, on-table arteriography also provides useful detail regarding potential problems, including the status of the anastomoses, tunneling issues, and the presence of retained valves, if any. Completion arteriography can be performed either through an up-and-over approach from the contralateral femoral artery or with a puncture in the ipsilateral inflow artery just above the proximal anastomosis (**FIG 11**). Some degree of spasm may be seen at the site of clamp placement or vessel loop manipulation. When tunneling concerns arise, dynamic arteriography with the leg flexed and extended in various positions can be helpful to prevent kinking of the bypass in the early postoperative period.

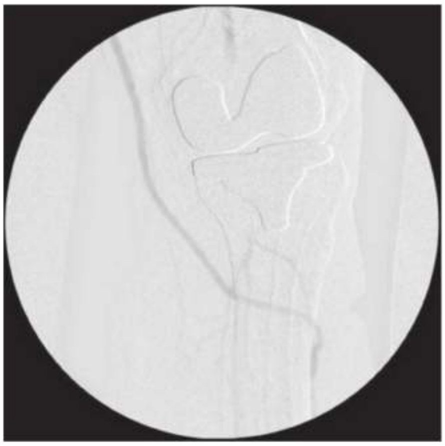

FIG 11 ● On-table angiography to assess the bypass following completion of the anastomoses.

PERIMALLEOLAR BYPASS TO THE DISTAL ANTERIOR TIBIALIS ARTERY

First Step: Exposure of the Anterior Tibialis Artery at the Ankle

- Simultaneous dissection of the vein and proximal inflow artery should occur while the distal bypass target is identified and controlled as described earlier. The distal exposure of the anterior tibial above the ankle is performed by identifying the tendon of the extensor hallucis longus and creating an incision just lateral to this and medial to the tibialis anterior tendon. Plantar flexing the ankle and palpating the space that opens between the two tendons often easily identify this groove in which the artery runs. The extensor retinaculum is divided at the malleolus and the vascular bundle should be easily identified at this level lying along the anterior surface of the tibia (**FIG 12**).

Second Step: Tunneling the Vein to the Anterior Tibialis Artery

- The GSV is harvested and either reversed or used in a nonreversed fashion depending on factors described earlier. The tunnel from the inflow artery to the anterior tibial can be maintained in a subcutaneous plane across the anterior surface of the tibia medial to the

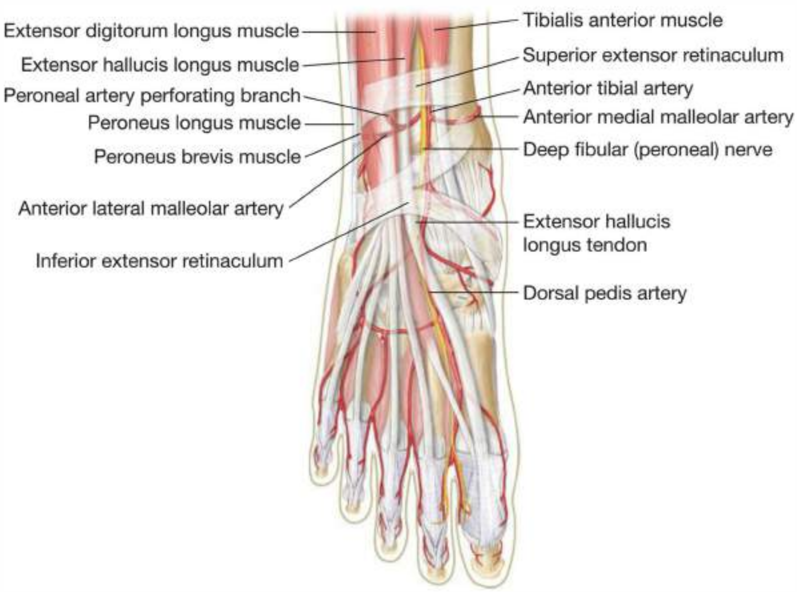

FIG 12 ● Exposing the anterior tibialis artery at the ankle.

exposure site. A counterincision may be needed at the ankle to allow for a gentler curvature of the vein graft toward the dorsum of the foot. If there is concern about potential compression of the vein graft in this region because of its superficial nature, the alternative is to tunnel through the interosseus membrane. This tunnel is created higher in the calf between the deep posterior and anterior compartments (**FIG 13**). Because the GSV harvest incision is already on the medial calf, the dissection can be extended deeper by retracting the gastrocnemius muscles posteriorly and partially dividing the soleus to reach the posterior tibial vessels. These are protected and gently retracted posteriorly while the fibers of the tibialis posterior muscle are separated and the tunneler is bluntly passed through the interosseus membrane here. Once the vein graft is in the anterior compartment, it can be tunneled in a subcutaneous or subfascial plane to reach the exposed anterior tibialis artery just above the ankle.

Third Step: Exposure of the Dorsalis Pedis Artery

- If the dorsal pedal artery is the target vessel, then the exposure distally is on the dorsum of the foot and the tunneling techniques remain similar to what is outlined earlier for the anterior tibial artery at the ankle. An incision is created on the dorsum of the foot just lateral to the extensor hallucis longus tendon and carried down through the fascia. The dorsal pedal artery lies lateral to the deep peroneal nerve here (**FIG 14**).

FIG 13 ● Tunneling through the interosseus membrane at the midcalf.

- Care should be taken to not leave self-retaining retractors in for too long in these smaller distal incisions to avoid tension on the wound edges and potential skin necrosis.

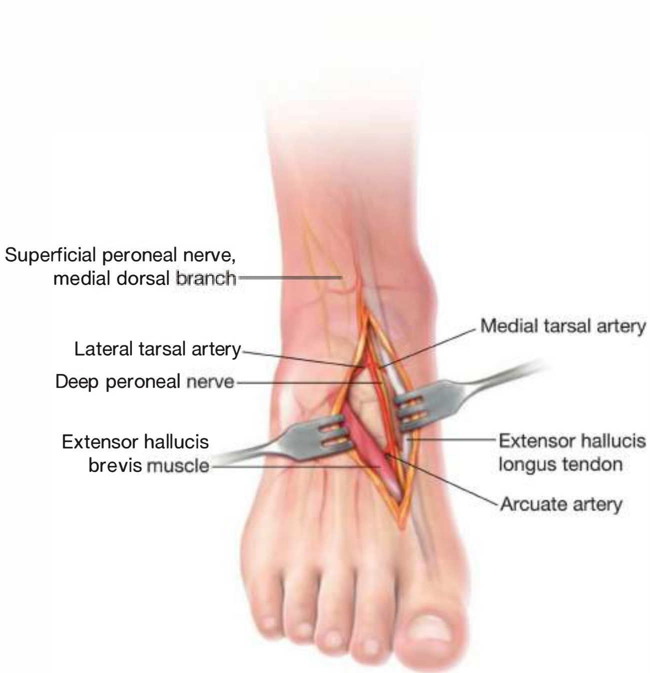

FIG 14 ● Exposure of the dorsalis pedis artery.

EXPOSURE OF THE PERONEAL ARTERY AT THE ANKLE

First Step: Peroneal Artery Anatomy

- The peroneal artery comes off the tibioperoneal trunk at the upper calf and then distally branches into two perforating branches, termed anterior and posterior perforating peroneal arteries, which supply the anterior and lateral compartments and communicate with the anterior tibial artery and some tarsal branches.

Second Step: Exposure of the Distal Third of the Peroneal Artery

- Because the proximal segment of the peroneal artery can be accessed easily from a medial approach, the perimalleolar or distal third of the artery needs to be approached from a lateral approach and requires resection of a portion of the fibula. An incision is created along the lateral border of the fibula and dissection is carried down through the fascia to the fibula after which the periosteum is cleared proximally and distally (**FIG 15**). The peroneal arteries are in close proximity to the fibula medially and care should be taken to avoid injury to the vascular bundle when clearing the bone medially (**FIG 16**). The bone can then be excised and the peroneal artery is identified behind the interosseus membrane. The bone can be transected using a Gigli saw or oscillating power saw. The advantage of either a traditional bone cutter or power saw is that the bone does not necessarily have to be circumferentially dissected.
- The peroneal artery can also be exposed posteriorly, but this is somewhat challenging to do when the patient is supine. An incision just above the ankle posterolaterally between the tendons of the flexor hallucis longus and the flexor digitorum longus reveals the artery in its most distal segment (**FIG 17**). This approach is favored when the small saphenous vein will also be harvested for the graft conduit.

Third Step: Additional Procedure: Spliced Vein

- Despite careful preoperative planning and efforts to fully interrogate adequate conduit, the greater saphenous vein may prove to be unsuitable for the intended purpose once exposed. If length of vein is a concern, then careful consideration should be given to either moving the inflow anastomosis more distally or moving the target artery more proximally. An additional alternative is to create a shorter tunnel, harvest the greater saphenous vein from the contralateral leg, or harvest arm vein when other options are not available or advisable.
- Occasionally, if no suitable autogenous vein conduit exists (especially in the case of redo bypass); consideration may be given to cadaveric cryopreserved vein or prosthetic bypass with vein cuffs or patches distally. The limitations of these nonautogenous options must be weighed against the known patency limitations of spliced vein or arm vein grafts.

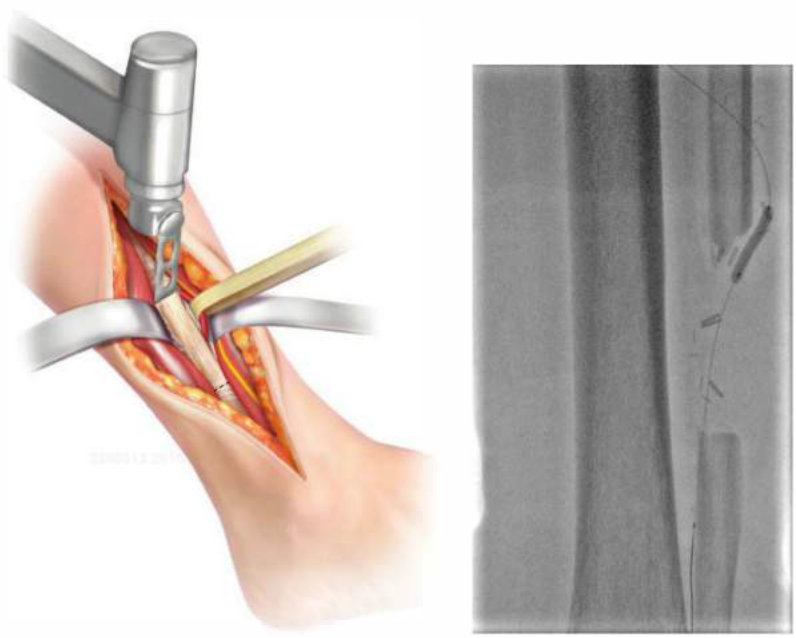

FIG 15 ● Clearing the fibular and resection for exposure of the distal peroneal artery.

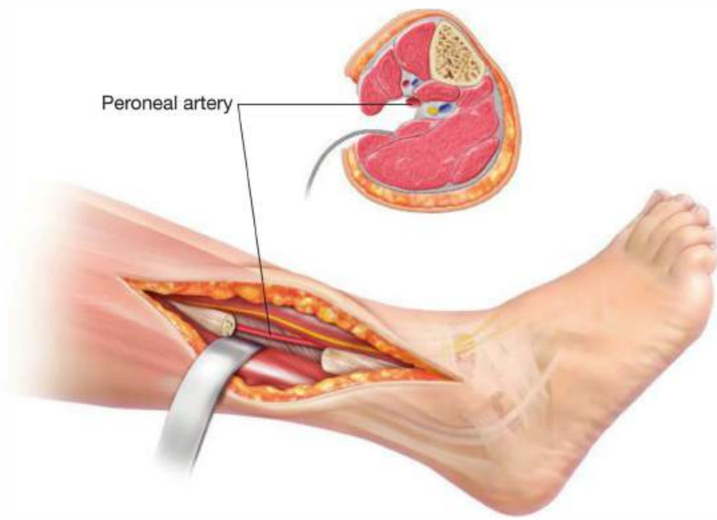

FIG 16 ● Exposure of the distal third of the peroneal artery.

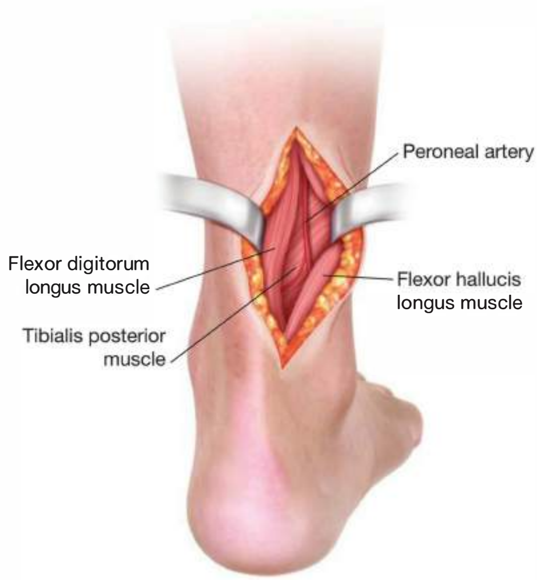

FIG 17 ● Posterior approach to the distal third of the peroneal artery.

PEARLS AND PITFALLS

Preoperative planning	▪ The bypass target is chosen to provide the best option for direct in-line perfusion to area of tissue loss on the forefoot.
Placement of incision	▪ Using ultrasound in the operating room to identify the GSV in relation to the proximal and distal incisions can help avoid raising flaps or creating postoperative wound complications. ▪ Use of a tourniquet above the knee can assist in avoiding unnecessary manipulation and potential injury to distal tibial vessels.
Tunneling	▪ Tunneling the bypass away from the vein harvest incision can help protect the bypass from exposure and infection in case of wound complications and wound dehiscence postoperatively.
Intraoperative assessment of bypass	▪ Manipulating the leg in slightly different positions can assist with evaluating the course of the vein bypass in the tunnel during intraoperative assessment with on-table angiography.

Wound closure	■ Avoid leaving self-retaining retractors in distal incisions for prolonged periods to avoid skin edge necrosis. ■ Closure of distal wounds is best accomplished with nylon suture in a vertical mattress fashion in order to avoid tension on the wound. Wounds over the dorsum of the foot can be closed with horizontal mattress sutures. Occasionally, a counterincision may be necessary to provide adequate coverage over the exposed artery at the ankle.
Postoperative care	■ A gently placed soft cast can prevent significant lower leg edema and subsequent wound breakdown in the immediate postoperative period. ■ Predischarge duplex assessment of the graft is important if intraoperative assessment of the bypass was not performed with angiography or duplex.

POSTOPERATIVE CARE

- Because of the length and location of incisions for inflow, vein harvest, and distal anastomosis, the patient will undoubtedly have significant edema postoperatively throughout the affected leg. To prevent blistering and potential wound breakdown, the foot, ankle, and lower leg may be wrapped in a soft cast consisting of an inner layer of Webril® and outer layer of gently compressive Coban®. Care needs to be taken to minimize external compression on the vein graft itself, especially in the areas around the ankle. The soft case is changed on postoperative day 3. The patient can ambulate starting on postoperative day 1, but the leg should be elevated when the patient is sitting or in bed. Patients are left on antiplatelet therapy perioperatively. There is some data supporting therapeutic anticoagulation in patients with high-risk vein bypasses (poor runoff, suboptimal conduit, etc.); however, this must balanced against the risk of bleeding in individual patients.
- For perimalleolar bypass patients who did not get an intraoperative assessment of their bypass with an on-table angiography, a predischarge duplex is performed to document patency and pedal perfusion. If a significant abnormality is identified on duplex (significantly low flows in the bypass or focally high velocities), then this should be addressed prior to discharge with angiography or exploration of the area with appropriate intervention.
- Once discharged, patients either return weekly for a change of their soft cast until their edema has sufficiently resolved or follow-up at the 1-month interval for formal duplex interrogation of the bypass. Certainly, more frequent visits may be warranted in patients with wound concerns.
- Surveillance duplex of vein bypasses is obtained at the 3-month, 6-month, 9-month, and 12-month postoperative time points with both ABI and graft duplex (**FIG 18**). After the 1-year time point, provided everything is stable clinically with the patient and there are no previous abnormalities on postoperative imaging, the surveillance can be moved to once a year. Occasionally, the surveillance interval is shortened for high-risk bypasses or prosthetic tibial bypasses.

OUTCOMES

- Primary patency of perimalleolar vein bypasses can be as high as 77% at 1 year, and limb salvage rates up to 85% at 1 year as well. Given the significant comorbidities in many patients with CLI, the rate of hospital readmission and poor functional outcome can be very high. Wound healing is adversely impacted by the presence of diabetes mellitus and renal failure.

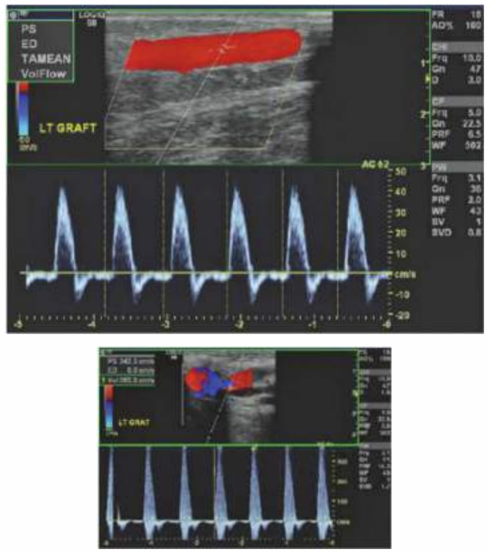

FIG 18 ● Surveillance duplex of vein bypass.

COMPLICATIONS

- Early complications of distal bypasses include bleeding, wound infection/breakdown, and graft occlusion. Late complications include graft stenosis, limb swelling, graft occlusion, and aneurysmal degeneration of the vein bypass. Most patients with CLI have concomitant coronary disease and the rate of perioperative myocardial infarction can be as high as 5%. It is very important to maintain patients on their cardiac medications in the perioperative period and manage fluids judiciously to avoid precipitating coronary events.

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Chapter **34**

Acute Iliofemoral Deep Vein Thrombosis and May-Thurner Syndrome: Surgical and Interventional Management

Sharon C. Kiang   Brian G. DeRubertis

DEFINITION

- Acute iliofemoral occlusion is defined as complete or partial thrombosis of any part of the iliac vein and/or the common femoral vein (CFV), with or without associated femoropopliteal thrombosis, in which symptoms have been present for 14 days or less or for which imaging indicates that thrombosis has occurred within the past 14 days or less.[1] Acute iliofemoral occlusion may occur de novo following unprovoked deep vein thrombosis (DVT) or may occur (or reoccur) in the setting of prior ipsilateral DVT or external compression (May-Thurner syndrome or neoplasia). Treatment options include (1) systemic anticoagulation alone; (2) open surgical venous thrombectomy; or (3) percutaneous intervention, including catheter-directed thrombolysis, pharmacomechanical thrombectomy, and stenting of intrinsic or extrinsic obstructive lesions or masses.

DIFFERENTIAL DIAGNOSIS

- Iliofemoral DVT most commonly presents with unilateral leg swelling and pain. Although patient history and simple diagnostic testing can generally distinguish from other causes, differential diagnoses include cellulitis or worsening of chronic conditions such as venous insufficiency or lymphedema.

PATIENT HISTORY AND PHYSICAL FINDINGS

- There are three objectives in the treatment of iliofemoral thrombotic occlusion: (1) Prevent propagation of DVT and subsequent pulmonary embolism (PE), (2) provide symptomatic relief for the patient, and (3) prevent the development of postthrombotic syndrome (PTS).
- A thorough history must be obtained prior to treatment because decisions regarding choice of treatment modality are impacted by severity of symptoms as well as the patient's overall functional status.
- Specific risk factors that merit individualized questioning include history of trauma, current or past episodes of DVT or PE, history of thrombophilia, history or current diagnosis of cancer, and a history of tobacco or substance use. Family history of DVT or PE is important to ascertain. A thorough investigation of current medications should be undertaken, making note of any contraceptive therapy, hormone replacement therapy, or use of anticoagulation (i.e., warfarin, enoxaparin, etc.).
- Symptoms of iliofemoral occlusion can range from nondescript mild symptoms to severe disabling symptoms, and manifestations of symptoms can vary widely. Commonly reported symptoms of iliofemoral occlusion include limb edema, heaviness, pain, lifestyle-limiting venous claudication, stasis dermatitis, and in advanced cases, venous ulcerations.[2] Duration of symptoms and consideration of inciting events at the time of symptom development will help differentiate acute occlusion from exacerbation of chronic disease.
- Symptom severity is an important differentiating variable in the management rubric of acute iliofemoral occlusion; severe and persistent symptoms, especially those continuing following the initiation of therapeutic anticoagulation, increase the likelihood of long-term disabling sequelae. The more severe and persistent the symptoms, the more justified the indication for aggressive thrombus removal.
- A detailed physical examination is essential. Conditions that produce symptoms mimicking those associated with iliofemoral occlusion should be excluded. A thorough abdominal and lower extremity pulse examination, with noninvasive physiologic testing if necessary, will exclude possibility of arterial insufficiency. Comprehensive assessment of peripheral motor and sensory nerve function and of the spine and lower limb joints can rule out these confounding etiologies.
- The affected limb(s) should be examined for evidence of chronic venous insufficiency and/or stasis dermatitis, as well as signs and symptoms of acute DVT. Signs of acute iliofemoral occlusion may include pain, swelling, and bluish discoloration. Extensive thrombus propagation throughout the ipsilateral venous system may lead to phlegmasia alba dolens, characterized by profound painful swelling and a pale, milk-like skin hue. Further thrombus propagation from the deep to the superficial venous system increases outflow obstruction to the point of impeding arterial inflow, precipitating phlegmasia cerulea dolens, limb threat, and tissue loss.
- In patients with either acute or chronic venous disease, objective evaluation and prognostic stratification is best accomplished by using the CEAP (Clinical, Etiology, Anatomy, Pathophysiology) system and venous clinical severity score (VCSS).[3,4]
- Because multiple interventions may be required to optimize outcome in acute iliofemoral disease, patients' expectations should be managed accordingly. In addition, iliac and femoral venous intervention commonly requires extended periods of postoperative anticoagulation (warfarin and/or low-molecular-weight heparin) to ensure long-term procedural success. The likelihood of patient compliance thus represents an additional important prognostic indicator.
- Long-term functional outcomes are discouraging for patients who refuse interventional management of acute iliofemoral occlusive disease. Forty-four percent of patients treated with medical therapy alone will experience venous claudication, and up to 60% will develop PTS within 2 years.[5–7]

IMAGING AND OTHER DIAGNOSTIC STUDIES

- Imaging provides important prognostic and interventional guidance to surgical management of acute iliofemoral occlusive disease. Current modalities include duplex ultrasonography; catheter-based contrast phlebography; and reconstructed, cross-sectional, contrast-based whole body (computed tomography [CT] and magnetic resonance [MR]) imaging.

Duplex Ultrasonography

- In experienced hands, duplex ultrasonography (US) provides extremely sensitive and specific information regarding the chronicity and extent of infrainguinal venous obstruction. Diagnostic accuracy in the iliocaval venous system is less predictable due to the presence of overlying bowel gas and abdominal adiposity.
- Duplex-derived criteria for acute venous occlusion include incompressibility under direct vision, partial luminal obstruction within the normally echo-free lumen, and absent or abnormal venous flow characteristics with respiration or following a Valsalva maneuver or distal compression.[8]
- The primary advantages of duplex imaging include its noninvasive nature, avoidance of ionizing radiation or nephrotoxic contrast agents, easy reproducibility, portability, and accessibility in the outpatient setting. Additionally, substantial cost savings are realized compared to other imaging modalities. Other advantages include the ability of duplex scanning to differentiate hematomas, lymphatic system obstruction, superficial thrombophlebitis, and other soft tissue abnormalities from deep venous obstruction. Thus, duplex scanning is the initial imaging modality of choice in all patients with suspected iliofemoral DVT. When sufficient imaging parameters are met, definitive therapeutic intervention may be safely performed based on duplex-derived anatomic and diagnostic imaging alone.

Computed Tomography Venography

- CT phlebography is frequently ordered for assessment of limb swelling in the inpatient setting. Advantages of this modality include nearly universal availability day or night, less reliance on skill and experience of the technical staff performing the procedure, outstanding spatial resolution, reproducibility and sensitivity throughout the entire venous system, the simultaneous ability to image pulmonary arterial flow and lung perfusion, freedom from limb pain induced by direct probe compression during ultrasound examinations, and the ability to incidentally diagnose concurrent conditions (such as solid organ neoplasia) that may influence thrombogenicity or suitability for treatment with open versus endovascular techniques.
- The modern helical CT phlebogram provides a diagnostic sensitivity and a specificity of nearly 100% per year and was found to detect previously unsuspected venous thrombosis at a prevalence of 1.1%.[9,10]
- CT phlebography also provides useful information regarding thrombus density (and thus chronicity), the presence of residual luminal patency in obstructed veins, and the nature and severity of extrinsic iliac vein compression when present.
- The applicability of CT phlebography to the diagnosis of venous obstruction is limited by the volume of iodinated intravenous contrast required to obtain optimal spatial resolution in target vessels, as well as considerable whole-body radiation exposure inherent in CT imaging. On average, the radiation dosage delivered by diagnostic CT phlebography is equivalent to that of over 1,200 chest x-rays or over 10 years environmental exposure at sea level (dosage equivalents courtesy of Radiation Physics Department, Stanford Hospital & Clinics). This is particularly true in patients with reduced creatinine clearance, women of childbearing age who may be pregnant, or in children. For many reasons, including the considerable expense associated with the study, CT phlebography should not be considered a first-line study but rather reserved for patients in whom duplex scanning does not provide sufficient anatomic guidance or where additional diagnoses (e.g., pulmonary embolization, solid organ malignancy, or external iliac vein compression, etc.) merit evaluation or exclusion.

Magnetic Resonance Venography

- MR phlebography shares many of the advantages and disadvantages of CT-derived cross-sectional imaging, including the ability to obtain high-quality, high-resolution images of surrounding soft tissues and delineate the extent of accompanying lymphadenopathy, soft tissue sarcomas, venous aneurysms, malformations, and compression syndromes that may influence treatment and long-term management considerations. MR phlebography also provides a sensitivity and specificity of nearly 100%, respectively, in the diagnosis of acute iliofemoral venous occlusion.[11]
- However, unlike computed tomography venography (CTV), magnetic resonance venography (MRV) can be used during pregnancy and provide reduced risk of nephrotoxicity in patients with reduced creatinine clearance (although gadolinium is contraindicated in patients with an estimated glomerular filtration rate [eGFR] of more than 60 mL per minute).
- Contraindications for MR-based venous imaging include the presence of implantable pacemakers/defibrillators/infusion systems or other ferromagnetic devices and surgical clips/endografts, as well as claustrophobia in affected patients. MR studies are also expensive compared to duplex US, and dedicated personnel and equipment are less widely available than are modern, multirow-detector CT imaging capabilities. Thus, MR phlebography is considered most appropriate as a secondary examination in the absence of suitable duplex imaging or in the presence of contraindications to CT phlebography. MR phlebography may be particularly useful in the evaluation of coexisting or complicating ipsilateral or central venous vascular malformations.

Catheter-Based Contrast Phlebography

- Despite continuing improvements in the quality and widespread availability of noninvasive imaging, catheter-based contrast phlebography remains the gold standard for iliofemoral venous evaluation. Sensitivity and specificity are also nearly 100%, and in addition to anatomic information, physiologic venous pressure and flow information are also provided throughout the iliocaval system when accessed in a retrograde fashion from the CFV.

- Typical fluoroscopic findings include abrupt vessel cutoff in the case of total occlusion or visualization of a filling defect with residual luminal flow around the margins, a phenomenon known as "tram tracking."
- An obvious limitation is the relatively high degree of operator dependency, both in terms of physician and facility capabilities. Catheter-based contrast phlebography may be nondiagnostic in up to 18% of cases due to misinterpretations, artifacts, or superimposition of overlying structures.[12] Thus, experience and suitable infrastructure are necessary to ensure accuracy and precision.
- Other major drawbacks include the inherent invasiveness of the procedure and attendant procedural risk, radiation and contrast exposure (although significantly less than that required for CT imaging), and cost. Thus, contrast phlebography is also inappropriate as the initial diagnostic modality for most patients and best employed in conjunction with planned interventions directed at active thrombus removal.

Intravascular Ultrasound

- Intravascular ultrasound (IVUS) with the 9F Volcano IVUS catheter (Volcano Corporation, San Diego, CA) provides direct intraluminal visualization during catheter-based phlebographic assessment and intervention.
- IVUS-based imaging allows for precise measurement of cross-sectional area and maximum and minimum lumen diameter. Flow within the residual lumen may be determined, as well as precise analysis of residual luminal irregularities. The superior two-dimensional imaging characteristics of IVUS compared to contrast phlebography make this modality the measurement instrument of choice when assessing extrinsic iliac vein compression from tumors or overlying iliac arteries (e.g., May-Thurner syndrome).

INTERVENTIONAL AND SURGICAL MANAGEMENT

Preoperative Planning

- Serologic and hematologic evaluation should include the basic metabolic panel (to assess renal function and concomitant electrolyte abnormalities), complete blood count, and a coagulation profile. It is also important to ascertain the status of antiplatelet or anticoagulation therapies when present (e.g., dose, dosing frequency, prior complications, etc.).
- Prior to operative intervention, the index treatment limb should be marked as required for World Health Organization's preoperative checklist and "time-out" requirements and extent and severity of edema "baselined" for future comparison.
- When appropriate access requires multiple sites (e.g., bilateral femoral and/or internal jugular vein approaches), those should be marked and initialed as well.

Positioning

- Patients can be placed supine or prone depending on the site necessary for access. On the operating table, the patient should be placed supine, with their arms secured at the side to facilitate ancillary access from the groin or neck. When popliteal access is required, prone positioning is required.

PERCUTANEOUS MANAGEMENT OF ILIOFEMORAL DEEP VEIN THROMBOSIS (+/− VENOUS COMPRESSION SYNDROMES)

Duplex-Guided Femoral Vein Access

- Access site is chosen based on duplex US findings, proximal (peripheral) to the site of thrombotic occlusion. This may be the CFV in patients with isolated iliac DVT or the popliteal or tibial veins in patients with iliofemoral DVT.
- Under ultrasound guidance, a 0.018-in micropuncture set is used to access the target vein. In the setting of proximal obstruction, the vein is typically large and easily identified. Wire and catheter exchanged is performed to upsize to a 5-Fr interventional sheath.

Baseline Phlebography

- The initial phlebogram is performed either through the interventional sheath or through a diagnostic catheter advanced to the suspected site of occlusion. When using digital subtraction angiography, a mixture of 50% Visipaque and 50% saline provides adequate volume and visualization while minimizing contrast load.
- The ease with which guidewire passage is accomplished, as well as historical information regarding duration of symptoms, informs interventional decision making. Patients with symptoms of less than 7 days duration are frequently conclusively treated with single-session pharmacomechanical thrombectomy, whereas patients with longer duration will more frequently require pretreatment with multiday courses of catheter-directed thrombolytic therapy. The initial phlebogram is instrumental in determining the course of therapy in this regard. Regardless of approach, the goal of therapy is to achieve rapid thrombus removal, minimize venous obstruction, reduce the likelihood of venous valvular damage, uncover underlying venous compression syndromes, and at least theoretically, reduce likelihood of symptomatic recurrence.

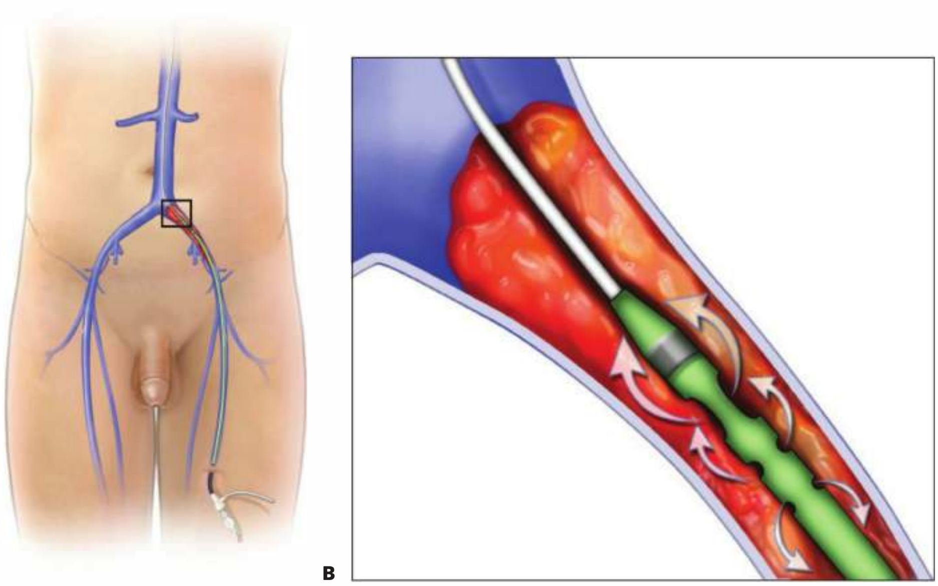
Catheter-Directed Thrombolysis

- Until recently, catheter-directed thrombolysis has been the mainstay of interventional management for iliofemoral DVT. Following guidewire traversal of thrombus, treatment length is determined via insertion of a marker catheter. Subsequently, an appropriately sized sidehole infusion catheter is positioned over the occluding thrombus. Infusion catheters come with infusion (perforated segment lengths) ranging from 5 to 50 cm or longer, and infusion segment length should be selected to direct infusate specifically into luminal thrombus only—for example, not into patent luminal segments where it will be rapidly dissipated into the venous and systemic circulation. Prior to initiating infusion, the multipurpose guidewire used to position the catheter is exchanged for a purpose and catheter-specific end-occlusion wire, which typically forces the infusate to exit through the side holes rather than leak out coaxially along the guidewire lumen.

- Once proper positioning is obtained, a continuous infusion of tissue plasminogen activator (tPA or alteplase, Genentech, San Francisco, CA) is initiated at the rate of 0.25 to 1.0 mg per hour, depending on the extent of thrombus burden and perceived chronicity. A concurrent, coaxial heparin infusion (400 to 700 units per hour) is administered through the sheath to prevent thrombus accumulation around the infusion system.
- Monitoring in a step-down or intensive care environment is an essential safety requirement during extended periods of catheter-directed intravenous thrombolysis outside of the cath lab. Fibrinogen levels, coagulation profile, and hematocrit are assessed every 4 to 6 hours. Typically, tPA infusion is halted if/when fibrinogen levels drop below 200 mg/dL or evidence of bleeding is present. Repeat phlebography is performed every 12 to 24 hours to assess therapeutic progress and residual thrombus load. As thrombus burden recedes, replacement catheters with shorter infusion segments are typically chosen to concentrate drug delivery within the remaining clot. Infusion rarely continues beyond 48 hours regardless of progress, as experience has demonstrated that complication rates vary directly with total tPA dosage and length of infusion. Also, infusion rates may be reduced when significant progress is noted during periodic phlebographic assessment, again to reduce risks of dosage-related bleeding complications while still pursuing complete dissolution of clot.
- Ultrasound-assisted thrombolysis using the EKOS infusion catheter (EKOS Corporation, Bothell, WA) may reduce the duration of infusion and total tPA dose. This 6-Fr catheter is also available in multiple infusion lengths and contains a core wire producing ultrasound energy that may disrupt fibrin bonds and increase tPA diffusion within thrombus. Clinical studies have demonstrated equivalent clinical outcomes with reduced infusion times using the EKOS system.

Pharmacomechanical Thrombectomy

- Pharmacomechanical thrombectomy (PMT) uses mechanical forces to assist tPA dispersion within the thrombus, typically during a single treatment session. Concurrent aspiration capabilities help remove thrombus fragments during treatment sessions. Devices currently used for this purpose in the venous system include the AngioJet catheter (MEDRAD, Warrendale, PA) and Trellis (Covidien, Mansfield, MA) infusion systems.
- The AngioJet systems comprise an infusion catheter and dedicated reusable drive unit. Radially oriented infusion ports generate high-pressure jets to disperse heparinized saline, with or without tPA, into the thrombus and an adjacent aspiration port to export fragments and debris.
- The AngioJet catheter is most commonly used in acute iliofemoral occlusion in the "power pulse" mode; in this setting, the aspiration function of the catheter is temporarily disabled, whereas tPA pulsation is delivered directly into the thrombus. Typically, 6 to 8 mg of tPA is delivered in this fashion at the beginning of a treatment session. With power pulse activated, the catheter is repeatedly advanced and withdrawn through the thrombus over the guidewire (FIG 1). After allowing the tPA to dwell for 10 to 15 minutes, the aspiration function is activated and thrombus removed to the greatest extent possible.



A B

FIG 1 ● **A.** The 6-Fr AngioJet thrombectomy catheter is useful in the treatment of DVT. This catheter is advanced through a sheath situated in the popliteal or femoral vein over a 0.035-in guidewire. The catheter has radially oriented infusion side holes that deliver saline and tPA directly into the thrombus **(B)** and aspiration ports that remove dissolved thrombus and debris.

FIG 2 ● The Trellis peripheral infusion system is an 8-Fr catheter with a single-use disposable drive unit. The catheter has compliant occlusion balloons that are inflated on either side of the treatment zone after advancing the catheter over the guidewire through the thrombus. The treatment zone of the catheter (either 15-cm or 30-cm length) contains both infusion side holes and aspiration ports. (Figure courtesy of Covidien, © 2014.)

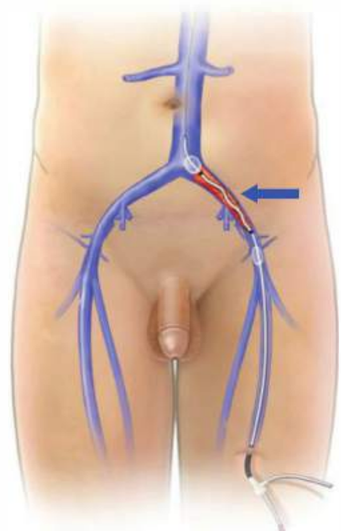


FIG 3 ● Once the Trellis catheter is in position, the guidewire is replaced by the mechanical dispersion wire, which is attached to the drive unit and enables the treatment portion of the catheter to oscillate back and forth *(arrow)* to facilitate tPA dispersion. During the 10-minute treatment time, tPA is infused through the infusion port at a rate of 1 mg (1 mL) per minute, and following treatment, the dissolved thrombus and remaining tPA is aspirated through the aspiration port.

- The Trellis system is composed of an infusion catheter of either 15- or 30-cm infusion length, with compliant occlusion balloons at either end of the infusion ports (**FIG 2**). Following placement over the guidewire, the end occlusion balloons are inflated in order to isolate the area of planned pharmacomechanical thrombolysis (**FIG 3**). A sinusoidal dispersion wire is then advanced through the core of the catheter and attached to a disposable drive unit, which when activated uses mechanical forces to disperse the tPA through the thrombus. After an infusion of 6 mg of tPA over the span of 10 minutes, aspiration of thrombus and debris is performed from the treated segment. The occlusion balloons concentrate tPA within the treatment segment, enabling multiple infusion and dispersal sessions during the same procedure with minimal systemic delivery of thrombolytic agent (**FIG 4**).

Stenting of Underlying Venous Stenoses or Venous Compression Syndromes

- Following clearance of acute thrombus from the iliofemoral system, underlying venous lesions that provoked DVT formation, or focal external compression may become apparent on completion phlebography. These lesions should be addressed during the same treatment session to minimize the risk of recurrence. IVUS may be particularly useful in this regard.
- Although fixed stenoses may occur throughout the venous system, the most common location for extrinsic compression occurs at the point where the left common iliac vein passes beneath the overlying right common iliac artery (RCIA) (**FIG 5**). After recognizing this compression and successful removal of thrombus proximal or distal to this lesion, the stenosis may be safely resolved with stenting (**FIG 6**). This is best performed by upsizing the interventional sheath to at least 10 Fr followed by

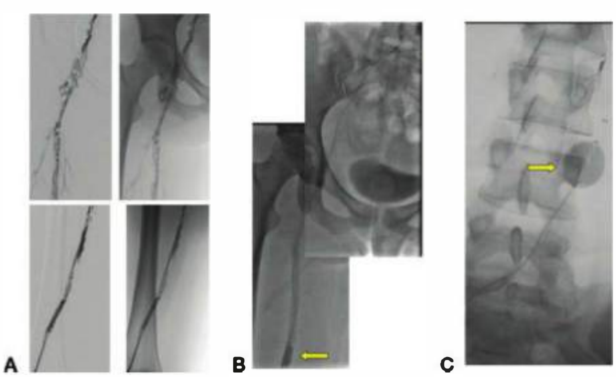


FIG 4 ● Patient with left iliofemoral venous thrombosis secondary to May-Thurner syndrome. Note the extensive thrombus within the iliac and femoral veins **(A)**. **B,C.** The patient is being treated in the prone position through popliteal vein access. The Trellis catheter has been inserted and advanced through the thrombus, and the occlusion balloons are inflated on either side of the treatment zone *(arrows)*. Note the oscillating dispersion wire that improves tPA delivery during infusion.

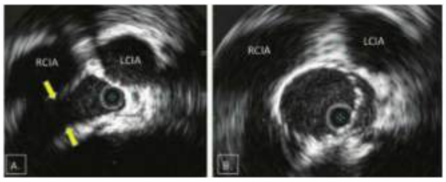


FIG 5 ● Intravascular ultrasound is the most sensitive assessment tool for detecting May-Thurner compression of the left common iliac vein. **A.** The RCIA is lying directly over and compressing the left common iliac vein (between *yellow arrows*). **B.** Following stenting of the left common iliac vein, there is complete resolution of the compression by the RCIA.

deployment of a self-expanding, braided, stainless steel Wallstent (Boston Scientific, Watertown, MA). In conjunction with completion venography, IVUS is then used to quantify the extent of residual compression.

- Stent diameter is chosen based on IVUS-obtained measurements, but diameters commonly chosen for common

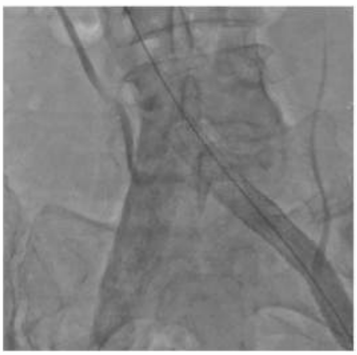


FIG 6 ● Stenting of the left common iliac vein for May-Thurner syndrome is performed with a braided self-expanding stainless steel stent, usually in diameters ranging from 16 to 20 mm.

iliac vein placement in May-Thurner patients range from 16 to 20 mm. In this application, it is important to choose longer stents that provide additional surface apposition in the common or even external iliac veins to present stent dislodgement and migration. Wallstents are particularly appropriate in this regard as they will shorten or extend in proportion to the ultimate treatment diameter and feature exposed wires at either end to optimize vein wall engagement.
- Once appropriately sited and deployed, poststent dilation is necessary to ensure optimal deployment and migration resistance. Some discomfort will be experienced by the "awake" patient during these procedures, and stenting molding should be guided by patient tolerance under these circumstances.

Completion Imaging

- Completion phlebography documents resolution of target stenosis and reciprocal reduction in collateral venous flow.
- The presence of persistent collaterals suggests residual venous stenosis or compression; IVUS should be reperformed in this circumstance to confirm wall apposition and stent expansion. Repeat balloon dilation may be necessary in these circumstances until sufficient expansion is achieved.

Closure of the Femoral Vein Access

- Following sheath removal, manual pressure is held over the venous puncture site. Closure devices are not appropriate or indicated for management of venous access.
- Patients need to remain supine for at least 1 hour following sheath removal.
- Therapeutic intravenous anticoagulation with unfractionated heparin is initiated at the completion of the procedure. Maintenance of full anticoagulation without interruption throughout the early postoperative period is imperative to procedural success.

OPERATIVE MANAGEMENT OF ILIOFEMORAL DEEP VEIN THROMBOSIS

Iliac Venous Thrombectomy

- For most clinical scenarios, open venous thrombectomy has largely been supplanted by the interventional, image-guided techniques described in the preceding sections. In patients with limb-threatening phlegmasia cerulean dolens or those with contraindications to lytic therapy or contrast administration, open surgical thrombectomy remains an effective and necessary treatment modality.
- Whenever possible, surgical thrombectomy is performed under general anesthesia with positive pressure ventilation to reduce the risk of intraoperative PE.
- A vertical inguinal incision is made to allow exposure and control of the CFV, femoral vein, saphenofemoral junction, and the profunda femoris vein. Once these venous structures have exposed, the patient is systemically anticoagulated with 100 units/kg of intravenous heparin.
- A longitudinal venotomy is made in the CFV, and a no. 8 or no. 10 venous thrombectomy catheter is then passed up to the level of the common iliac vein and thrombectomy is performed. Attempts are made to clear the majority of the iliac thrombus before passing the thrombectomy catheter into the vena cava in order to reduce the likelihood of pulmonary embolization.
- Back-bleeding may not be present due to competent iliac vein valves, or back-bleeding can occur from the hypogastric vein even without clearance of the thrombus within the common iliac vein. Therefore, back-bleeding should not be used as an indicator of effective thrombus clearance and venography should be performed as a routine after completion of iliac and infrainguinal thrombectomy.

Infrainguinal Femoral Venous Thrombectomy

- Following iliac venous thrombectomy, heparinized saline should be used to flush the iliac vein, the proximal external iliac vein (or distal CFV) should be clamped, and then any thrombus at the proximal (peripheral) aspect of the venotomy should be extracted with forceps.
- Infrainguinal thrombus can then be removed by manual massage or by exsanguinating the leg with an Esmarch bandage, sequentially applied from the foot to the groin, with sufficient overlap to provide continuous compression (**FIG 7**). Clot is delivered through the venotomy at the groin.
- Balloon thrombectomy can be performed using a no. 3 thrombectomy catheter passed from the venotomy in the CFV in a retrograde fashion down toward the popliteal and tibial veins. Following thrombectomy, the infrainguinal venous circulation should be flushed vigorously with heparinized saline before closure of the venotomy.
- If infrainguinal thrombus persists after thrombectomy, additional techniques for thrombus removal include on-table tPA administration. For on-table tPA administration, 6 mg of alteplase in 200 mL saline is infused retrograde into the femoral vein through the venotomy in the CFV, then the vein is clamped and the solution is allowed to dwell for 10 to 30 minutes.
- If the infrainguinal venous thrombectomy is not successful due to chronic thrombus in the femoral vein, the femoral vein is then ligated below the profunda, and balloon thrombectomy is then performed on the profunda vein and its branches.
- After open thrombectomy is complete, the venotomy is closed with running continuous monofilament suture, avoiding postclosure stricture of the CFV by precision suture placement. If narrowing is apparent, vein or bovine pericardial patch angioplasty may be performed as necessary to restore luminal diameter.

Adjunct Arteriovenous Fistula Creation

- Rates of rethrombosis following surgical thrombectomy can be as high as 80%. Creation of an arteriovenous fistula (AVF) may significantly reduce this risk and are incorporated in the procedure by most surgeons.
- The same groin incision may be employed for AVF creation, transposing the proximal segment of the ipsilateral greater saphenous vein to the superficial femoral artery (**FIG 8**).
- Surgical ligation or interventional occlusion of the AVF is ultimately required for optimal long-term outcome, usually employed within 6 weeks following the procedure. Documented patency of the venous system should be demonstrated on follow-up duplex imaging. Failure to close this fistula may result in significant long-term limb and cardiovascular complications, and follow-up is essential to ensure that this part of the procedure is completed.
- Open thrombectomy procedures by their nature are associated with significant blood loss from the central venous system, and preparations should be made both to crossmatch and bank sufficient packed red blood cells (RBCs), as well as employ operative scavenging systems to recycle and reinfuse lost blood to ensure that appropriate

FIG 7 ● Acute thrombus can generally be extracted during open surgical thrombectomy by exsanguinating the leg with an elastic Esmarch tourniquet. After performing the venotomy in the CFV in the groin, the tourniquet is wrapped from the foot up to the groin, expelling thrombus through the venotomy.

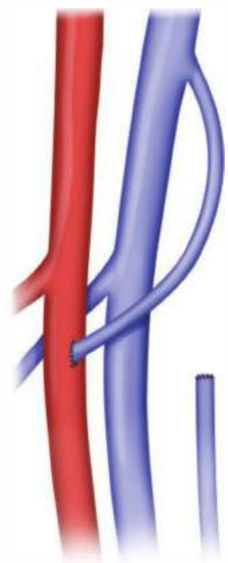


FIG 8 ● Patency rate following open surgical thrombectomy is significantly improved by creation of an AVF. Following thrombectomy of the iliac and femoral veins, the venotomy is closed with running monofilament suture and an end-to-side anastomosis is created between the saphenous vein and superficial femoral artery.

hemodynamic conditions may be maintained throughout the procedure.

Completion Imaging

- Completion venography of the iliac venous system should be performed following open surgical thrombectomy to assess the adequacy of the thrombectomy.
- Following closure of the venotomy and reestablishment of venous flow through the iliofemoral venous system, an 18-gauge access needle and guidewire can be used to puncture the CFV and place a 5-Fr sheath. Contrast injection directly through this sheath is performed to evaluate the iliac veins and assess for residual thrombus. Following venography, the sheath is removed, and a single monofilament stitch can be used to close the puncture site.

Wound Closure

- A careful search for any transected lymphatics should be conducted prior to wound closure.
- A closed suction drain should be placed in the groin wound to prevent seroma formation.
- The wound is then closed with multilayered running absorbable sutures for hemostatic and lymphostatic closure.

POSTOPERATIVE CARE

- Following open surgical thrombectomy, full therapeutic anticoagulation is imperative to prevent rethrombosis. An intravenous heparin infusion is immediately initiated and maintained for 24 to 48 hours before the patient is transitioned to oral anticoagulation with a low-molecular-weight heparin bridge prior to discharge.
- Ambulation should begin on the first postoperative day. Patients may usually be discharged within 48 to 72 hours following thrombectomy.
- On discharge, the patient should be placed in elastic compression stockings (30- to 40-mmHg ankle gradient), and the importance of compression should be stressed to the patient in the discharge instructions.

OUTCOMES

Endovascular Intervention

- Pharmacomechanical venous thrombectomy provides clinical success rates of 70% to 100% and may reduce the incidence of the PTS, although this latter conclusion remains controversial.
- Following successful procedures, long-term venous patency is reported at 84% in 5 years.
- Valvular competence is preserved at 80% in 5 years and 56% in 10 years in recent series.

Surgical Thrombectomy

- Surgical thrombectomy provides long-term iliac venous patency, with rates approaching 80% when combined with inclusion of a temporary AVF.
- At 5 years, over one-third of patients can be expected to be symptom free and have retained valvular competence.

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